
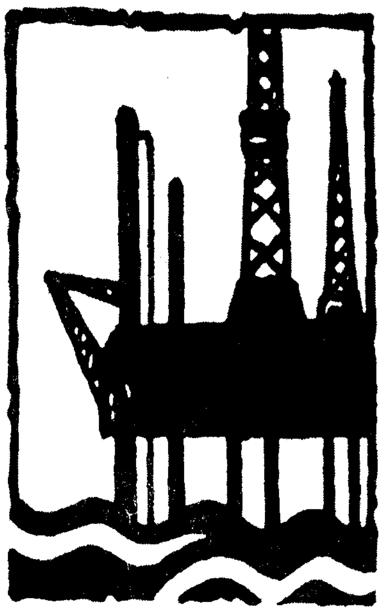
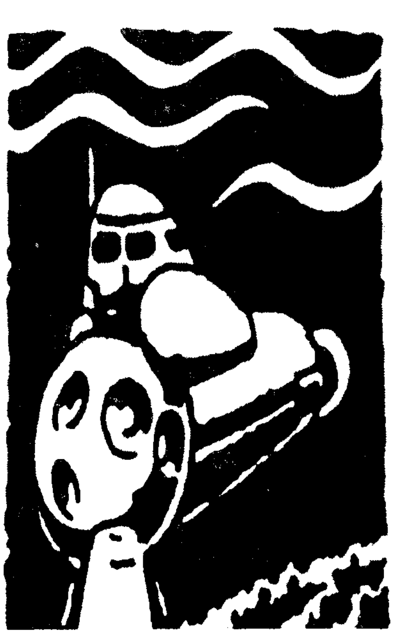

PACON 97

Proceedings

Symposium on

RESOURCE DEVELOPMENT

Environment Issues and the Sustainable Development of Coastal Waters

August 6-8, 1997
The Chinese University of Hong Kong
Hong Kong, China

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PREFACE

The **PACON 97 Proceedings** is a compilation of papers presented at PACON 97, a regional symposium held at The Chinese University of Hong Kong, Hong Kong, China on 6-8 August 1997. The theme of the symposium, "Resource Development - Environment Issues and the Sustainable Development of Coastal Waters" represents the growing interest and importance placed upon the environment and its sustainable development.

The third symposium of its kind held by PACON International, the PACON 97 symposium drew 200 participants from 11 countries around the world. Eighty-three papers were presented at PACON 97 with 63 accepted for publication in these proceedings.

Since the papers deal in areas of ocean sciences, technology, management and policy, we have tried to group related papers to facilitate the reader's use of this publication. I hope the readers will find this volume of 63 papers useful.

I wish to thank Paula Kuriyama and Richelle Tashima of PACON, without whose untiring efforts this publication would not have been possible. Acknowledgment is also extended to Sunyeen Pai of the Pacific Mapping Program for assisting in editing this publication. This work has been made possible due to the generous support of our sponsors: PACON China Beijing Chapter, China; The Chinese University of Hong Kong, Hong Kong, China; the State Oceanic Administration (SOA), China; the Chinese Society of Oceanography, China; PACON International; PACON Hawaii Chapter; Department of Business, Economic Development and Tourism (DBEDT), State of Hawaii; Office of Sustainable Development and Intergovernmental Affairs, U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration; The Hong Kong Polytechnic University, Hong Kong, China; the Hongkong Telecom Foundation, Hong Kong, China; The Croucher Foundation, Hong Kong, China; the Sea Grant College Program and College of Engineering, both of the University of Hawaii at Manoa.

Honolulu
September 25, 1997

Narendra K. Saxena

PACON 97 TECHNICAL REPORT

by
N. Saxena, N. Estabrook, and R. Podgorny

OCEAN SCIENCE AND TECHNOLOGY (OST)

Norm Estabrook from Science Applications International Corporation prepared this report. Lorenz Magaard of the University of Hawaii shared the responsibility for the OST forum. Twelve sessions covering a broad range of coastal development issues were conducted within this category.

OST-1, Marine Mining, chaired by John Wiltshire, was a well attended and lively session, with four papers covering technology, near-shore mineral deposits, deep water manganese deposits and pollution control. Applications of diving and ROV technologies were explored in the context of marine mineral exploration and development, with the Loihi Seamount used as a model for hydrothermal exploitation. Land-based deposits can often be reevaluated on the basis of current seafloor processes and the Loihi model was applied to an area in the south of China, thus demonstrating some new opportunities. The next paper explored the viability of seamount manganese crusts as a source of mineable cobalt and platinum. Layers in which platinum is accumulated may be used to guide future mining operations. A third paper dealt with placer resources of the East China Sea, which have potentially economic concentrations of magnetite, ilmenite zircon, and garnet. These placers are both of terriginous sources and from marine authigenic accumulation. Finally, the utilization of manganese tailings was explored. Using these tailings in building applications appears to be an interesting and economically viable method for tailing management.

The session on Sedimentation and Pollution in the Coastal Ocean, OST-2, was chaired by Zuosheng Yang and C. K. Wong. It dealt with a variety of topics concerning seafloor sediments around China. The discussion first focused on the use of magnetic measurements to monitor contamination levels in Hong Kong sediments. The spatial distribution patterns of magnetic and heavy metal concentrations in selected locations in Hong Kong were explored. Over fifty core samples were subjected to measurements for magnetic properties. Results reinforce the notion that magnetic properties can be useful both as a heavy metal tracer and environmental indicator. This will lead to a broader understanding of the distribution patterns of contaminated marine sediments in Hong Kong. The geomorphy of Weizhou Island was then discussed, along with an explanation of the island's origins and sediment characteristics and distribution. Erosion from wind, waves, tides and surface water was the primary contributor to alongshore sediment makeup. Then the geochemistry of sediments in Hong Kong's Victoria Harbor was presented. Physico-chemical analyses of sediment core samples taken from 6 locations were performed, which indicated concentrations of trace metals declining with increasing distance from identifiable sources. The information has been valuable in determining pollution status and trends, as well as providing solid input for successful harbor management. Finally, moving from sea floor to atmosphere, researchers studied the characteristics of metals in the atmosphere over the Western Taiwan Strait. They explored the interactions between the atmosphere and rivers, monsoon runoff, wind-driven crustal soils, and natural sea spray. Results confirm the importance of the air-sea exchange of trace metals in coastal and open oceans.

A second session of the above topic covered additional areas. First, a fascinating treatise was conducted on the use of biological systems for the early detection of low levels of pollution. Since they can give early warning signals of aberrant environmental conditions, three particularly useful bio detectors monitored for reactions to heat shock, alcohols, and heavy metals. One was a patented system based on a decrease of light emission. Another used the mobility characteristics of *Daphnia magna* populations, and the third used the increased expression of stress proteins from custom lab-cultured human cell-lines. The data were compared with respect to sensitivity, threshold of detection, reliability and rapidity of response. There was a discussion of pollution prevention measures to address the operation of oil and gas mining in the East China Sea. Potential pollution sources were construction, drilling, production, and accidents. This effort evaluated the influence of these operations on the environment and what measures could be implemented to deter the harmful effects of such activity.

OST-3 addressed Coastal and Island Engineering in two sessions chaired by Yongxue Wang and Osamu Saijo. A plan for an artificial reef "in harmony" with the ecosystem of Nakabayashi fishing port in Japan was presented. Such an installation would be an effective countermeasure to ongoing erosion without harmful effects on the environment. The next paper covered a design approach for marine structures that departs from the traditional criteria based on current and wind data taken over a 100 year period. It was proposed that a more realistic assumption of sea conditions could be used to design marine structures. Similar approaches are taken for fixed platforms, risers, moorings, and cables. The third paper discussed the use of wavelet transforms to analyze breaking waves. By separating transient signals into basic building blocks, the singularities and sharp variation points carrying information associated with breaking waves can be more accurately examined. Finally, a unique plate-type structural system with the potential for supporting floating structures such as airports was described. Experiments using silicon rubber elastic plate models were conducted both in air and in water. The results were analyzed to refine theoretical estimates.

The second session started with a presentation on an experimental study of elastic circular cylindrical shells positioned vertically in water. Historically, studies on the interaction of vertical cylinders in an ocean wave field have been performed theoretically, with few experiments. This effort reported an experimental technique that coordinated wave tank data with modal analysis using FFT and STAR systems. This technique calculated computer predictions. Then there was an exciting study on the harnessing of tidal-generated energy by alternately sluicing tidal flows from the East and West Harbors of Xiamen, China. Particular emphasis was placed on environmental conditions, special zone planning, and technical considerations.

Three presentations were made during OST-5, Marine Positioning, chaired by Yong-qi Chen and Norm Estabrook. First, several applications of GPS in marine geodesy were explained, including precise and standard positioning services. Code differential GPS for vessel positioning has revolutionized the accuracy and precision of hydrographic surveys. Real-time applications with carrier phase and on-the-fly ambiguity resolution strategies must be applied in order to obtain precise positioning and navigation. RTK-GPS systems allow GPS to be used to measure tide and swell, as well as attitude determination for vessels. Next, the history, development and current status of the Hong Kong Hydrographic Office were discussed. The office has acquired a variety of modern equipment, including a multibeam echo sounding system, a DGPS reference station and a sophisticated charting capability. The new Hong Kong DGPS universal reference station was discussed. It is located on Kau Yi Chau Island and operated by the Hydrographic Office. Tests were conducted to determine the accuracy of its reference coordinates in the WGS84 datum by calculating repeated baselines to 5 other Chinese IGS core stations. While latitude and longitude agreement was close, a three meter discrepancy in height was found.

OST-6, Marine Environment and Mixing, was chaired by Xiankun Ke and Clark Liu. There were presentations concerning wastewater mixing and sediment dynamics. Taiwan's Tansui River is heavily polluted due to the discharge of untreated municipal and industrial wastewater directly into the river. This has led to a large water pollution control project that will provide a sewer system to intercept the waste before it reaches the river. Waste will be redirected to the Pali wastewater treatment plant. The project and dilution techniques for injecting the treated wastewater into ocean waters were explained. Another paper focused on a technique for determining sediment transport phenomena in the Wash embayment of eastern England. Sediment pathways and quantities coincided with seasonal tidal variations, with suspended sediment transport rates measuring greater than those of bedload transport.

Rongxing Li chaired the OST-7 session on Marine GIS and Shallow Water Mapping, which yielded 4 presentations. An interesting paper was delivered on the use of laser airborne depth sounders and laser bathymetry in Australia. The paper described an airborne laser system to measure shallow water depths. The Royal Australian Navy (RAN) applied this technology to many unmapped areas. A third paper introduced the results of a GIS project in Malaysia for shoreline erosion monitoring which was supported by the Asian Development Bank. GPS and aerial photogrammetry were used for GIS data acquisition. The erosion data were integrated with other social and economic factors to design spatial models for purposes such as placing erosion control structures. Results of a pilot project on the island of Penang were also discussed. Finally, the principles and applications of remote sensing as applied to coral reef mapping were presented, with examples given of the potential for satellite imagery to support such mapping. Results of an experiment using SPOT satellite imagery for coastal mapping in the area southeast of Oahu, Hawaii demonstrated the viability of this approach, as well as the capability for supporting 3-D visualization.

OST-9, Ocean Energy, was an exciting session chaired by Yukihasa Washio. There were 5 presentations on a wide variety of ocean energy topics. First, there was an interesting discussion of the progress of ocean energy technology in China. China is engaged in several different projects, including tidal power plants, wave-activated generators, ocean thermal energy and salinity gradient energy conversion. Eight tidal plants generate a total of 6,025 kW, with the largest generating 3,200 kW in Zhejiang province. Most of these were built in the 1970's. Now several plants with a capacity of 10 mW are in the planning stages. Five hundred wave-activated generators have been produced in China to power navigation beacons along the coast, and a small on-shore wave plant has been undergoing tests since the 1980s. The next paper introduced a prototype caisson breakwater which is capable of extracting wave power developed by the Japanese Ministry of Transportation. Field experiments have been carried out since 1996 in Sakata Port, Yamagata Prefecture. These experiments will verify the level of this system's durability. The next presenter described a study where a solar power system was combined with the JAMSTEC "Mighty Whale" floating wave power generator to form a hybrid system that could accommodate periods of calm seas and still produce a more uniform total output. Capacity of the solar power system was 20 kW and the unit was installed on the sloping surface of the wave power generator. A pendular wave power station was introduced next. It was designed and built as a pilot plant at Xiaomaidao, Qingdao City, China. This system is expected to generate 8 kVA at a 33% efficiency with mean wave height of 0.9 m and a 5.2 second mean wave period. Annual energy output is anticipated to be on the order of 41,000 kWH. A fourth paper discussed the energy potential of geothermal sources lying within the Northwest Pacific marginal zones. In areas with deep trenches outside the island arc, heat flow values are extremely low, often with values of less than 20 mW/m^2. Areas inside the arc and in the back-arc area have very high heat flow values. These areas promise a wealth of geothermal resources, including energy, petroleum, and minerals.

OST-10, Oceanography, was chaired by Huasheng Hong and Lorenz Magaard. The first paper considered whether corrected WWII SST data can still be used or must be discarded altogether as unreliable. Called into question is the sudden "jump" in SST data from this period, indicating an oceanic warming. The deviation is probably due to the use of non-insulated sample buckets or from the practice of measuring SST at engine water inlets, which was not true sea surface water. It was concluded that any use of SST data from 1939-1945 requires due consideration of WWII conditions and cannot easily be used in a measurement history of this parameter. Next was a presentation of a numerical study conducted to establish a credible basis for estimating impact pressures on marine structures due to surface wave slamming. The numerical study is based on the Reynolds time averaged equations, from which separate equations for kinetic energy and dissipation energy are derived. The results presented reflected a wave tank setting. Experiments in such a tank are currently being planned to determine the degree of correlation with the established theory. The final paper addressed a new way to display numerical results for tidal currents in semi-enclosed basins. In addition to the traditional approach of displaying tidal ellipses, co-tidal lines, phase lines for tidal currents and charts for tidal current ellipticity were used. Tidal currents in the South China Sea are now displayed in this new manner.

MARINE RESOURCE MANAGEMENT AND DEVELOPMENT (MRMD)

MRMD Coordinator Richard J. Podgorny from the Office of Sustainable Development and Intergovernmental Affairs, U.S. Dept. of Commerce, NOAA, prepared the following summary of the Marine Resources Management and Development sessions at PACON 97 in Hong Kong. Prof. Ying Wang of the State Pilot Laboratory of Coast and Island Development in Nanjing, China shared the responsibility for the MRMD forum. Session summaries were submitted by session chairpersons. There were 12 topics on which authors presented papers on recent achievements related to marine science and technology.

The first of two sessions on Marine Education, MRMD-1A, was chaired by Colin Brown. There was a discussion of the developmental history of post graduate marine science courses in China, followed by an explanation of mandatory and optional courses available to students today. Some comparisons made with courses offered in the United States showed many similarities. The session also addressed the history of shipping ownership and management. One paper explained the International Marine Pollution Convention (enacted in the past two decades), and two new Conventions about to come into force. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers addresses training standards for ships' crews. In addition, the International Convention on the Code for the Safe Operation of Ships and for Pollution Prevention was also discussed. There were doubts whether national administrations and shipping company owners would be able to implement the conventions by their 1998 deadlines.

Edwin Clausen chaired MRMD-1B, the second of two sessions on Marine Education. The first paper explained the link between sustainable development education and a global perspective. It described a new sustainable development curriculum being developed at the Arizona International Campus, University of Arizona. The presentation explained how it is being incorporated throughout the undergraduate course of study. Pacific partnerships are being developed by University of Arizona's International Campus with universities in China, Singapore, Canada and Mexico. Another paper discussed outcome-based assessments and evaluation techniques being developed at Arizona International Campus to address the question "How do you know students are learning?" A detailed presentation on the ways undergraduate critical thinking skills could be enhanced through the interactive study of marine science and technology issues was also given. For example, one course incorporates marine biology, quantitative analysis, humanities and social sciences demonstrating the value of interdisciplinary learning. Another presentation outlined a case study of a course that involved students in the study of a specific watershed on the coast of Washington State. The course is interdisciplinary, tied to real policy issues, and involves students in internships. Possible applications of this type of course to other nations were presented and discussed.

The Land Reclamation session, MRMD-2, was chaired by Zengcui Han. One presentation illustrated the effects of huge projects on the ecological environment of the Changjiang Estuary. The projects included the transfer of water from south (China) to north (China), land reclamation, and the regulation structure of the Changjiang Estuary. Shanghai, the largest city in China, is located in the delta area of the Changjiang River. The presenter discussed the important and complicated issues of sedimentation and salt water intrusion. Another author used the Qiantang Estuary to focus discussion on the protection offered by seawalls and groin heads. Several kinds of groin heads were illustrated with their characteristics of suitability, construction method, and engineering effects. Finally, issues concerning tidal bore, large estuarine sand bars, mathematical models with 1-D and 2-D simulations, and the statistical analysis of tidal variations (after severeal large-scale reclamation/construction projects in the Qiantang Estuary over the past 30 years) were vigorously discussed.

MRMD-3, the Coastal Environmental Issues session, was chaired by Ying Wang and Kenji Hotta. The first presentation discussed the negative financial impacts and toxicity damage from algal blooms caused by *Cochlodinium* in the coastal waters of Korea during three successive years beginning in 1993. The paper also addressed the causes and prevention of red tide. There was a review of Japan's new ocean environmental improvement technologies and techniques. Topics included an ocean space construction project of a new airport for Tokyo, gentle slope protection, man-made headlands, up-welling research, and the use of construction material adapted from the ocean. Discussion included other issues related to Japan, such as drainage problems in Japan's fishing ports and villages and its effects on development. Requirements for developing drainage facilities and wastewater treatment facilities were presented with the objective of improving water quality, minimizing degradation of the environment, and increasing usage of fishing harbors. Discussion included land use in the metropolitan areas of the coastal zone. Tokyo Bay and its developments were used to illustrate a succession of waves of economic growth beginning with the establishment of industries and followed by residential settlements. Industry is the main user of land reclamation in Tokyo Bay. Suggested models for future development in Japan included several coastal zone management techniques developed in the United States.

Two sessions on Marine Policy and Sustainable Development Programs were chaired by Richard J. Podgorny and Mao Bin, MRMD-4A and MRMD-4B. China's Master Plan for National Economy and Social Development with a focus up to the year 2010 was presented in the context of Agenda 21 and sustainable development. China has 18,000 kilometers of coastline, with fisheries, transportation, and tourism as the top 3 industry sectors in the coastal area. These are followed by sea salt, oil and gas, sand, and shipping. Opportunities and challenges are being addressed by the Chinese government to ensure sustainable development in the marine environment. Leaders are aware that humans must depend on the ocean to meet their future needs. Also presented in this session was a well organized and graphic presentation illustrating sedimentation in the Pearl River Delta, wastewater disposal in Victoria Harbor, land reclamation plans and their status, flooding and subsidence, and economic development related to container terminals, power plants and mariculture. Impacts of natural disasters such as typhoons were also addressed. Subsidence of reclaimed land is about half a centimeter per year. This is a major physical and policy issue that must be addressed. Waterman's Model for an integrated coastal policy was advocated. Another paper discussed the recent development of special compensation for subordinate salvage of marine property in the coastal and marine environment. Case studies presented included legal implications and a discussion of liability issues and objections from the salving industry. In the following presentation, the U.S. Country Studies Program was introduced and explained. Discussion included greenhouse gases caused by man-made activities which drive climate change. Agenda 21 and the Framework Convention on Climate Change were explained. So far, 55 developing nations use the U.S. Country Studies Program's expertise and guidance to inventory emissions of greenhouse gases, assess impacts of climate change, evaluate mechanisms to reduce greenhouse gas emissions, and develop nationally integrated action plans for responding to climate change. Workshops and training for more than 2,000 scientists and decision makers have already been provided. The Country Studies Program provides technical support and financial assistance to developing nations. For more information see website HTTP://WWW.GCRIO.ORG/CSP/WEBPAGE.HTML. The Intergovernmental Oceanographic Commission's (IOC) representative explained how United Nations organizations adopted the IOC's resolution to have a year of the ocean. The United Nations' theme for the

International Year of the Ocean, 1998 is "Our oceans are the greatest heritage we have, and we cannot live without them. Our Common Heritage". There will be a major Expo'98 in Lisbon, Portugal. Individual and national pledges to care for the oceans will be collected and recorded by the Government of Canada. U. N. organizations are encouraging events in 1998 to be designated as part of the International Year of the Ocean (IYO). PACON 98 has been designated an IYO event by South Korea's conference organizers. For more information see website HTTP://WWW.UNESCO.ORG/IOC/IYO/IYOHOME.HTML

The Ocean Resource Management session, MRMD-5, was chaired by Craig MacDonald. One paper presented the results of a six-year study of the Guangdong Islands' resources and the role they play in natural resource management and the islands' economy. Also discussed was a study of the role of state port authorities in controlling ports to ensure that ships continue to comply with acceptable standards of maritime safety. It was concluded that it is best to keep sub-standard ships out of port and out of the region, only being allowed in when commercial benefits exceed risks. Selected marine areas in Hawaii were also discussed during this session. Jurisdiction and authority effectiveness was evaluated in terms of management objectives and mechanisms. It was determined that there is a need to establish carrying capacities and to engage in comprehensive regional planning of certain management areas.

Cathie Kueh chaired MRMD-6, the Marine Pollution and Toxicology session. Problems of ship pollution such as sewage, garbage and oil were discussed in the context of legalities and control mechanisms. Several papers presented concerns regarding trace metals, metal binding proteins, and toxicological assessment techniques using various fresh water and marine species of fish, barnacles, and diatoms.

Three Fisheries and Mariculture sessions were chaired by Ka Hou Chu and Clive Keenan, MRMD-7A, MRMD-7B, and MRMD-7C. Many of the papers presented during these 3 sessions related to fishing, fisheries management, and mariculture activities. Fisheries in marine waters in Northeastern Hong Kong have been impacted by trawlers and mariculture farms prior to artificial reef deployment. Trawlers supply much of their catch to fish farms as "trash fish". The total catch has declined 20% and mainly consists of small sardines. Several larger species are no longer found, and large fish are rare. None of the fisheries regulations are enforced. In the South China coastal region, there are efforts to develop seafood freshness indices as a guide for quality control. Different methods of measuring the freshness of seafood items included the comparison of biochemical, microbiological and sensory tests. Cage fish production in Hong Kong has increased 7 fold in the past 20 years, although declines in tonnage caused by red tides and oxygen depletion may be caused in part by the use of minced trash fish as mariculture fish food. Pathogens are another factor in mariculture. Ultrasound, used in combination with drugs, can achieve 100% mortality of fish bacterial pathogens. Research will eventually lead to the development of a new technique for the prevention and treatment of diseases of cultured aquatic organisms. Disease is a major problem in shrimp farming throughout the world. We now know that shrimp larvae at different developmental stages have different susceptibilities. Experimental exposure of prawns to hormones like progesterone continues to provide inconclusive results regarding crustacean ovarian maturation. To demonstrate the presence of 4 distinct species of commercially important crabs in the Indo-West Pacific, genetic sequencing was developed. This information is crucial for further aquaculture development of the species. Fisheries regulations for the west coast of peninsular Malaysia have been in effect for two decades, but there is little enforcement and compliance is up to the individual. Many fishermen do not comply with these regulations. Studies have shown that there is positive correlation between the level of education and the duration of a fisher's employment, to fisheries regulation compliance. Also, studies in Malaysia have indicated that cultured oysters are capable of removing heavy metals from their flesh during depuration, occurring over a period as short as several weeks.

Sessions MRMD-8A, MRMD-8B, and MRMD-8C on Marine Biotechnology, were chaired by King Ming Chan. The first paper focused on the vaccination of silver seabream against the bacteria *Vibrio alginolyticus*. Data showed that formalin-killed bacterium gave the best protection against *Vibrio* in seabream, while antibodies remained in the sera for eight weeks. This may provide a new tool in fighting this bacterium. Another paper explored the effect of Gonadotropin-releasing hormone analogues and dopamine D_2. cDNA clone encoding for DA receptors and membrane receptors for GnRH were isolated. Further research examined other species such as black seabream and seabass. The third paper focused on black seabream, centering on the multiplicity and localization of GnRHs. Three forms were found in the seabream, and determining their exact role in gonad development was essential in the applications of GnRH peptide for inducing spawning in black seabream. The next paper presented recent work on the cloning of cDNA and gene fragment encoding for metallothionein. The cloned MT gene promoter fused to EGFP, and therefore shall be used as a reporter gene system for metal assay and as an inducible gene promoter in transgenic fish research.

In the second part of the Marine Biotechnology session, a paper discussed the effect of hormones on the acceleration of reproductive maturation in economically important crustaceans. Two hormones induced development in the reproductive organs of crustaceans, while one inhibited development. It was concluded that the classical method of eyestalk removal of individual crustaceans could be replaced by applications of newly identified hormones to promote the growth and reproduction of crustaceans. Another paper discussed the use of cloning in the production of a recombinant hormone of a molt-inhibiting (MIH)-like neuropeptide from white shrimp. This is the first report of a recombinant expression of MIH-like peptide from shrimp. The expressed hormone will facilitate the functional analysis of the cloned MIH-like peptide and hence, applications of the MIH-like peptide in crustacean aquaculture will become possible.

In the third part of the Marine Biotechnology session, one author explained China's marine biotechnology and opportunities for mariculture. The major accomplishments and advances of marine biotechnology for Qingdao's Institute of Oceanology were covered. Advances include transgenic research in seaweed, fish, etc. and the production of disease resistant marine species. The genetically engineered organisms are ready to be used in mariculture sites in China. The next paper described studies of genetic variations and phylogenetic relationships in thirteen species of marine shrimp. To assess the phylogenetic relationship of marine shrimp, the authors used the RAPD method. It was determined that RAPD will be useful in providing quick and reliable genetic markers for shrimp identification. Finally, the use of mitrochondrial DNA sequences to study the phylogenetic relationship of *Penaeidae* shrimps was presented. After studying nineteen species of shrimp, the resulting data provided useful genetic information for studies of the evolutionary relationship of the *Penaeidae* shrimps.

The Coral Reefs session, MRMD-11, was chaired by Loke Ming Chou. Discussion included the results of a coral translocation exercise conducted by a non-governmental organization in Singapore. The National University of Singapore monitored the survival rates of transplanted coral. Low survival rates were attributed to improper securing/attachment techniques plus unfavorable factors at the translocation site. Also discussed was the development of a computer model (based on an object-oriented approach to incorporate individual-based interaction) to simulate the structure of a community having four coral species of different growth forms. Behavior exhibited from model output provides an understanding of mechanisms influencing stability and dynamics of the coral reef system.

Yuk-Shan Wong chaired, MRMD-12, the Integrated Coastal Zone Management session. The integrated coastal zone management programs of Xiamen, China, the Philippines, and Indonesia were presented during this session. A management model for sustainable coastal development was also introduced. Discussion included the differential sedimentation of the Lingdingyang Estuary over the last 5,000 years and its effect on the planning of the Hong Kong infrastructure project. The final paper examined the conservation and management of mangrove ecosystems.

Three Marine Ecology and Biodiversity sessions were chaired by James Sullivan and C. K. Wong, MRMD-14A, MRMD-14B and MRMD-14C. A range of topics, including primary productivity analysis using Coastal Zone Color Scanner data and deep ocean water use for sustainable coastal development were discussed during these sessions. Papers presented also covered studies and experiments on larval development and settlement of several species of marine organisms, including barnacles, bacteria, diatoms, scallops, and oysters. Geographic areas represented by these studies and experiments include Clear Water Bay, Hong Kong; the Luzon Strait between the Philippine Sea and the South China Sea; Beibu Gulf, China; Qingdao, China; and Hawaii. Also discussed were new technologies and techniques developed at the Natural Energy Laboratory in Hawaii. These could provide major new opportunities for sustainable coastal development in tropical, subtropical and even warmer temperate areas adjacent to deep ocean water. The unique attributes of deep ocean water include a virtually unlimited supply of 6° C water, absence of surface pathogenies, and enhanced nutrient levels. Primary uses of cold deep ocean water to date include: air conditioning, industrial cooling, temperate agriculture production in tropical desert conditions and aquaculture. Technologies are available to support development of these applications and can be developed at relatively low cost. The feasibility of electrical power generation and fresh water production has also been demonstrated. Recent technological advances discussed in this session indicate the high probability of cost effective applications of these uses in the near future.

KEYNOTE ADDRESS

"SUSTAINABLE DEVELOPMENT AND PROTECTION OF MARINE ENVIRONMENT AND ITS RESOURCES"

Wenhe Yang
State Oceanic Administration
Beijing, CHINA

Mr. Chairman, Ladies and Gentlemen,

It is a great pleasure for me to see the convening of PACON 97 in Hong Kong which returned to its motherland not long ago. On behalf of the State Oceanic Administration of China, I would like to extend my warm congratulation on the opening of the Symposium.

The title of my presentation today is Sustainable Development and Protection of Marine Environment and its Resources, which consists of three parts.

I. GENERAL STATUS OF THE IMPLEMENTATION OF RIO RESOLUTIONS IN CHINA

"Agenda 21" adopted at the UN Conference on Environment and Development held in Rio in 1992 states that the marine environment forms an integrated whole that is an essential component of the global life-support system and a positive asset that presents opportunities for sustainable development. Since the Rio Conference, the Chinese government has attached great importance to the issue of environment and development and has become more aware of the importance of marine development and protection to the economic and social development and environmental protection in China. The Chinese government has taken a series of significant actions over the past five years:

1. In order to turn the ocean into a powerful mainstay of the human life support system and to give full play to the dominant functions and maximize the overall benefits of China's coastal areas, the State Oceanic Administration (SOA) of China designated 3,642 functional zones all over China with the assistance of coastal provincial, regional and municipal governments in 1993. Of these functional zones, 2,482 are for development and utilization, 529 are for control and protection, 221 are nature reserves, 330 are of special functions, and 80 are reserved zones. The functional zoning has provided a basis for policy-making in the establishment of a good order for the development, utilization, control and protection of the ocean.

2. In 1993, a demonstration zone for coastal development and integrated management was established in Xiamen, China. This was one of the joint projects on marine pollution prevention and management sponsored by UNDP, IMO and GEF in the East Asian Sea, aiming at establishing a demonstration area for integrated coastal zone development and management

which focuses on marine pollution prevention. This project has been going on smoothly and good results have been achieved over the past two years.

3. During the 8 years for the implementation of the National Program for Comprehensive Investigation of Coastal Islands, a large amount of information about the resources, environment, social and economic conditions of the islands and their adjacent waters were obtained. On the basis of this information, pilot projects on island development were executed. From 1993 to 1995, six islands were designated as National Comprehensive Development Zones, for which the central government allocated 6 million yuan and the local governments 120 million yuan. These pilot projects have achieved remarkable success.

4. In 1994, the Chinese government promulgated "**China's Agenda 21 --- White Paper on China's Population, Environment and Development in the 21st Century**", which listed the sustainable development and protection of ocean resources as one of the important program areas.

5. In June 1995, with the approval of the State Council, the National Ocean Development Plan was published. The coastal provinces and municipalities were requested to have relevant components of this plan be incorporated into their own Ninth Five-Year Plans and Long-term Programs up to 2010. The National Ocean Development Plan stipulates that ocean development programs should be made and implemented simultaneously with programs for environmental protection and resources conservation so as to ensure the health of the marine environment and the sustainable use of ocean resources.

6. To help the local governments to have a better understanding of the sustainable development strategy and to raise their consciousness to implement China's Agenda 21, SOA hosted two training courses in the second half of 1995, which were attended by people responsible for formulating programs and plans in the coastal provinces, autonomous regions, municipalities, and SOA.

7. In March 1996, China Ocean Agenda 21, an integral component of China's Agenda 21, was formally promulgated. This agenda forms the policy guidelines to sustainable ocean exploitation and utilization in China. In order to effectively implement China Ocean Agenda 21 and to guide government at all levels of the country to follow the principle of sustainable utilization in ocean development, China also drew up Action Plans for China Ocean Agenda 21.

8. In May 1996, the Fourth Session of China's Eighth National People's Congress approved the Ninth Five-Year Plan and Long-Term Plan up to 2010 for National Economic and Social Development of the People's Republic of China, in which, "strengthening marine resources investigation, developing marine industry and protecting the marine environment" were identified as important elements of the nation's comprehensive development program.

9. In 1995, departments concerned in China initiated the revision of the Marine Environment Protection Law of the People's Republic of China in accordance with China Ocean Agenda 21. It was emphasized that the objective of marine environmental protection is to avoid environment

deterioration, protect ecological equilibrium, ensure human health and sustainable utilization of marine resources. Consequently, marine ecological environment protection was proposed to be added to the law.

10. In order to develop the capacity for integrated coastal management and realize sustainable development in the coastal areas, China has listed the Research Program on Key Technologies for Utilizing Coastal Resources and the Marine Environment as a key national S & T project for the years from 1996 to 2000. The program covers research on ICM technologies, marine information system, etc.

11. Over the past five years, we have strengthened our efforts in marine environment management and ecological protection, improved the permit system for ocean dumping, carried out trial monitoring of ocean waste dumping, designated 39 ocean dumping sites, and effectively halted wanton ocean dumping operations. We have also implemented the report system for the prevention of pollution caused by offshore oil exploration and exploitation. Offshore oil companies are requested to be equipped with devices for waste water treatment and disposal, instruments for monitoring purposes and necessary equipment to deal with oil spill events. Up to now, we have established 60 marine nature reserves with a total area of around 1.3 million hectares, of which 15 are of the national level and 45 are local level. These efforts have resulted in the effective protection of typical marine ecosystems and previously endangered species in China's sea areas.

II. OBJECTIVES OF PROTECTING MARINE ENVIRONMENT AND ITS RESOURCES

The above major measures clearly demonstrate the objectives defined by the Chinese government in protecting the marine environment and its resources. These objectives include: the establishment of a well-cycled marine ecosystem and the development of a rational ocean development system and subsequently the realization of sustainable use of the ocean and the sustainable development of marine economy. The specific objectives are as follows:

1. To avoid deterioration of the marine environment, restore and improve the quality of the marine environment. For example, to reduce pollution in the nearshore area, enable some heavily-polluted estuaries and bays to be rectified, prevent pollution in new development areas and mitigate the impacts of ocean-related natural hazards.

2. To develop a well-cycled marine ecosystem and effectively protect important ecosystems, rare species and marine biodiversity; To accelerate the development of marine nature reserves and to gradually make it a common practice to utilize marine living resources in line with the principle of sustainable development; To restore fishery resources in the coastal and offshore areas, protect habitats in the tidal flats and shallow sea areas and to cultivate better species so as to lay a solid foundation for the development of large-scale ocean farming.

3. To optimize the structure of marine industries so as to facilitate the expansion and propagation of marine industrial groups. To expand the scope and increase intensity of ocean utilization, renovate and upgrade traditional industries and develop some new industries for the purpose of facilitating the rapid development of marine economy, aiming at an increase of the percentage of marine industrial output value in the national GNP from 4% to 5-10%, which will account for 20-30% of the GNP of the coastal regions.

The three specific objectives stated above shows that China is determined to protect marine ecological environment, achieve a balance between the exploitation and the regeneration of resources and to pursue sustainable development while exploiting marine resources and accelerating the development of marine economy at a moderate rate. China's embarkation on the road of sustainable development is not only a realistic necessity for promoting the development of our economy and for preserving and utilizing resources, an inevitable outcome of historical development, but also an obligation for ensuring the benefits of our future generations.

III. BASIC MEASURES FOR PROTECTING MARINE ENVIRONMENT AND ITS RESOURCES

Our basic measures for sustainable development of the marine environment and its resource are as follows:

1. Formulate and improve laws and regulations for comprehensive ocean management, establish and reinforce law-enforcing system, improve the qualifications of those engaged in law enforcement and intensify law enforcement activities so as to realize effective management of our coastal, offshore and other areas under national jurisdiction.

2. In light of the marine functional zoning program and the marine development and protection plan, guide the marine industrial sectors to follow the principle of sustainable development and reasonably allocate marine resources and space through comprehensive coordination so as to minimize wastage and make better use of resources.

3. Give adequate attention to the coastal islands which are part of our territory, combine the development, utilization and conservation of coastal islands with the economic development and sustainable development in the coastal areas. Special attention should be paid to the ecological equilibrium and biodiversity on and around the islands.

4. Preserve marine living resources for sustainable utilization, establish marine protected areas of coral reefs and mangroves and protected islands. Designate protected spawning and nursery grounds of fishes, shrimps and crabs in the bays and coastal areas, protect biological species and special ecosystems, properly manage artisanal fishery, improve fishing methods and technologies, prevent wanton fishing and over-fishing, pursue the no-fishing season system, manage the mariculture in the tidal flats and shallow waters, reasonably develop and exploit waters suitable for mariculture, develop ocean ranching technologies and enhance artificial propagation of high-quality fishery resources.

5. Protect the marine environment, strictly control the discharge of both land-based pollutants and pollutants from operations at sea, limit the gross pollution load in key waters; formulate and carry out contingency plans for preventing marine pollution so as to mitigate the effects of pollution events on the marine ecological environment; enhance marine environmental monitoring and surveillance and disseminate information on marine environmental quality on a regular basis and exercise effective management of the marine environment.

6. Implement the strategy of promoting the development of coastal economy by relying on science and technology, develop new technologies to improve the overall efficiency and benefits of the development and exploitation of marine resources, stimulate the transfer of extensive ocean development to an intensive one and thus promote the formation and development of new marine industries.

7. Improve ocean observation, marine environmental forecasting, disaster early-warning and mitigation, improve the ocean observing and early warning systems, make timely and accurate forecasting of natural marine disasters, adopt disaster-prevention and mitigation measures and contingency plans so as to reduce the losses from natural disasters.

8. Strengthen both public and professional education on ocean knowledge, promote public involvement in ocean affairs so as to develop a new situation where the whole nation cares for the ocean, exploits the ocean and protects the ocean.

9. Strengthen international cooperation. People all over the world share the oceans. Concerted efforts should be made by all coastal states to solve the problems associated with the oceans. We shall actively promote international cooperation in the fields of ocean development, marine environmental monitoring and protection, marine disaster reduction, and researches on ocean science and technology among the coastal nations in the Northwest Pacific region.

Ladies and gentlemen!

With the progress and development of mankind, we are all confronted with the tasks to peacefully utilize marine resources, rationally protect the marine environment, effectively conduct ocean management and sustainably exploit the oceans. China is willing to work jointly with other coastal nations all over the world and to make the contributions to the fulfillment of these challenging tasks and to the final solution of the problems with the oceans.

Thank you.

GENERAL LECTURE

"SUSTAINABLE DEVELOPMENT: THE INTEGRATION OF ECONOMIC GROWTH, ENVIRONMENTAL PROTECTION, AND SOCIAL EQUITY"

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ABSTRACT

Environmental problems, such as ocean and air pollution and resource degradation, affect every nation's economic prosperity, political stability, social fabric, and health of available natural resources. Environmental degradation is compounded by an expanding world population, especially in coastal areas with 60 percent of the global population living within 100km of the coast.

Sustainable development is a new decision-making process which ensures that economic growth is linked to environmental stewardship within a framework of social equity. Sustainable development involves building consensus among stakeholders, forming partnerships, and integrating participatory bottom-up management. Sustainable development is the essence of activities such as the redevelopment of brownfields, the creation of eco-industrial parks, and the formation of natural disaster-resistant communities.

A growing economy and healthy environment are essential to achieving sustainability and global security. The Office of Sustainable Development and Intergovernmental Affairs (SDIA) at the National Oceanic and Atmospheric Administration (NOAA) is one of several similar offices in the federal government. SDIA responds to marine fisheries crises and focuses on community initiatives to promote sustainable development. SDIA also provides a focus for sustainable development initiatives within the U.S. Department of Commerce.

In 1993, the President's Council on Sustainable Development (PCSD) was created to provide guidance on how to achieve sustainability. PCSD Members have found that forging strong partnerships, creating goals, and broad-based input at the community level are important in leading the nation toward sustainability. In 1996, the Joint Center for Sustainable Communities, a project of the National Association of Counties and the U.S. Conference of Mayors was created with initial funding from SDIA and other Federal agencies to help local officials incorporate principles of sustainable development into management of their communities. Sustainable development must be a global concept implemented at the local level for the benefit of future generations.

INTRODUCTION

Sustainable development has been defined by the Brundtland Commission as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The present generation confronts obstacles that previous generations did not face. The intensive development of technology and industry has taken its toll on the environment. With greenhouse emissions destroying the ozone, industrial and agricultural effluent pouring into estuaries, oceans, and lakes, and contamination leaching into the soil, we are destroying the necessities of life: land, air, and water.

But we do have the opportunity to make changes in the way we live to preserve natural resources and improve the economy for future generations. We now understand that to achieve sustainable development, jobs, productivity, wages, knowledge, and education must grow and that pollution waste and poverty must not.

During the last 25 years, the United States has made great progress in protecting the environment. In addition, advances in science and technology have helped to improve economic efficiency and modify consumption patterns. Sustainable development employs a collaborative decision process that addresses the environment, economy, and social equity. These items are interrelated and positive change cannot be made without addressing all three together.

President Clinton and Vice President Gore have been committed to sustainable development since the beginning of their administration in 1993. They see this concept as part of reinventing the Federal Government — making it smaller while forming strong ongoing partnerships with government at the state and local community levels.

The Department of Commerce (DoC) realizes the importance of sustainability. According to its Mission Statement, the "Department of Commerce promotes job creation, economic growth, sustainable development, and improved living standards for all Americans, by working in partnership with businesses, universities, communities, and workers..."

In fact, the late Secretary of Commerce Ron Brown often remarked that "in a real sense the Department of Commerce *is* the Department of Sustainable Development." Secretary Brown worked diligently to integrate the activities of the National Oceanic and Atmospheric Administration (NOAA), with its focus on the scientific monitoring of the environment, into the DoC, whose primary purpose is to stimulate the business, trade, and technology sectors.

NOAA created the Office of Sustainable Development and Intergovernmental Affairs (SDIA) in 1993, the first of several similar offices in the Executive Branch. The Office provides a focus for sustainable development initiatives within the Department of Commerce.

In 1995, SDIA organized a National Teleconference on Sustainable Communities on behalf of the DoC. The teleconference, which featured Vice President Gore, Secretary Brown, and other officials, focused on community efforts to achieve sustainability nationwide. It brought together community leaders to share their ideas about sustainable development in their home environments. It was a profound success and helped provide needed space for dialogue, coalition building, and information sharing.

NOAA's Office of Sustainable Development works with the National Marine Fisheries Service (NMFS) and other federal agencies to respond to marine fisheries crises by providing financial assistance and guidance to fisherman, as well as taking measures to protect fisheries stocks. In this area of activity, SDIA designed and implemented the Northeast Emergency Assistance Program, and the Northwest Emergency Assistance Plan. In addition, SDIA is the lead policy office for the design and implementation of programs which provide assistance to fishermen in the Gulf of Mexico after natural disasters destroy fishing gear and fisheries resources.

SDIA also focuses on community initiatives. For example, SDIA contributes to the President's Council for Sustainable Development (PCSD), the Joint Center for Sustainable Communities (JCSC), and assists local municipalities in bringing important stakeholders and valuable community information together.

PRESIDENT'S COUNCIL ON SUSTAINABLE DEVELOPMENT (PCSD)

In 1993, President Bill Clinton established the PCSD. The Council's initial tasks were to draft recommendations on a national action strategy, to create and implement an awards program honoring achievements toward sustainable development, and to conduct outreach to educate the American public on the importance of sustainable development. They created eight task forces to accomplish this mission.

The members of the Council and its task forces included representatives from government, industry, environmental organizations, and others. Two Department of Commerce (DoC) executives — Secretary of Commerce William Daley and NOAA Administrator D. James Baker — are PCSD Members. The initial 25 PCSD Members established common ground among themselves and adopted 16 statements of "common belief" in addition to ten national goals. The goals were interdependent and accompanied by indicators — yardsticks to measure the progress toward each goal. They found that collaboration on a community level with place-based management equaled success in achieving sustainable development.

In 1996, the PCSD presented its initial report, *Sustainable America: A New Consensus for Prosperity, Opportunity, and A Healthy Environment for the Future*, to President Clinton and the public. The report contained 38 policy recommendations and 154 specific action items.

The President then asked the PCSD to monitor the implementation of the recommendations. He also called for the creation of the Joint Center for Sustainable Communities (JCSC), a project of the National Association of Counties and the U.S. Conference of Mayors. Four bureaus of the DoC currently contribute to the JCSC. They are NOAA, through its Coastal Services Center in Charleston and its Office of Sustainable Development and Intergovernmental Affairs; the Economic Development Administration; the Minority Business Development Agency; and the National Institute of Standards and Technology.

The JCSC was designed to help local officials incorporate principles of sustainable development into management of their communities. The Center provides technical assistance, information, training, and grants to community leaders to address issues such as job diversity, education and job training, affordable housing, and community safety.

Three PCSD task forces were created to implement the recommendations in the *Sustainable America* report:

1) Innovative local, state, and regional approaches,
2) National opportunities, and
3) International leadership.

In addition, interagency working groups were formed to deal with specific issues such as sustainability indicators, education, and materials and energy flow. In each task force area, coordination among stakeholders and the formation of partnerships were critical for success.

Good examples of successful sustainable development can be found within many communities across the United States. For example:

> Chattanooga, Tennessee — A victim of suburban sprawl after World War II, this medium-sized city lost much of its retail and residential development. Local manufacturing jobs were eliminated, companies closed or laid off many workers, quality education disappeared, racial conflicts arose, and the infrastructure eroded, leading Chattanooga down a road of urban decline. In 1969, Chattanooga was voted the "worst polluted city" in America. The citizens faced this situation with a positive attitude and creative minds. More than 1700 citizens participated in writing a vision for the city and developed 40 goals for the future. Collaborative efforts among government, business, community organizations, and citizens generated funds, political commitment, and civic momentum to deal with complex issues such as affordable housing, public education, transportation alternatives, urban design, air and water pollution, and many more. They rebuilt the economy and dramatically reduced air pollution, which were two priorities within the community. The key factor in their success was community involvement in planning these efforts. Chattanooga serves as a model for other communities to learn from. Their municipal slogan is appropriate for all communities, regions, and nations all over the world: "It takes all of us . . . it takes forever."
>
> Port of Cape Charles, Northampton County, Virginia — Many urban centers in the United States contain so-called "brownfield" properties. These very often are abandoned industrial sites which remain polluted or contaminated as a consequence of previous manufacturing and related activities. The careful redevelopment of these brownfields can revitalize local economies, return the properties to productive uses, and create new jobs and recreation opportunities. By reclaiming these properties for commercial purposes, communities also reduce the pressure to develop valuable green spaces — or "greenfields" — which

surround existing cities and towns. Cape Charles took advantage of the opportunity before them to revitalize the brownfield property in their area. The city built an eco-industrial park on the brownfield site, creating clean, safe jobs for residents and simultaneously protecting valuable wetlands. The preserved wetlands became the focus of an annual bird-watching festival which attracted tourists and stimulated the local economy.

In addition to collaboration among government, public, and private sectors, another important element to sustainable development is using indicators — tools to measure progress and help decide when sustainability has been reached. The importance of indicators is reflected in words spoken by Senator Robert F. Kennedy in 1968:

> The gross national product includes air pollution and advertising for cigarettes, and ambulances to clear our highways of carnage. It counts special locks for our doors, and jails for the people who break them. The gross national product includes the destruction of the redwoods and the death of Lake Superior. It grows with the production of napalm and missiles with nuclear warheads . . . .
>
> And if the gross national product includes all this, there is much that it does not comprehend. It does not allow for the health of our families, the quality of their education, or the joy of their play. It is indifferent to the decency of our factories and the safety of streets alike. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials . . . .
>
> The gross national product measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to country. It measures everything, in short, except that which makes life worthwhile.

Indicators must be measurable and must accurately define what citizens actually value within their communities. It is also important to make linkages between societal factors. For example, salmon abundance can be linked to child poverty — poor children are more likely to commit crimes, which creates unsafe streets, which causes people to move to suburbs, which increases the number of people who drive cars, which creates pollution that enters streams and kills salmon. The interdependence that exists between the economy, environment, and society must be realized to achieve truly sustainable development.

In early 1997, the PCSD published a second interim report, *Building on Consensus: A Progress Report on Sustainable America*" and presented it to President Clinton.

At the present time, the PCSD is working at the direction of the President to craft sustainable development policy recommendations in four major areas:

1) Reforms in the system of environmental management,
2) Response to the challenge of global climate change,

3) Development of metropolitan and rural strategies to achieve sustainable development, and
4) International activities and outreach.

Meanwhile, the JCSC continues to encourage cooperation among cities and counties and to provide information and technical assistance to empower communities. And SDIA continues to be committed to the PCSD, the JCSC, the protection of fisheries resources and well-being of fishermen, as well as other sustainable development community issues.

In summary, sustainable development is the recognition that the pursuit of one set of goals affects others and that we must pursue policies that integrate economic, environmental, and social rights. As President Franklin D. Roosevelt said more than a half century ago, "Men and nature must work hand in hand. The throwing out of balance of resources of nature throws out of balance the lives of men."

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GENERAL LECTURE

"GEOLOGICAL PROCESSES, LAND-OCEAN INTERACTIONS AND HUMAN IMPACTS TO THE COAST EVOLUTION" +

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ABSTRACT

Coastal ocean is characterized by the active dynamic processes of land-ocean interactions, and closed related to the human beings. The new conception of coastal ocean covers the area including surf zone, continental shelf, continental slope and continental rise. Coastal zone is an independent environment with their own natures which differs from neither oceanic environment nor terrestrial. It has important and potential resources with the nature of low cost, less polluted and being able to be nourished. This paper offers the regional examples of coastal evolution impacted by natural processes and human activities.

INTRODUCTION

Definition of the Coastal Zone

Coastal zone is where that the land meets the sea, a transitional zone between land and ocean, and an active dynamic zone of land - ocean interactions. People have different conception on the coasts and coastal ranges that implicates the progress of the scientific knowledge of coastal zone.

(1) During the early time of this century, most of geo - scientists studied and explained the coasts only as a narrow belt of land area surrounded the ocean (sea), it is limited by the low tide water level, such as D. Johnson (1919).

(2) In the 1950's, people realized that coastal zone was an "amphibious" zone, as a transitional zone between land and ocean, including coastal land, sea shore or inter - tidal zone, and the submarine coastal slope offshore, upper limited by the break waves (swash) or tidal current acted zone, ended at the outer boundary area where wave acted on the sea bottom of coastal slope, *i.e.* the water depth is normally equal to one half or one - third of average wave length of the region (Wang, *et al.*, 1987, 1994a) (Figure 1), China adopted the definition of the coastal zone basically for its whole nation wide environment and resources survey along the mainland coastal zone in the 1980's. The definition indicates the progress on the coastal sciences, people realize that the coasts include land and ocean interacted zone.

(3) Concerned the Global Changes since 1990's, the LOICZ Core Project (Pernetta, *et al.*, 1995) defines the coastal zone as "extending from the coastal plains to the outer edge of continental shelves, approximately matching the region that has been alternately flooded and exposed during the sea level fluctuations of the late Quaternary period". It indicates the land ocean interaction and has improved the advance of the coastal sciences. However, the continental slope and continental rise should be included in the dynamic zone of coastal water by all means either during the late Quaternary period or present time.

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⋆ Contribution: Typewrite by Zhang, Yongzhan

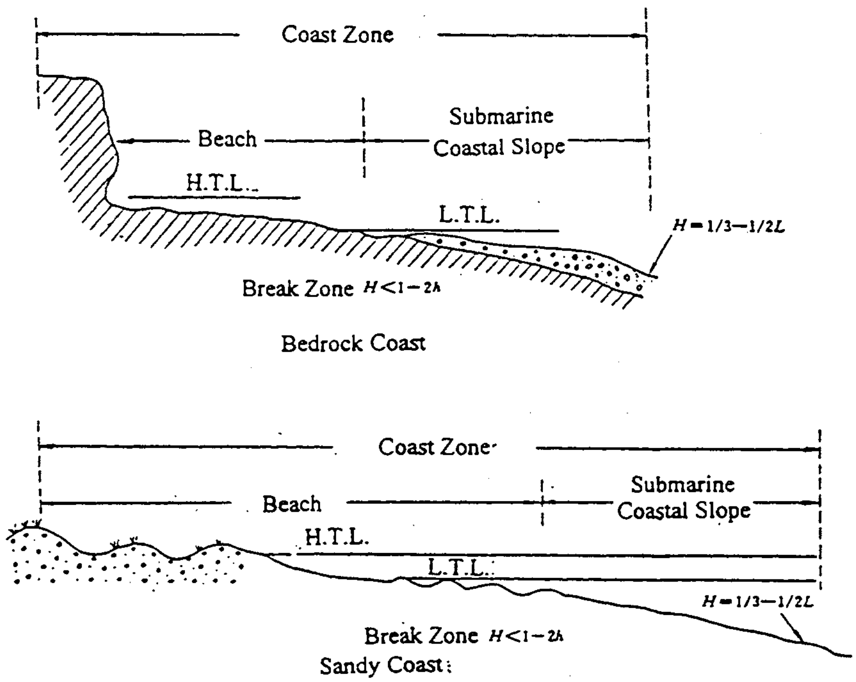
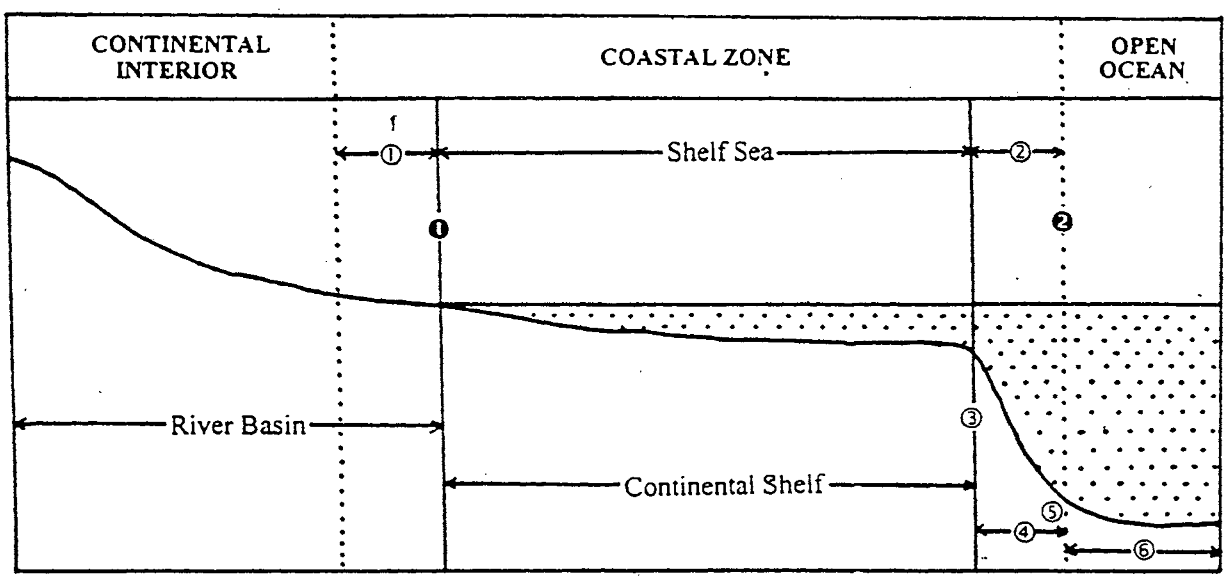


Figure 1 Coastal zone—an amphibious zone



❶Land/Sea Interface ❷Shelf Sea/Ocean Interface

①Surf Zone ②Shelf Edge Zone ③Shelf Break ④Continental Slope

⑤Continental Rise ⑥Ocean Floor

Figure 2 Coastal Zone — Land and Ocean Boundary

Thus, coastal zone is where that the land meets the sea, a transitional zone between land and ocean, and characterized by the active dynamic processes of land-ocean interactions. Coastal ocean or coastal sea covers the area including surf zone, continental shelf, continental slope and continental rise (Kennett, 1982) (Figure 2). The area is an independent and closed inter-related system characterized by air - sea, land -sea interactions, and human beings impacts.

Characteristics of Coastal Zone

Coastal zone is an independent environment, which differs from neither oceanic environment nor terrestrial, because the land - ocean interactions produce the coastal dynamics with their own natures. Such as wind normally speeds up their velocity and changes their direction in the coastal zone. According to 20 years statistics data from Jiangsu coasts of China, wind speed (U), it is an index power relations with the distance to the sea shore (x) (Organization for comprehensive survey on coastal zone and resources in the tidal flat in Jiangsu province, 1986).

$$\begin{aligned} y &= U(U_0)^{1/2} \\ &= 0.70 + 0.30e^{-0.0415x} \end{aligned}$$

U is a maximum wind speed of several years average in the x_1 distance to the sea shore, U_0 is a maximum wind speed of several years average along the sea shore, while the x is 0 (sea shore) to 40 km, U increases rapidly; while the x is more than 60 km, the value of y is almost a constant of 0.7, *i.e.* Thus, the wind speed is 30% less in the out side of the coastal zone.

The wave produced by the action of the wind are the most important type of sea waves. While waves approach to the coastal zone or the shallow waters, they also change their nature of wave rays, speed up the velocity and shorten the period. Waves refract, reflect and form standing waves, diffract, converge or diverge their energy, produce break waves and wave currents, storm surge, *etc.* (Wang, *et al.*, 1994a). Tidal dynamics are even with special features, accumulate enormous energy and act as an active dynamic factor along the coastal zone (Wang, 1983; Wang, *et al.*, 1990, 1994b). River - sea system bears the most unique processes especially in the coastal zone or coastal ocean (Wang, *et al.*, 1986).

Resources in the Coastal Zone

Coastal zone has important natural resources, which are mostly with low cost, less polluted, and can be nourished. These resources are (Wang, 1988, 1992):

(1) energy resources: wind, wave, tide, potential energy of temperature and salinity of sea water;
(2) sandy material and placer resources;
(3) space resources, including tidal flats and wild land, sandy beaches, harbor and estuary *etc.*
(4) food and medicinal resources, *etc.*

GEOLOGICAL PROCESSES

Under marine dynamic processes, the lithosphere of coastal land has formed different coastal features, the debris from the coastal erosion entered the coastal zone consisting the sedimentary dynamics. Thus, there are two groups of factors to control the coastal evolution: (1) marine dynamics; (2) geological structures, lithologic and Geomorphological natures of coastal lithosphere (Wang, 1992). Here, a few examples indicate the geological affection to the coastal evolution.

Global Plate Tectonics Control the Largest Scale of Coastal Types (Inman & Nordstrom, 1971; Shepard, 1973).

(1) Collision coasts, including those on the collision or subduction side of continents and island arcs, such as Japanese islands, American Pacific coasts, there are characteristics by straight coastline with mountain ranges of morphologies, sea cliffs, uplifted terraces. Offshore are deep ocean with narrow or without continental shelf. Earthquake is often, such as the eastern coasts of Taiwan in China.

(2) Trailing - edge coast, including those on the sides of continents and islands that are moving away from the rising and spreading oceanic ridges. Such as American Atlantic coasts and African coasts: gentle coastal landforms with larger river delta and wider continental shelf, earthquake and volcanic activities are weak.

(3) Marginal sea coasts, that lie on the protected side of island arcs, such as the Pacific marginal seas of Asia.

Secondary Scale Coastal Features Controlled by Regional Geological Structures, Taking Coasts of China as Example (Wang, 1980, 1996; Wang, *et al.*, 1987) (Figure 3).

The continental shelf and adjacent mainland of China is composed of a series of NE or NNE trending uplifted and depressed belts that intersect obliquely with the coastline, from west to east, these are the Bohai basin, Shandong - Liaodong uplift, the South Yellow Sea depressed belt, the Zhejiang - Fujian uplift, the East China Sea depressed belt and Taiwan fold belt. A bedrock - embayed coast with rock islands is formed along the uplift belts, such as the coasts of Dalian, Liaodong Peninsula, while a plain coast, usually with a large river is always formed along the depressed belts. In the South China Sea, NE trending block faults define the main trend of the bedrock embayed coast, with inlets develop along NW trending faults.

Tectonic Movement Influences the Coasts, Taking the Hawaii Island as an Example (Kennett, 1982; Montgomery, 1986; Wang, *et al.*, 1997a) (Figure 4).

During the last 70 million years, the Pacific plate has acted as a conveyor belt, moving the islands northwest off the hot spot at a rate of about 4 inches a year. The active volcanoes, Kilauea and Mauna Loa, continue the island - building processes that have formed the 3,500 mile Emperor Sea MountHawaiian Island Chain. But they are not the last, to the southeast, Lo. ihi sea mount is rising from the ocean floor. Thus, volcanoes are land builders, and are still adding land to the island of Hawaii. Mauna Loa is the most massive mountain on earth, occupying an area of 10,000 cubic miles. Measured from its base on the sea floor, it rises 30,000 feet, more than a thousand feet higher than Mount Himalayas. Kilauea produces lava flows, added layer upon layer, produced a barren volcanic landscape that served as a foundation for life. Hundreds of specious of plants and animals found their way across the vast Pacific on wind, and the wings of birds. So as the humans, first Polynesians, then, Asian and Europeans.

Volcanic coastal features (Hawaii, Japan and Hainan Island)

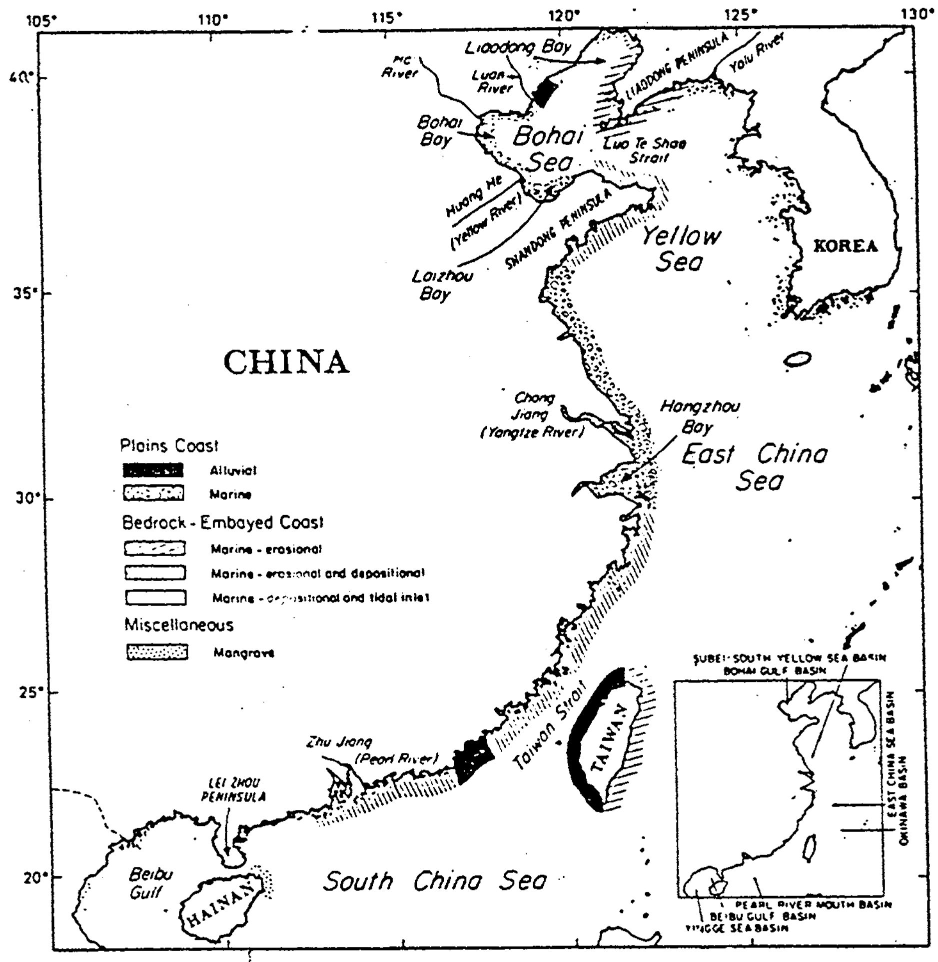


Figure 3 Coastal type of China

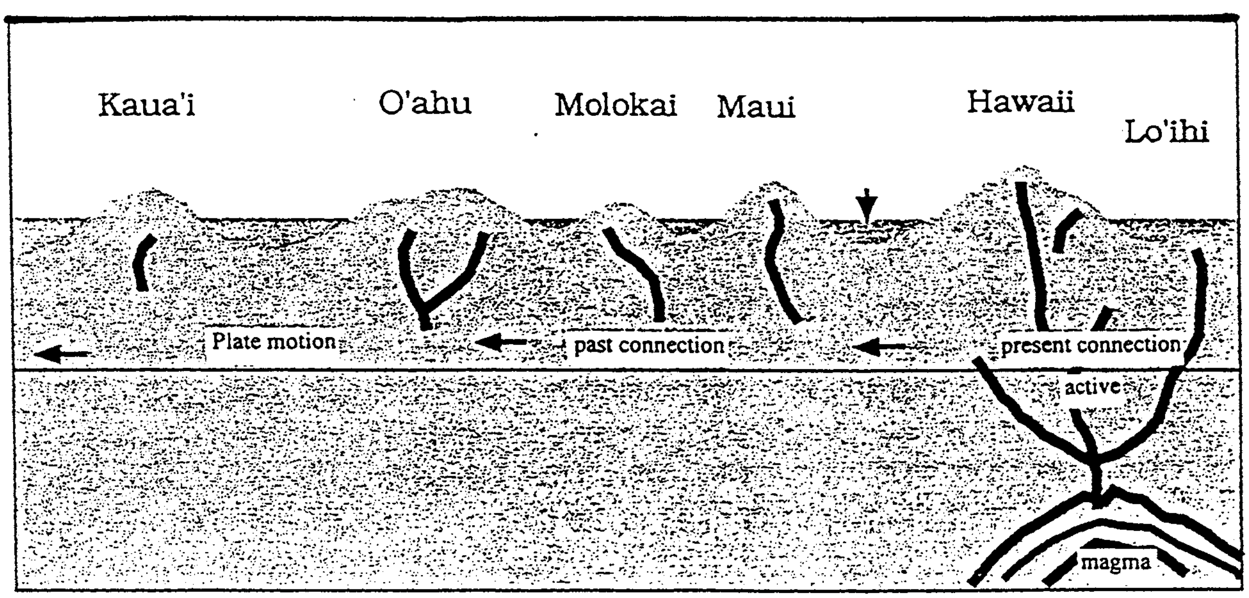


Figure 4 Hot spot —formation of Hawaiian Island Chain

The Last Example Shows the Geomorphologic Control on the Coasts of Drumlins from Glaciated Area of Atlantic Coast, Canada (Wang, *et al.*, 1982).

Two fundamental types of drumlin coasts are distinguished: hilly coasts with rock - cored drumlins, and valley coasts with thick till drumlins. Their development can be described in terms of three stages (Figure 5). These stages do not express different coastal age, because all three stages may be seen in the same area, and coastal processes of all drumlin coasts, there in Cape Breton Canada, started at much the same time, at the beginning of the Holocene transgression. The stage reflects difference in the speed of coastal development, determined by the intensity of wave action and availability of sediment supply. However, these factors are governed by the original landform and coastline configuration.

LAND-OCEAN INTERACTIONS

It is a complex processes and need to be studied. The river - sea system can be taken as one of the leading processes to explain the interactions. River - sea system is involved in the Global Water Circulation system, and the river processes, from land to sea, are influenced by human activities.

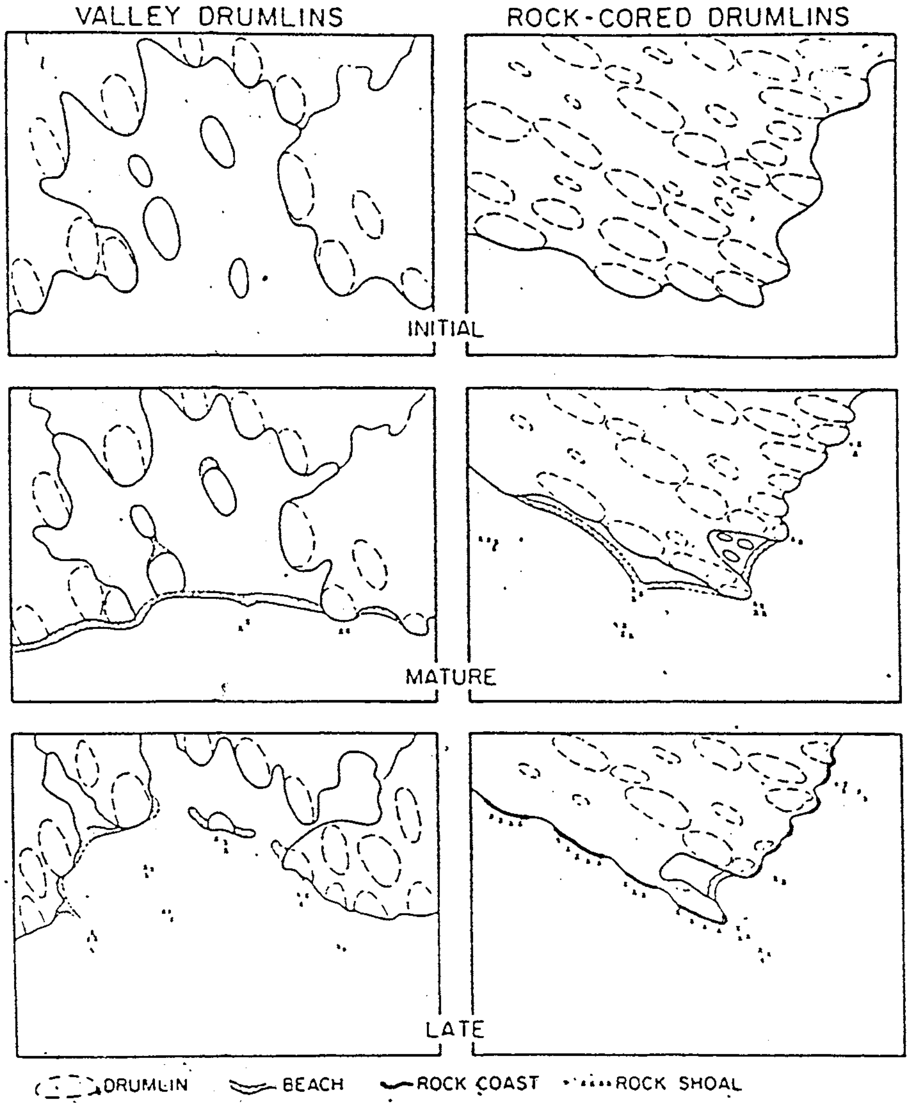
Outline

Rivers are the major pathway for the transfer of water and solids from land to the sea, and they are partly as the joint forces of sedimentary dynamics in the coastal waters. Collectively they annually discharge about 40,000 km^3 of water and more than 25 billion tons of particulate and dissolved soils (Milliman, *et al.*, 1995). Besides natural sediment, land - based contaminants are diffused by river flow. Nearly one - third of the pollution sources reaches the coastal ocean through fluvial transport processes in China (Fu, *et al.*, 1996). Several key factors influence river sediment discharges: these are tectonic activity, climate patterns, regional features and structure, anthropologic activity and climate - sea level relationship. Take one of the factors as an example:

Most large rivers with annual sediment discharges of more than 100 million tons originate in the most active tectonic mountain settings (Wang, *et al.*, 1998). Such as the Himalayas, the Alps, the Rockies and the Andes, where the snow, glaciers and abundant precipitation supply large volumes of runoff. Active tectonic uplift provides continuous energy for rapid river erosion that transport huge amounts of sediment along steep river channels that led to the ocean. The predominant features is that more than 1/3 of total sediment discharge of the world is supplied by 7 rivers, those are the Yellow River, the Changjiang River (Yangtze), the Brahmaputra, the Ganges, the Irrawaddy River, the Mekong River and the Indus River (Table 1). These seven rivers originate from the Qinghai - Tibet Plateau, the highest part of earth surface.

Table 1 Sediment load of rivers originated from Qinghai-Tibet plateau

River	Area ($X10^6$ km^2)	Load ($X10^6$ t/a)
Yellow (Huanghe)	0.75	1115
Changjiang (Yangtze)	1.81	461
Brahmaputra	0.61	540
Ganges	0.98	520
Irrawaddy	0.43	260
Mekong	0.79	160
Indus	0.97	59
Total	6.34	3115



(a) hilly rock-cored drumlin areas,

(b) valley thick drumlin till areas.

Figure 5 Cartoons illustrating stages of coastal geomorphic evolution of drumlin areas

The regional features or geological structure can exert substantial influence on the sediment load of river. Such as the runoff of the Yellow River is about 1/15 of that of the Mississippi River, 1/183 of the Amazon River, and 1/2 of the Nile River, but the sediment load of the Yellow Rover is as three times as that of the Mississippi River, twice that of the Amazon River, and nine times more than the Nile River. The difference in sediment concentration is even higher. The reason is that the Yellow River flows through the region of the Loess Plateau, and the unconsolidated loess is easily eroded. The major load of silt carried by the Yellow River is eroded mainly from the Loess Plateau and lower reaches of old alluvial fan (Wang, *et al.*, 1997b).

Under the combined effects of human activity, climate and sea level changes, a decreasing trend of world - wide river sediment discharge can be expected in the future. It is estimated that the present global sediment flux is probably about 110 X 10^8 t/a (Wang, *et al.*, 1998).

The Study on Terrigenous Fluxes and Transporting Processes(Wang, *et al.*, 1986, 1998)

Take the five river mouths and associated continental shelf as examples (Table 2), showing the terrigenous flux and transporting processes, it can be divided into three dynamic types.

Table 2 Data of five Chinese rivers

River	Drainage area (km^2)	River Length (km)	Annual water discharge (m^3)	Annual sediment discharge (t)	Average sediment concentration (kg/m^3)	Tidal range (average) (m)
Yalu	64000	859	27.8X10^9	4.75X10^6	0.33-0.42 (ebb-flood)	4.48
Luanhe	44900	870	38.9X10^8	24.08X10^6	3.94	1.50
Yellow	752443	5464	48.5X10^9	11.9X10^8	37.7 (Shanxian)	0.80
Changjiang	1807199	6380	9.25X10^{11}	4.86X10^8	0.544	2.77
Pearl	542616	2197	3.70X10^{11}	0.85-1.0X10^8	0.12-0.334	0.86-1.63

The high energy wave regimes.

This is seen on the innershelf off the Luanhe River. Sediment distributed as a series of narrow belts oriented parallel to the coast. Mainly, there is a transverse sediment movement by wave action driven by SE and NE ward monsoon winds toward on land.

Tidal current regimes.

In the macrotidal estuary of Yalu River (4.48 m6.92 m tidal ranges, semi - diurnal tides), tides are converged and diverged as the affection by funnel - shaped estuary at the north end of the Yellow Sea to produce powerful currents which are oriented either perpendicularly or obliquely to the coast, sediment distribution follows the direction to form the pattern of sandy ridge fields.

The microtidal environment of the Yellow River mouth and nearby continental shelf shows sediment either deposited as a finger bars pointing to the sea or distributed as sediment tongues (muddy tongues) oriented parallel to the coast.

River runoff and longshore current regimes.

In the Changjiang and Pearl River estuaries and adjacent shelves, sediment accumulates as sand shoals or sand banks. The sediment diffuses to the sea following the direction of the joint forces of the two types of current.

Geologically, each river examined occurs in an environment where sediment supply is so great that regardless of marine energy, all five areas are site of sedimentation. The amount of deposition is directly related to the geographic stability of the river mouth. When the river mouth shifts, sediment supply is reduced or stopped at the site. The previously deposited sediments undergo erosion and the coarser grained sediment is reformed as a series of sand ridges along the direction of current. Most of the sediment from the rivers is deposited on the innershelf near the river mouth. The maximum measured distance of longshore sediment movement is 105 km (the Yellow River, Bohai Bay). The farthest distance sediment transported into the deeper water area of the continental shelf is 50 km (the Changjiang River, East China Sea). The distal margin of the Pearl River deposits is approximately 35 km from the shore at a water depth of 20 - 30 m. Sand beyond these margins is relict after the last low sea level of the Pleistocene period. Modern sediment distribution by the Luanhe River is at a water depth of 10 m, 4 km from the coast. Beyond this are the relict sands of lower sea level. It seems that river driven sediment is mainly deposited near the river mouth and on the nearby inner shelf except when sea level changes occur.

River deltas advance gradually onto the continental shelf. During the lower sea levels of the late Pleistocene, the coastal plain which forms today's continental shelf was crossed by many rivers. The ancient Yellow and Changjiang Rivers built a series of deltas during that time. These delta systems provided the framework which built the continental shelf of the China Seas.

SEA LEVEL CHANGES, HUMAN IMPACTS AND COASTAL RESPONSES

Sea Level Changes (Wang, 1997)

According to IPCC (International Panel on Climate Change) Climate Change 1995 that:

- global mean sea level has risen 10 - 25 cm over the last 100 years. This range is slightly higher than that reported in IPCC 1990 (*i.e.* 10 - 20 cm). The estimated results is largely from the use of geodynamic models for fluttering out long - term vertical land movements, as well as from the greater reliance on the longest tide gauge records for estimating trends.
- there has been no detectable acceleration of sea level rise during this century. However, the average rate during the present century is significantly higher than the rate averaged over the last several thousand years.
- for the period 1990 to 2100, the high, middle and low estimates, using a range of parameter values based on key model uncertainties, were made for IS 92a (the emission scenario most comparable to the IPCC 1990. Scenario A, the Business - as - usual scenario).
  (1) 50 cm higher than today by the year 2100,
  with a range uncertainty of 20 - 86 cm;
  (2) "best - estimate" model parameters.
  Sea level is projected to be 38 - 55 cm higher than today by the year 2100;
  (3) the extreme range of projections is 13 - 94 cm.
- most of the rise in sea level is due to thermal expansion, followed by increased melting of glaciers and ice caps.

According to SCOR WG 89, it estimated that global sea level rise over the past 100 years is 1 - 2 mm/a (SCOR WG 89, 1991).

State Oceanic Administration of China had summarized tide gauge data from 44 stations along the China Seas over last 30 years' period (19591989), the mean rate of sea level rising was 1.4 mm/a.

According to the geodetic survey data from 9 stations along the China Seas by State Survey Bureau of China in 1992[1], the sea level rising during recent one hundred years is 19 cm in the East China Sea, and 20 cm in the South China Sea, the rate of sea level rising is 2 - 3 mm/a, and it is continually rising in the future.

The result of calculating 102 stations data of tide gauge in the world is as following: the average sea level rise is 15 cm during last hundred years. It is 29 cm rising of sea level in the Atlantic Ocean, 10 cm rising of sea level in the Pacific Ocean, and 39.6 cm rising in the Indian Ocean as the maximum one. After the correction on the rate of vertical movement, the annual average rate of mean sea level rising is 2.0 mm along the coast zone of China (Chen, *et al.*, 1994; Ren, 1993).

The process of sea level rise has decreased wave winnowing on submerged coastal sediment, but enhanced break waves eroding the upper beaches. On the other hand, following the rise of sea level, slopes of the river beds have reduced, decreasing the fluvial sediment discharges to the ocean. Human beings impact it through diverting river discharge, constructing dams in the lower reaches of rivers for fresh water supply. Thus, the lack of coastal sediment supply is a world - wide phenomenon, combined with the frequency of storm surges and EL NINO events to strengthen hydrodynamics, as a result, beach erosion and sand barriers retreating to land ward are commonly happened along coastal zone. By using Bruun model, while sea level rising to 0.5 m during next century, that the net result of beach erosion of five famous tourist beaches of China will be lost 13 - 66% of the present area (Wang, *et al.*, 1995) (Table 3).

Human Impacts and Coastal ResponsesExamples from China.

In the past, human impact on the coastal evolution has been mainly through the river - sea system, because of several large rivers across the larger area of China, from the west, Qinghai - Tibet Plateau, to the east, the China Seas, which bring great influences to the China's coastal zone. For example, the Yellow River is unique for its extremely heavy sediment load (11.9 X 10^8 t/a), rather small water discharge (485 X 10^8 m^3/a), and migrated rive channel in the lower reaches (Wang, *et al.*, 1986). Silts are the main component of sediment, and have been carried out by the Yellow River from the Loess Plateau. Because of immigrant cultivation, mainly since the west Han dynasty (200 BC), forests and pastures were destroyed, which caused serious soil erosion, and huge quantity of sediments have been carried out to sea to accumulate on the great North China Plain. As a result, it changed the coastal water environment both in the Yellow Sea and the Bohai Sea.

The Yellow River has experienced eight major changes in its lower courses since 2278 BC, discharging either into the Bohai Sea, or into the Yellow Sea via the Huaihe River. The shifted distances between north and south were more than 600 km long (Wang, 1983). Two major changes of the river channel migration were created artificially as a result of human activities for military purpose (Wang, 1994; Wang, *et al.*, 1997b).

One major event was in 1128 AD On November 15th, the capital official of Southern Sung Dynasty excavated the Yellow River bank at Kaifeng in order to use flood water as a weapon to prevent an invasion of Jin Dynasty soldiers from the north. Even though this effort was unsuccessful, it initiated a change that caused the Yellow River to flow through the Sishui River, one of the distributors of the Huaihe River, to the south. Since then, the river shifted often in the Huaihe River area and entered the

[1] State Survey Bureau of China, 1992. Annual sea level changes in China. People's Daily (Overseas), July 8th, 1992

Table 3 The calculated net result of beach erosion in China by 0.5m of sea level rising during next century

Location		Modern Beach				Estimated Beach Response of 0.5m Sea Level Rising								
						Natural Flooding			Beach Erosion			Sum Value		
		Length (m)	Average Width (m)	Relative Height (m)	Areas (m²)	Beach retreating (m)	Lose of the area (m²)	Rate of lose (%)	Beach retreating (m)	Lose of the area (m²)	Rate of lose (5)	Beach retreating (m)	Lose of the area (m²)	Rate of lose (%)
Dalian	Xing Hai Park	2125	68.5	6.1	145613	6.8	14450	9.9	26.5	56314	38.7	33.3	70764	48.6
	Dongshan Hotel	510	42.4	3.8	21645	7.4	3774	17.4	15.8	8073	37.3	23.2	11852	54.7
	Grand Beach	756	56.3	3.8	42560	7.9	5972	14.0	24.7	18674	43.9	32.6	24646	57.9
	Summary	3391	61.9		209818	6.8~7.9	24196	11.5	15.8~26.5	83066	39.6	23.2~33.3	107262	51.1
Qinghuangdao	Bei Dai He	7850	87.1	5.9	683456	8.7	68295	10.0	48.8	383080	56.1	57.5	451375	66.1
	West Xiang He Zhai	3124	223.6	6.4	698466	6.7	20930	3.0	41.5	129650	18.6	48.2	150580	21.6
	Shandong Bao	756	88.2	3.5	66672	7.5	5670	8.5	25.4	19202	28.8	32.9	24872	37.3
	Summary	11730	123.5		1448594	6.7~8.7	94895	6.5	25.4~48.8	531932	36.7	32.9~57.5	626827	43.3
Qingdao	Qingdao Bay	1356	72.8	6.0	98650	8.5	11526	11.7	37.9	51455	52.2	46.4	62981	63.9
	Hui Quan Wan	1124	70.6	6.0	79356	7.0	7868	9.9	38.6	43386	54.7	45.6	51254	64.6
	Fu Shan Sou Mouth	1625	193.1	5.4	313857	8.9	14462	4.6	26.4	42932	13.7	35.3	57394	18.3
	Summary	4105	119.8		491863	7.0~8.9	33856	6.9	26.4~38.6	137773	28.0	35.3~46.4	171625	34.9
Beihai	Wai Sha	2530	60.8	6.2	153750	5.8~9.5	17254	11.2	27.9	70587	45.9	33.7~37.4	87841	57.1
	Da Dun Hai	5516	258.4	5.0~9.2	1425588	5.4~9.8	41926	2.9	48.1	265335	18.6	53.5~57.9	307261	21.5
	Bai Hu Tou	5165	183.2	5.0~7.2	946363	5.4~8.7	36457	3.9	45.2	233458	24.7	50.6~53.9	269915	28.6
	Summary	13211	191.2		2525701	5.4~9.8	95637	3.8	27.9~48.1	569380	22.5	33.7~57.9	665017	26.3
Sanya	Da Dong Hai	2650	81.5	5.9	215905	7.9	20935	9.7	12.2	32330	15.0	20.1	53265	24.7
	Ya Long Bay	8880	166.1	5.4~13.4	1475184	6.8~9.8	74592	5.1	12.7	112776	7.6	19.5~22.5	187368	12.7
	San Ya Sand Bar	16360	296.2	3.3~11.6	4846024	5.6~10.2	137654	2.8	43.6	713296	14.7	49.2~53.8	850950	17.5
	Summary	27890	234.4		6537113	5.6~10.2	233181	3.6	12.2~43.6	858402	13.1	20.1~53.8	1091583	16.7
Total		60327	185.9	3.3~13.4	11213085	5.4~10.2	481765	4.3	12.2~48.8	2180553	19.4	20.1~57.9	2662314	23.7

Yellow Sea for more than 720 years. With the enormous sediment supply from the Yellow River, the North Jiangsu coast along the Yellow Sea were created mudflat plain coast instead of the original sand barrier and lagoon system, and the plain prograded for 40 km wide, and its associated Yellow River delta, prograded 90 km into the Yellow Sea. The total area of accumulated coastal land was 157,000 km^2. It was 1/6 of present land area of Jiangsu province. However, the coastal zone along the Bohai Sea, at the same time, suffered from erosion, with the active coastal wave action, mudflats retreated and coastal shell beach ridges were formed instead of the original mudflat coast with tidal currents as coastal dynamics.

In 1855, the Yellow River returned back to the Bohai Sea. Since then, coastal erosion has been extensive along the North Jiangsu coast as a consequence of the cut in the huge volume of sediment supply, 15 - 30 m retreating annually along 150 km long abandoned Yellow River delta. A total of 1,400 km^2 of land has been lost completely, and a new rank of shell beach ridge has been formed by present day breaking wave patterns. It is still the major project of coastal deference along the delta. On the other hand, the total 160 km long coastline of modern Yellow River delta in the Bohai Sea has been prograded for 20.5 - 27.5 km to the sea since the Yellow River shifted back in 1855. The new and average progradation is 0.2 - 0.27 km per year, *i.e.*, an average of 23.5 km^2 land has been accumulated each year. The new river mouth grows fast, 6 - 10 km in a single year, even though the sea level is rising and the tectonic subsidence in that area continuous since Tertiary time. Mudflats develop widely along the Bohai Bay and Laizhou Bay off the original chenier shoreline, with clayey silt sediment supplied by the Yellow River, and tidal currents as the major dynamic agent along the whole coastal zone. The example has shown clearly the human effects on coastal evolution through a river - sea system.

Future development of the modern Yellow River delta may be slower, because the annual sediment discharge of the Yellow River has been decreased to 9.5 X 10^8 tons annually as the annual water discharge is 37.9 X 10^8 m^3, a consequence of water diversion for irrigation along middle and lower reaches. It is estimated that more than 150 X 10^8 m^3 of water per year has been taken from the Yellow River for irrigation over the last decade, and with the volume of water about 1.74 X 10^8 t of sediment per year. The increasing diversion of water for irrigation and other purpose over the next decade will withdraw considerable amounts of sediment from the Yellow River. The construction of the large Xiaolangdi Reservoir, for example, scheduled to be completed by 2000 AD could trap 3.3 X 10^8 t of sediment per year. Recently, sediment has been pumped from the Yellow River channel to widen and strengthen the main dikes along its lower reaches (total length about 1,400 km). In this way, large amounts of sediment were taken away from the river. Progress in soil conservation in the Loess Plateau, about 34.8% of total eroded area has been under control, then, 300 million tons of sediment flux have been decreased annually during recent 20 years[2)]. Thus, the sediment discharge to the sea of the Yellow River maybe reduced 6 - 7 X 10^8 t/a in the next 20 years.

At present, human impact on the coastal zone of China has been more an more effective because of the large scale of economic development in the coast area. Still, human impacts on the coastal environment through the river - sea system appear more and more often and seriously, because there are more than 1,500 rivers entering the coastal zone of China.

(1) To divert river discharge for urban water supply, decreasing sediment discharge at same time, and accompanied by the trend of global climate warming, mentioned in example of the Yellow River, as a result, to cause non - water discharges in the river mouth area and gradually extending to the lower reaches. The records are (Wang, *et al.*, 1997b): 71 days' non - water discharges in 1970's, maximum

[2)] People's Daily. Overseas Edition, Jan. 4th, 1995 period was 19 days (1979); 103 days in 1980's. longer period was 37 days there were no water in river bed; 128 days in 1992; 133 days in the Lijin station, 6.22 km away from river mouth, from 4th March to 14th July 1995; 142 days in the Lijin station since 24th Feb. to 14th July in 1996; river bed no water in and all of river channels in Shangdong province had completely dried out; situation is even more seriously this year, there were non - water flow two times of the Yellow River from Jinan city to the river mouth during spring of 1997. Consequently, the coast erosion emerged at the delta area because of the reduction in the sedimentary dynamic balance. Such as the Luanhe River, original water discharge was 4.19×10^9 m^3 with total sediment supply of 2219×10^4 tons. After diverting the water discharge of 3.55×10^8 m^3 for water supply to Tianjin city, the sediment supply is only 103×10^4 tons, the delta coastline of Luanhe River has been retreated in a rate of 17.4 m/a since 1988 (Qian, 1994), and the salt water intrusion changed the salinity from 27.3 to 32.6 in the delta area. Solving one problem has caused other serious problems as the river - sea is a close related system.

(2) North Jiangsu Plain had been previously divided by numerous canals and channel networks in the early 1950's as a strategy for frontier defense. This project changed the natural environment (Wang, 1994) with the positive effect of bringing more farmland under irrigation. For preventing salt water intruding and preserving fresh water resources along plain coast area, local people dammed up river mouth for most of rivers in North Jiangsu coast plain. The constructions have caused serious under - dam siltation in the lower part of river mouth. The dams also have blocked fish, prawn and crabs breeding up stream from river mouth. As a result, local people not only lose economic income from the decreasing precious sea food products, but also, the silted river mouth channels become smaller and smaller day by day, gradually losing navigable water depth, and often suffering flood disaster.

(3) Using a river as a natural channel to flush out chemical wastes of industry, through irrigation of polluted water which damaged crops, and the rich nutritious water and sediment entering the sea, it causes serious red tide in the coastal zone. The red tide almost "killed" aquiculture of prawn each time in the plain coast area.

(4) Over exploitation of underground water in the plain coastal zone. Such as in the Laizhou and Longkou county of the plain coast along the Bohai Sea, underground water table subsided 15 - 30 m in the late 1980's compared with 1977. Thus, it destroyed the natural water balance between fresh and saline water. As a result, salt water intruded more than 100 km and caused large area of farmland to be abandoned.

Over exploitation of underground water and heavy load construction on the coastal low land and delta area have caused rapid ground subsidence to accelerate local sea level rise, for example, 0.5 m subsidence has been recorded during 1966 to 1985 in Tianjin Tanggu harbor of the Haihe River delta according to the State Survey and Mapping Bureau data in 1992. Relative sea level rise during the same period was 4.5-5.5 mm/a in Tianjin area; 2.0 mm/a in the Pearl River delta; 11.5 mm/a at the Changjiang River delta, and 24.7 mm/a at abandoned Yellow River delta (Tianjin) (Ren, 1993).

Sea level rising and the decreasing of river sediment supply, plus the human impacts directly through the beach sand mining, this has speeded up the sandy beach erosion to the rate of 1 - 3 m/a as its average in the most parts of China's coastline.

CONCLUSION

1. Human activity is one of the most dynamic agents in the coast formation, especially in the plain coast evolution though the river - sea dynamic system, where the impacts become more and more effective by using the advanced scientific techniques.

2. The river - sea system is a natural cycle keeping the environmental balance between air and water, land and ocean. Even though the human activities are on land, they still directly or indirectly add to the influences on the coastal waters through the river connection.

People should pay great attention to set up a harmonious relationship between human activity and the natural coastal environment. It is urgent to set up and improve systematic regulation and integrated management of the coastal zone to preserve natural environmental balance for a long period sustainable development in the coast area.

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FINE-SCALE PLATINUM-RICH ZONES AS STRATIGRAPHIC MARKERS IN SEAMOUNT FERROMANGANESE CRUSTS

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ABSTRACT

Hydrogenetic ferromanganese crusts are highly enriched in platinum relative to other marine sediments. In this work, eight crusts from three areas in the Pacific ocean (Johnston Island, Kiribati and Hawaii) were sampled at 2 mm intervals. Major elements including Mn and P, minor elements including Ba and trace elements including Pt and Ce were analyzed by ICP-OES and ICP-MS. Pt concentrations range from 0.2 to 1.4 ppm in Fe-Mn crusts. Pt abundance generally decreases stratigraphically from the bottom (old crusts) to the top (young crusts). A strong correlation between Pt and Ba was observed in each crust suggesting that Pt accumulation may be controlled by a process associated with the incorporation of Ba in crusts. Pt also displays a weak, but positive relationship with Mn in several crusts. The latter suggests that hydrogenetic factors (Mn) also exert some control on the distribution of Pt. One of our samples shows a very distinct stratigraphic marker. It is a large positive Pt anomaly within the carbonate fluorapatite (CFA) substrate of crust 6RD08-08 from Kiribati. In this crust, the Pt abundance reaches 9 ppm and does not appear to be associated with any mineral phase. Based on biostratigraphic dating results, this large Pt peak may have been contemporaneous with the K/T boundary, a period often proposed to have included catastrophic meteorite impacts. Unfortunately, this stratigraphic marker has not been correlated with the other samples. Even within one geographic area, such as the Johnston Island Exclusive Economic Zone, it is difficult to fully correlate the zones of high platinum abundance. Nonetheless, with more detailed study, platinum microstratigraphy has the potential to be an important tool in the detailed mapping of manganese crust fields for future mining operations.

INTRODUCTION

Seamount ferromanganese crusts are considered a potential mineral resource. They are enriched in Co, Ni, Pt and Mn. Crusts in the Johnston Island Exclusive Economic Zone, in particular, may be a potential future source of cobalt and possibly platinum. The cobalt market is expanding world-wide as new high-tech demands for cobalt grow. This is particularly true for the rapidly growing battery market for lithium-cobalt batteries which may be critical for the widespread development of electric cars. Cobalt is not mined in the United States although the U.S. use one third of the world's cobalt and possess one of the world's highest grade and largest tonnage deposits on the ocean floor south of Johnston Island. Several companies are now considering leases in the south Johnston area to initiate a mining operation.

Among the economically valuable elements, platinum is the only precious metal significantly concentrated in ferromanganese crusts (Wiltshire, 1990). It is the focus of our current study. Previous studies of platinum in marine environments and marine sediments have shown that platinum is markedly enriched over other platinum group elements in ferromanganese minerals (Hodge *et al.*, 1985). This anomalous behavior, similar to that of cerium in the rare earth series, was previously attributed to the oxidation of platinum from the dissolved divalent state in seawater to the tetravalent state during mineral formation (Halbach *et al.*, 1990). Unfortunately, concentrations of Mn^{2+} are at least an order of magnitude too low to accomplish this oxidation of platinum (Wiltshire, 1990). Therefore, the geochemistry of platinum in crusts is still debated.

In the open ocean, platinum shows a nutrient-type profile (Goldberg and Koide, 1990; Hodge et al., 1985; Baker and Anders, 1968). However, the chemical behavior of platinum in seawater remains unclear. Recent studies of Fe-Mn crusts indicate that certain geochemical signatures and elemental distributions within crusts can be used to infer temporal changes in oceanic chemistry during the growth of the crusts (Wen *et al.*, 1997; McMurtry *et al.*, 1994; Hein *et al.*, 1992; DeCarlo, 1991; Segl *et al.*, 1989; Halbach, 1986; Halbach and Puteanus, 1984). A striking difference between ferromanganese crusts and other marine sediments is that hydrogenetic Fe-Mn crusts appear to have experienced little post-depositional diagenesis or remobilization of elements after they initially formed (Wen *et al.*, 1997). This very useful feature allows a more straightforward use of the distributions of elements in ferromanganese crusts as a paleoceanographic indicators of biological activity, particle fluxes, and redox conditions in the ocean.

The distribution and abundance of Pt in crusts can help us understand the oceanic chemistry of Pt. Pt in ferromanganese crusts is enriched by a factor of 10^6 over seawater (Ptmn/Ptsw) and by 10^3 over marine pelagic clay on an Al normalized basis (Wen *et al.*, 1997). One of the difficulties in studying Pt results from its low concentration in the open ocean. High Pt concentrations and the unique characteristics of crusts enable us to investigate the chemistry of Pt in the ocean. In this paper, we will investigate the geochemical processes responsible for Pt enrichment in Fe-Mn crusts. We have begun the study of platinum microstratigraphy in manganese crusts.

Platinum stratigraphy offers good potential for correlating manganese crusts, hence for understanding the development of a whole crust field on top of a seamount. One of the problems facing crust mining will be mastering the stratigraphy of the crusts and the continuum of crusts from one area to the next. Crusts must be continuous, thick and flat to allow efficient mining by bottom crawling robotic devices. The crusts are layered but it is quite difficult, often impossible, to trace layers from one sample to the next over distances of more than several kilometers. Fortunately, many crusts have a central platinum-rich layer and some crusts also contain a stratigraphically lower platinum-rich layer. The detailed origin of these layers is not fully understood, in large measure because we do not fully understand the geochemistry of the platinum being laid down in these crusts. However, the platinum stratigraphic trends in each crust are quite similar.

Platinum in manganese crusts is likely derived from several sources. They are: biogenic, lithogenic, hydrogenic and extraterrestrial origin. We believe that two components precipitate: a primary component originating in the metal-rich solution emanating from seafloor volcanism (hydrothermal origin) and a scavenged or co-precipitated component originating in seawater. The chemical composition of crusts in general can be characterized by four elemental associations (Wen et al., 1997). These are inferred to represent a hydrogenetic group (Mn, Co, Ni), a biogenetic or hydrothermal group (Ba, Zn,Cu), a detrital group (Si, Al) and a carbonate fluorapatite group (P, Ca). Hydrogenetic and biogenetic processes appear to be the two most important factors in determining Pt distribution in crusts. In certain crusts there is platinum present as an iron-nickel-platinum alloy in the form of small spherules. These spherules are thought to have originated from a meteorite impact (Halbach *et al.*, 1990; Wiltshire, 1990). This source appears to concentrate the platinum in at least one narrow layer. In the ideal case this layer would be continuous across the crust fields as it is not dependent on local conditions. For this reason, it could make an excellent stratigraphic marker both as a way of determining position in the manganese crust and to determine the continuous nature of the crust across the field.

A successful system of platinum stratigraphic markers would provide a valuable tool to the mining engineer. For example, cobalt is generally more concentrated in the upper portions of the manganese crusts (Manheim, 1986). This may mean that the platinum marker zones could provide a gauge for the depth of cut that robotic miners should be adjusted to in order to avoid taking lower grade cobalt material which would be farther down in the section. The knowledge of the continuous nature of minable crust is also critical to both the design of an efficient underwater miner and programming that miner to operate economically once mining.

To address these needs, eight crusts collected at water depths of 2200 to 2500 meters from seamounts in three areas in the Pacific ocean (Kiribati, Hawaii and Johnston Island) were analyzed in this study (Fig. 1). To elucidate the platinum microstratigraphy, we will address the following questions: 1) what are the sources of platinum in ferromanganese crusts, 2) what biological/geochemical factors control platinum in crusts, 3) what is the stratigraphic distribution pattern of platinum in Pacific seamount ferromanganese crusts. Although chemical variations of ferromanganese crusts were demonstrated to directly relate to water depth, carbonate compensation depth, growth rate, bottom current and depth of oxygen-minimum zone (Halbach and Puteanus, 1984; Aplin and Cronan, 1985; Halbach, 1986; and DeCarlo *et al.*, 1987a,b), very few platinum variations were discussed. We hypothesize that the distribution and geochemical behavior of platinum in ferromanganese crusts reflects the present platinum water chemistry in the ocean. In addition, we also hypothesize that platinum enrichment in crusts is controlled by certain geochemical and biological processes in the ocean. Our data set is the most detailed and largest platinum data set for any ferromanganese crusts collected to date on Pacific seamounts.

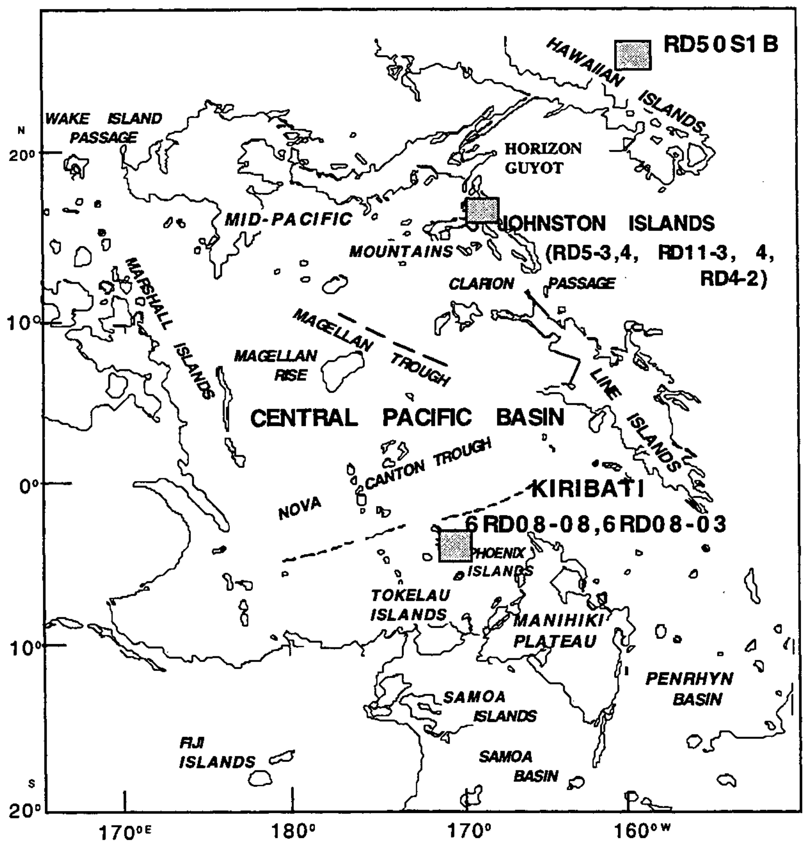

Figure 1. Sample locations of the eight manganese crust samples analyzed in this study.

METHODOLOGY

The crusts were dredged using a chain-bag guided by 3.5 kHz ecohsounding and seaMARC II sidescan acoustic imaging. Samples from Kiribati (6RD08-03, 6RD08-08) were recovered during *R/V Moana Wave* cruise 86-02. Samples from Johnston Island (RD4-2, RD5-3, RD5-4, RD11-3, RD11-4) were recovered during *R/V Kaimikai-O-Kanaloa* (KOK) cruise

KOK93-11. Sample RD50S1B from Hawaii was recovered during *R/V Kana Keoki* cruise 84-08-24-02.

The mineralogy of the crusts was determined by X-ray powder diffractometry (XRD) using a Scintag PAD-V automated diffractometer system equipped with a solid-state detector. Subsamples of the crusts were taken at 2 to 3 mm intervals within each crust with a micro-auto drill operated under microscope control (Wen *et al.*, 1997). Air dried powder samples were tape-mounted and scanned at rate of 2° two-theta per minute over the range of 2-70°. In the crusts, a typical pattern includes δMnO_2 (vernadite) as the dominant ferromanganese mineral phase with peaks at 2.43 angstroms and 1.41 angstroms (Burns and Burns, 1977; Ostwald, 1988). Other minerals, including goethite, francolite, carbonates, clays, quartz and feldspar, were also detected in minor to trace amounts. Polished thin sections of each crust were examined by reflected light microscopy and scanning electron microscopy (SEM) to identify internal structures and their morphologies.

Between 7 and 20 mg of each powdered subsample was weighed on a micro-balance and transferred to 3-ml Teflon microwave digestion vessels. To each vessel was added 250 µl each of ultra-pure concentrated HNO_3 and HCl; 100 µl of concentrated HF was also added to enhance dissolution of refractory aluminosilicates. The vessels were sealed and placed in a microwave oven and digested as described by DeCarlo (1991). Samples were quantitatively transferred to pre weighed bottles and diluted with 0.5 M H_3BO_3.

Chemical analysis of major and minor elements (Al, Ba, Fe, Mn) was performed by inductively coupled plasma optical emission spectrometry (ICP/OES), using a Leeman Labs plasma Spec I high -resolution rapid-sequential echelle grating spectrometer. Rare earth elements (REE) and Pt were determined on a Perkin-Elmer SCIEX, model Elan 5000 inductively coupled plasma/mass spectrometer (ICP/MS). The accuracy of analyses was ascertained by simultaneous analysis of U.S. geological survey standard nodules A-1 and P-1.

RESULTS

1) Johnston Island

Five samples were analyzed from the Johnston Island Exclusive Economic Zone. Pt concentration ranged from 0.2 to 1.3 ppm (Figure 2a,b, c, d, e). Pt abundance generally showed 1 to 3 narrow zones of higher concentration in each section. Ba distribution is highly correlated with Pt. Mn and P are inversely correlated. Pt and P are not directly related.

2) Kiribati

Two ferromanganese crusts were analyzed from a Kiribati seamount in the Phoenix Islands. Pt abundance increased from the top to the bottom of these manganese crusts (Figure 2f,g). Sample 6RD08-03 consisted of 80 mm of total section but the bottom 20 mm was highly enriched in carbonate fluorapatite. Platinum abundance ranged from 1.3 to 0.5 ppm within the top 60 mm. A strong Pt spike of 1.8 ppm was observed at the 76 mm interval. Sample 6RD08-08 consisted of 60 mm of Fe-Mn crust underlain by 20 mm of carbonate fluorapatite (CFA). Platinum abundance ranged from 0.3 to 0.9 ppm in the upper crust. A strong Pt spike of up to 9 ppm was observed in the CFA layer. In both crusts, Ba and Pt displayed strong correlation, and Mn and P were inversely correlated.

3) Hawaii

Hawaii sample RD50S1B consisted of a maximum thickness of 95 mm of Fe-Mn oxides. We report here from a 44 mm thick section taken from an area where the crust was about 65 mm

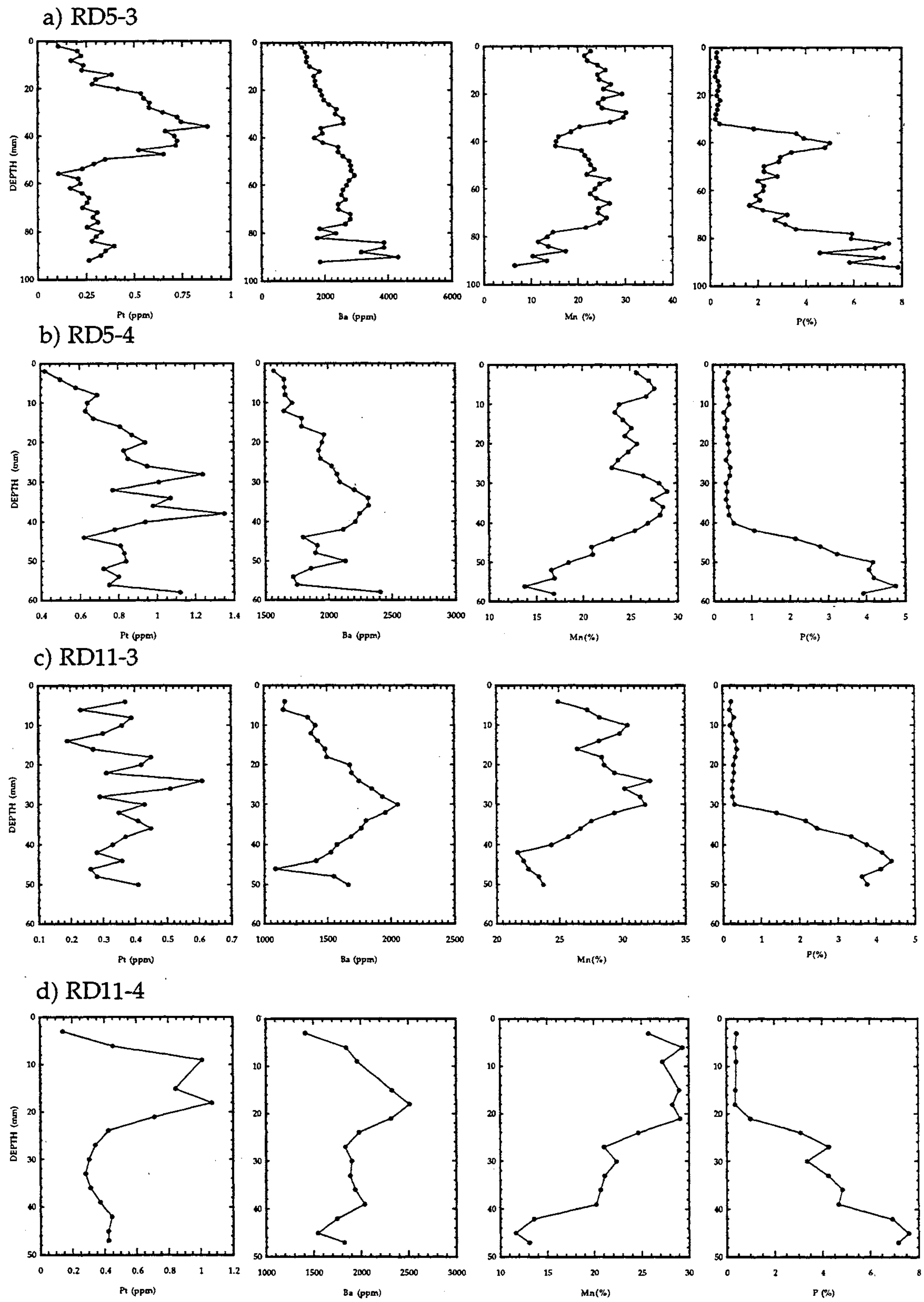

Figure 2a,b,c,d. Platinum, barium , manganese and phosphorous abundance in manganese crusts in 2 mm intervals.

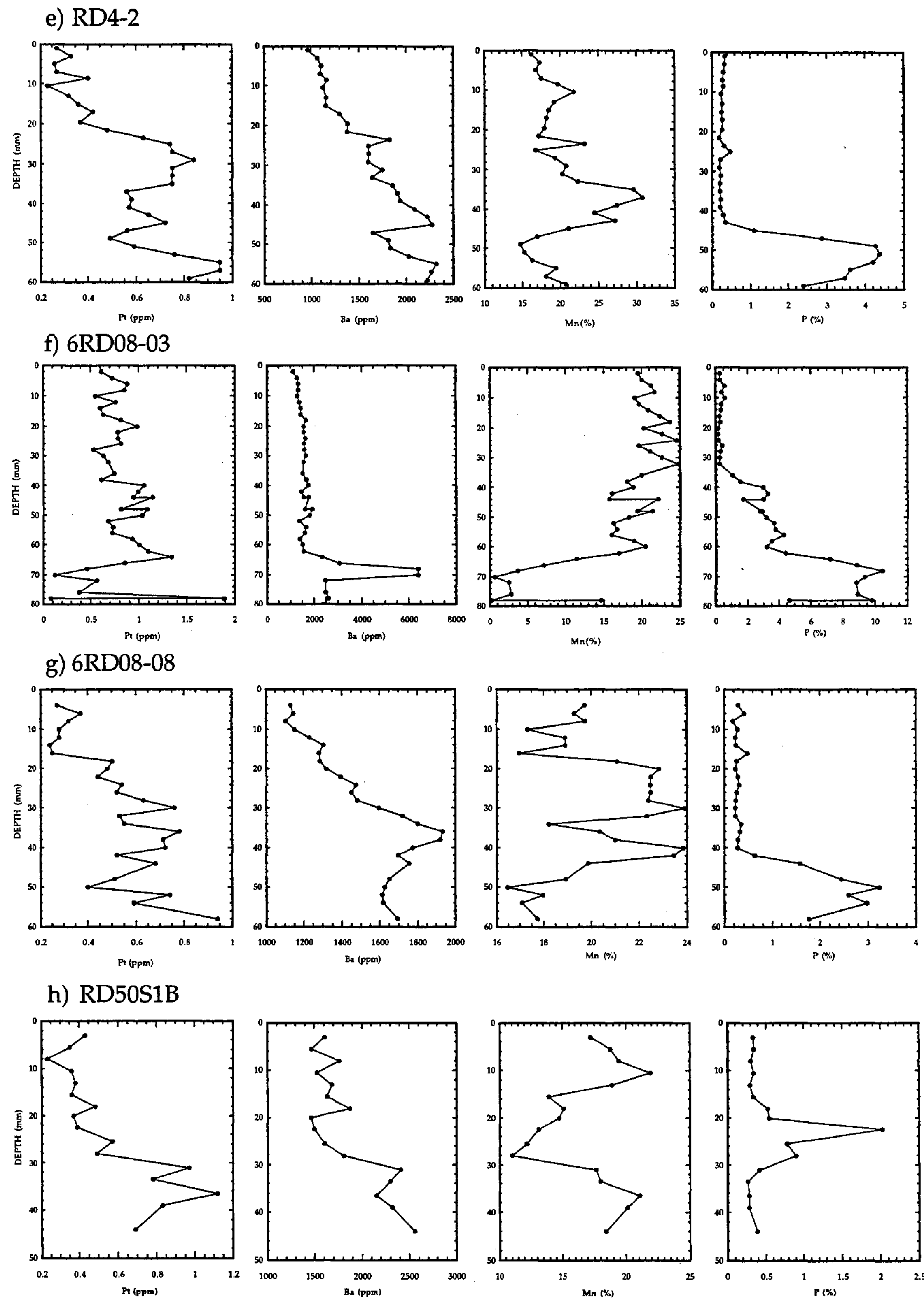

Figure 2e,f,g,h. Platinum, barium , manganese and phosphorous abundance in manganese crusts in 2 mm intervals.

thick. Pt concentration ranged from 0.2 to 1.1 ppm (Fig 2h). Pt abundance generally increased from the top to the bottom of the section. Ba and Pt were highly correlated.

DISCUSSION

We examined eight crusts from Central Pacific seamounts. The elemental distribution is highly consistent among these crusts. Pt stratigraphy generally shows a high Pt abundance increasing from the top toward the bottom of the crusts. Our data suggest that platinum abundance is controlled by both geochemical and biological processes. For example, a strong linear correlation is observed between Pt and Ba within crusts from all locations (Fig. 3).These results suggest that Pt enrichment may be influenced by the biogeochemical processes responsible for incorporation of Ba into crusts. A weak positive correlation was observed between Mn and Pt. This suggests that the major mineral phases are also exerting some control on the distribution of Pt in crusts.

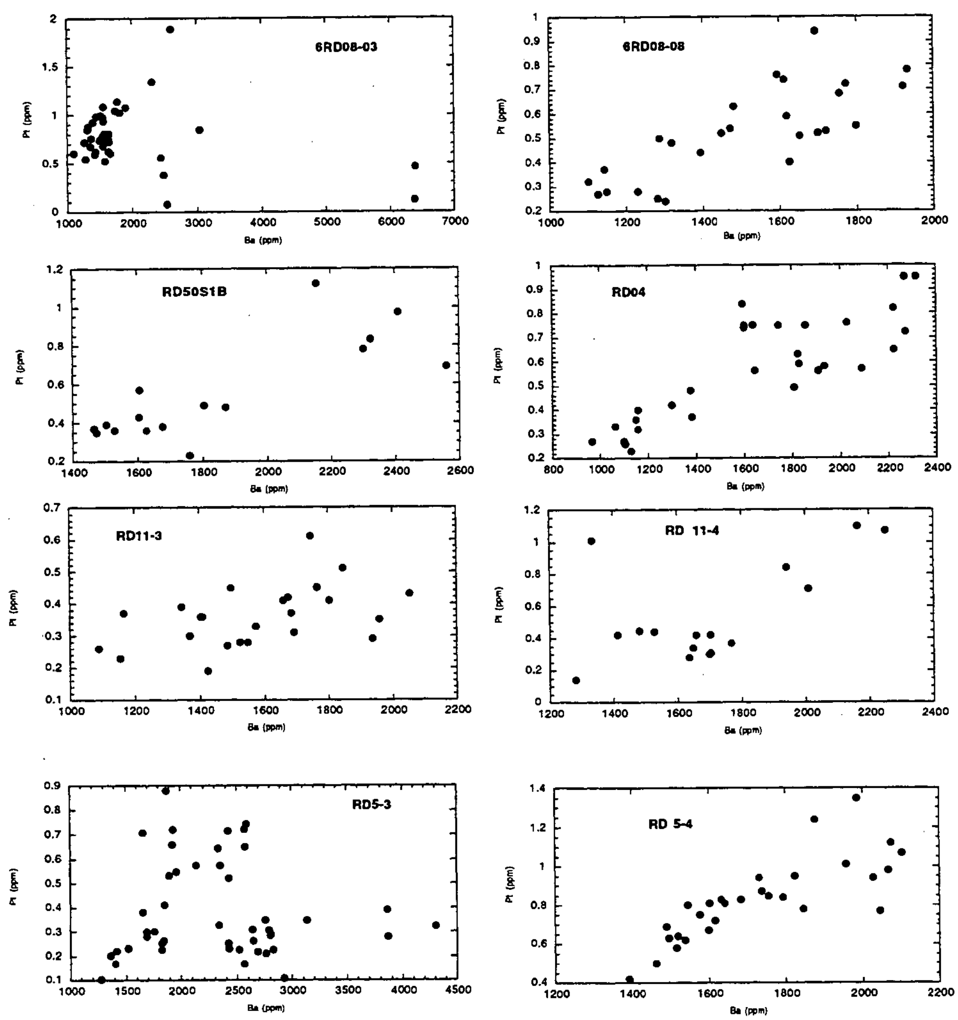

Figure 3. Relationship of platinum to barium in the manganese crusts, showing a strong direct correlation.

We speculate that the mechanism of Pt and Mn association is similar to that of the previously documented Ce and Mn association (Wen *et al.*, 1997). However, the Mn and Ce association is much stronger than Mn and Pt. Experimental data indicate that Ce anomalies were only observed in manganese oxide phases only and not in iron oxide phases in the absence of any biological activity (Koeppenkastrop and De Carlo, 1992). Ce anomalies are often observed in the marine environment and have previously been proposed as a paleoredox indicator (Glasby *et al.*, 1987; Elderfield, 1988; German and Elderfield, 1990). However, recent evidence indicates that Ce is also influenced by biological factors (Moffett, 1990, 1994; Wen *et al.*, 1997). Our current data indicate that there is a weak, positive relationship between Ce anomalies and Pt in some manganese crusts. For example, a strong correlation between Ce and Pt was observed in Kiribati crusts (Wen *et al.*, 1997) whereas no relationship exists between Mn and Ce anomalies in these same Kiribati crusts. Likely Cerium uptake is biologically mediated in Kiribati crusts. In contrast, Ce was associated with Mn in the Hawaii crust (Wen *et al.*, 1997) although Ce and Pt correlated only in the interval between 40 and 30 mm. Cerium and Pt did not covary in most zones of the crusts. These results suggest that enrichment of cerium in ferromanganese crusts can not solely be attributed to oxidative scavenging during the formation of the ferromanganese minerals as proposed by Goldberg and Koide (1990).

Often platinum and phosphorous are inversely correlated in manganese crusts. Sometimes there is no correlation at all between the two. These two relationships suggest that the distribution of Pt is not directly related to the formation of carbonate fluorapatite (CFA) in crusts. However, we speculate that Pt and P were likely initially coupled through biological activities. After biogenic particles containing Pt and P sank to the seafloor or during the formation of CFA, P and Pt decoupled hence do not show any direct correlation once incorporated in crusts.

In summary, the microstratigraphic distribution of Pt within the crusts is strongly correlated with the biogenetic element group (Ba, Zn, Cu) and weakly correlated with the hydrogenetic element group (Mn, Ni, Co). The sources of platinum in Fe-Mn crusts are mainly from seawater, and possibly also from CFA.

The best platinum stratigraphic marker found in our crust collection is illustrated in figure 4. It is neither of biological nor hydrogenetic origin. Previous work (Wiltshire, 1990; Halbach *et al.*, 1990) using scanning electron microscopy (SEM) revealed small spherules in other crust samples. These spherules are typically iron-rich but also appear to be a site of significant platinum concentration. The unusually large platinum spike in our study was observed only in sample 6RD08-08 recovered from Kiribati. The large positive Pt anomaly (9ppm) occurred within the CFA substrate at 72 mm depth from the crust surface (Fig. 4) The anomaly does not appear to be associated with any other elements. Scanning electron microscope (SEM) backscatter images revealed the presence of cosmic spherule shapes only in this interval; they were not found in other intervals or crust samples. Biostratigraphic dating results give an approximate date of 59-56 Ma at 47 mm (Cowen, pers. comm.). This constrains the minimum age of the large Pt peak, which may have been contemporaneous with the Cretaceous/Tertiary boundary.

Seamount ferromanganese crusts are predominately of hydrogenetic origin. By contrast, our results suggest Pt accumulation to be mainly associated with biological elements. We speculate that the Pt distribution in the ocean may also be mediated by biological activity. For example, platinum shows a nutrient-type profile. Some researchers suggest Pt is involved in biological cycles where, like other metals, it is taken up by phytoplankton and later transported downward as the plants play out their role in food chain dynamics (Goldberg and Koide, 1990). The elemental associations of Pt in crusts generally support the concept that platinum is mainly controlled by biological activities in the ocean. However, further investigations are needed to establish if Pt uptake is directly/actively mediated by organisms or is simply associated with a biogenetic mineral such as barite or phosphorous. The situation is actually much more complex. The relationship between Pt, Mn, Ba suggests that both biological and hydrogenetic factors play an important role in determining the distribution of these elements in the ocean. In the ocean, the sources of platinum are terrestrial material weathering (continental, dust and seafloor sediments), hydrothermal input and extraterrestrial origin (Crocket and Kuo, 1979).

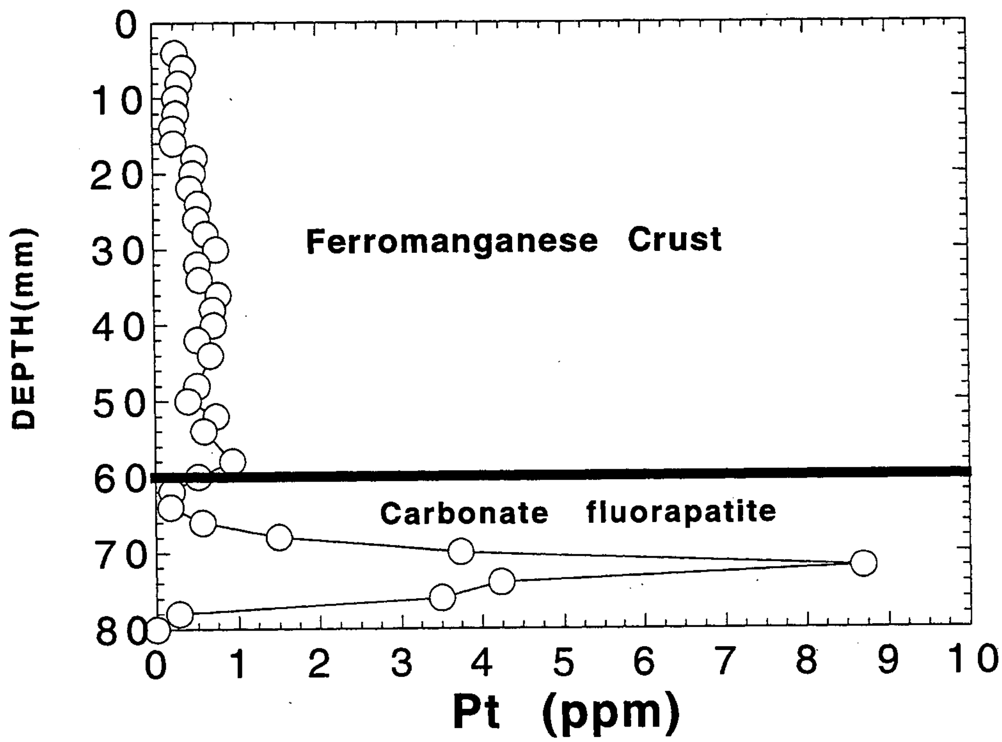

Figure 4. Kiribati crust section showing a platinum spike in the CFA layer.

Although P is a major nutrient element in the ocean, we observed no direct relationship between P and Pt. The distribution between P and Pt in crusts suggests disseminated CFA is a post-depositional formation in seamount ferromanganese crusts. It is plausible that biological processes transport phosphorous, platinum and barium into crusts through indirect/passive microbially mediated processes. Microbial processes are also the primary driving force behind the transformation of deposited particulate phosphorous into dissolved phosphate, a critical first step in the formation of apatite. However, the formation of the CFA itself is widely controlled by kinetic factors (Krajewski *et al.*, 1994). Platinum uptake may be incompatible with the formation of CFA. However, at this time, we cannot determine the importance of the release of Pt during CFA formation compared to Pt derived from other sources.

CONCLUSIONS

The abundance of platinum varies greatly within each manganese crust as well as between crusts. Generally, Pt concentration decreases from the bottom to the top of crusts. The platinum also concentrates in narrow zones thereby potentially providing useful stratigraphic markers. The strong, positive correlation between Ba and Pt suggests that Pt enrichment in ferromanganese crusts is influenced by biological activity. We believe that: 1) slow accumulation rate, 2) abundant biogenetic detritus (Ba, Zn, Cu) and 3) abundant hydrogenetic precipitates (Mn, Co, Ni) are the three main factors favoring high platinum concentration in most crusts. The large positive Pt anomaly found in the carbonate fluorapatite substrate of one Kiribati crust, however, likely represents cosmogenic particles, which may be directly related to K/T boundary meteorite impacts. We also suspect that the CFA formation and concomitant high P concentration underlying crusts are a potential source of Pt and Ba. The platinum layering in manganese crusts clearly merits further detailed study. The information from such studies could be used to perfect efficient mining equipment designs for future crust recovery as well as to give insight into the history of the ocean basins and possibly meteorite impacts.

ACKNOWLEDGMENTS

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INDUSTRIAL APPLICATION OF WASTE MANGANESE: INITIAL TESTING AND ECONOMIC EVALUATION

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ABSTRACT

Environmental challenges are mounting in the mining industry. It is now very difficult to open a new terrestrial mine in the continental United States. Environmental requirements will also be stringent for future ocean mining operations for manganese nodules and crusts. In both terrestrial manganese mines and future marine nodule and crust operations tailings disposal will be a pivotal environmental issue. However, these manganese tailings can be used for a variety of beneficial uses. One of the major applications which shows great promise is in industrial coatings. Four areas of experimentation were undertaken. All experimental coatings were made by adding measured amounts of tailings to selected chemical carriers. The resulting mixtures were applied to wood, metal and concrete. Four kinds of coatings were tried: those for rust-resistance, termite resistance, antibiofouling and undercoating (including high temperature automotive undercoats). The coatings were applied by brush, roller and in one case sprayed. The coatings went on well and imparted a series of very useful qualities, including hardness, rust resistance and an even matte finish. The useful coatings properties can be traced back to the chemical composition of the tailings. These beneficial properties are derived from the highly oxidized state of the manganese, the chemical nature of manganese (which preferentially scavenges and tightly binds other elements), the small angular grain size of the particles, the metallic nature of the resulting coatings and the fact that manganese has a repelling effect on organisms. This paper looks at some of these industrial applications as well as the possible economic effects of trying to develop a tailings industry.

INTRODUCTION

Large manganese mines in Australia, China, the Ukraine, Mexico and South Africa are producing millions of tons/year of manganese tailings. Korean and Chinese mining interests are actively planning to mine manganese nodules at sea early in the next century (Markussen,1990; Johnson, 1990). Several groups are also actively considering mining manganese crusts in the Exclusive Economic Zones of several islands including Johnston Island. Large tonnages of fine grained manganese tailings will be left after the processing of these ores (NOAA,1981,1991; DOI, 1990). Ongoing work at the University of Hawaii and elsewhere has looked at beneficial uses of this material (Osaki *et al.*, 1987; Wiltshire, 1991; Loudat, 1992; Lay and Wiltshire, 1997). Manganese tailings may be an economically viable resource in their own right.

Manganese tailings make excellent coatings. These coatings were made by mixing the tailings with a binder (carrier) to create a paint or spray mixture which was then applied to a variety of surfaces as a sealant, rust coating, termite coating, stain inhibitor/resistor, undercoating or automotive high temperature coating. The coatings experiments have been ongoing for 18 months to two years at the time of writing. The coatings are holding up exceptionally well. This article documents the experiments performed and presents a discussion of the results obtained.

Manganese tailings were provided by the Broken Hill Proprietary Company (BHP) from their largest manganese mine at Groote Eylandt, Northern Australia. These tailings are virtually identical both chemically and in grain size to nodule and crust tailings from an acid leach process. Considerable work was done to quantify the properties of the tailings and to insure that for a variety of types of industrial application there was no significant difference between the BHP tailings and the nodule tailings. This work was done in association with the Department of Mining and Metallurgical Engineering at the Technical University of Nova Scotia and is presented in Lay and Wiltshire (1997). The result was not surprising as the Groote Eylandt deposit is a marine manganese crust deposit which is now uplifted on land on an island a few tens of feet out of the water (William A. Scheel, BHP Mine Manager, Groote Eylandt, personal communication).

MANGANESE TAILINGS PROPERTIES

Many terrestrial manganese mines, such as BHP's Groote Eylandt Mine, beneficiate and separate the manganese size fractions by physical processes that do not involve acid leach. After extensive testing, we found the fine grained tailings produced by such processes to be very analogous to the marine mineral acid leach tailings after the acid residues are neutralized. As these analogous terrestrial tailings are abundant and consistent in composition between batches they were the focus of this study. What makes manganese tailings unique with respect to a range of other tailings is a series of unusual chemical properties.

Chemical and physical property tests of the tailings used in this study, were done at the University of Hawaii as well as by BHP and Micromeritics Corporation (for particle size distribution and gas absorption). Similar detailed tailing studies have been done for a range of nodule tailings by Haynes *et al*. (1985a, 1985b, 1982). Summary data are presented in Table 1 for chemical composition and Table 2 for other properties. Basically the tailings are small angular manganese dioxide grains intermixed with clay and small amounts of iron oxide and silica. They pack well because of their angularity but have a high surface area.

Table 1: Chemical Composition

Oxide	Percentage	Element	Percentage
MnO_2	36.0	Mn	22.6
SiO_2	28.1	Si	13.1
Al_2O_3	20.3	Al	10.7
FeO	5.6	Fe	4.4
BaO	0.60	Ba	0.54
TiO_2	0.48	Ti	0.29
K_2O	0.3	K	0.25
MgO	0.14	Mg	0.08
SrO	0.04	Sr	0.03
CaO	0.04	Ca	0.02
Na_2O	~0.5		
H_2O	~8.0		

Table 2: General Chemical Properties of the Tailings

Specific Gravity	3.46
Melting Range	1240-1285^{o}C
Ph	5.5 (in water suspension)
Grain Size Range	0.1 to 300 microns
Median Grain Size	3 microns, 50 % of sample mass was between 0.7 and 9 microns
Mineralogy	36% pyrolusite, 51% silicates (largely kaolinite), trace quartz
Magnetic Properties	Pyrolusite (paramagnetic), Kaolinite(non-magnetic)
Hardness	6 on the Moh's scale
Particle Surface Area	very high, 26.9 m^2/g
Average Pore Diameter	146 angstroms
Gas Absorption	0.30 cm^3/g absorption of CO gas
Electrical Properties	Resistor at all temperatures
Solubility	Insoluble in water
Appearance	Gray-black , fine grained powder, no odor
Toxicity	Non-toxic (standard EPA type toxicity tests run by BHP)

SEALANT

The first trial application of tailings as a filler in a coating was as a sealant on asbestos siding done in 1994 using neoprene and acrylic carriers. The mix was sprayed on asbestos siding in a Wood Valley, Island of Hawaii warehouse made available to the research project. The idea was to seal the asbestos making the warehouse more usable. Extensive discussions were undertaken with polymer division of Dupont Chemical who suggested using neoprene latex 400, one of their specialty products, a gallon of which they provided. We also used an acrylic based carrier. There are two noteworthy results.

1. The application of the tailings/carrier mix was done with power equipment (8 hp compressor with commercial Binks model 2001 spray gun). Generally speaking, the tailings sprayed well and the desired coating was achieved.

2. After 2 years, the acrylic/tailings coating has performed well with no deterioration or chipping. This was not true for the neoprene/tailings coatings which can be readily scraped off the asbestos siding.

RUST PREVENTION

The same facility on the Island of Hawaii made available by I'o Makuahine Corporation (a Hawaiian agriforestry business) for the sealant experiment was used for two rust prevention experiments using tailings mixes.

Experimental Procedure

Rusted iron beams were scraped and wire-brushed to remove surface rust. JASCO "prep & primer" was then applied and allowed to dry. Several commercial rust prevention formulations were then applied. The rust prevention formulations are outlined in the table below with the respective treatments and the performance ranking (based on % visible rust-through) of the treatment. The carrier preparations chosen for the tailings were those based on the opinions of the technical persons at the coatings supplier. The commercial rust prevention materials were chosen as controls. The experiment lasted 18 months.

Table 3: Results of rust prevention experiment

rank	carrier/rust preventative	% tailings
2	water based epoxy latex enamel	45
3	rust destroyer-Advanced Protective Products	0
1	alkyd reinforced urethane	45
4	alkyd metal primer	0
5	water based acrylic roof paint	38

As the table shows, the best performing rust prevention treatments were tailings mixtures. This is the case in spite of the fact that the mix of tailings and the carrier was clearly non-optimal since the tailings often settled out of suspension or clumped. This problem can be resolved by adding dispersing agents. It is noteworthy that two of the tailings formulations out-performed the commercial rust prevention materials designed specifically to prevent rust.

ROOF COATING - ELASTOMERIC SEALER

The second rust prevention experiment was also done in the Wood Valley, Island of Hawaii warehouse. For this experiment, a series of tailings mixtures was used as a roof coating and sealing experiment.

Experimental Procedure

The corrugated tin roof of the warehouse was brushed to remove debris and excess rust. Three mixtures of United Coatings Roofmate elastomeric roof sealer/coating were then applied to two different areas of the roof with different degrees of rust - severe and marginally rusted. The three mixtures were the Roofmate alone (control), the Roofmate with 10% (by volume) tailings (treatment 1) and the Roofmate with 25% (by volume) tailings (treatment 2).

Results

The first observation to note was the ability of the tailings to mix with the elastomeric sealer material. Treatment 1 presented some minor difficulties for some of the mixes as the tailings tended to clump. We have no explanation as to why tailings tended to clump in some instances and not in others. In contrast, for treatment 2, it proved very difficult to mix 25% by volume tailings with 5 gallons of the elastomeric sealer material as the tailings caused significant thickening of the mixture. According to a United Coatings chemist, the clumping is caused when the tailings level is high enough to "break" the stability of the emulsion which also results in the mixing problems experienced. This problem can be rectified by adding a dispersant (Tamal 850 produced by Roman-Haas) to the elastomeric sealer material before adding the tailings.

Of the three treatments, treatment 1, the 10% tailings mixture, spread the best. Treatment 2 clumped and dried rapidly making it difficult to obtain a consistent, uniform spread of the mixture. Treatment 1 also performed the best of the three treatments showing the least bleed through of the rust on the significantly rusted portion of the roof. Treatment 2 performed better than the control of the straight elastomeric material with respect to rust bleed through. We do not consider this result to be due to the fact that the color of the tailings mixtures (treatments 1 and 2) was medium to dark gray in contrast to the control which was white (elastomeric material with no tailings). Rather, we feel this result is due to characteristics the tailings give to the elastomeric sealer which make it a stain resistor.

With respect to roof sealing capabilities, the control and treatment 1 appear to work equally well based on observed surfacing cracking, chipping or peeling. Treatment 2 showed significant cracking and thus would not provide adequate roof sealing capabilities as formulated for this experiment. The marginally rusted portion of the roof coated with the tailings/elastomeric sealer material performed well.

STAIN RESISTANCE

A single-family residence in Kaneohe, Hawaii with a previously painted roof flashing was made available to assess the rust/stain prevention characteristics of tailings coating mixtures.

Experimental Procedure

The flashing was scraped and wire-brushed to remove surface material. Various different stain prevention/inhibitor formulations were then applied. These formulations are outlined in the table below with the respective treatments and the performance ranking (based on observation) of the treatment. The carrier materials chosen for the tailings were those based on the opinions of the technical persons at a local Honolulu paint supplier. The stain prevention materials were chosen as controls.

Table 4: Results of stain resistance experiment

rank	carrier/stain preventative	% tailings
6	black high gloss polyurethane	0
5	white polyurethane	0
7	white polyurethane	50
2	1-2-3 water based tintable white	0
1	1-2-3 water based tintable white	50
4	X-I-M solvent based primer	0
3	X-I-M solvent based primer	50

Results

The three polyurethane coatings showed the poorest performance. The polyurethane material used (United Coatings) can be applied as a 1 (B)- or 2 (A+B)-part system. It was applied as a 1-part system (B only) for the experiment. This may partially explain the overall poor performance of the polyurethane especially considering the "best" performance of a urethane/tailings mixture for the rust prevention experiment. The performance of the 1-2-3 was marginally better (both with and without tailings) than the X-I-M. The stain resistance performance of each of these carriers was enhanced by the addition of the tailings.

There was little if any problem with tailings settling out of the mixture for each of the 1-2-3 and X-I-M carriers. X-I-M is an oil-based carrier. Oil-based carriers to date generally hold the tailings in suspension better than water-based carriers. Thus, this result is not that surprising. However, it was somewhat surprising result for the 1-2-3 which is a water-based carrier. As noted above, tailings clumped and settled rapidly in other water-based carriers. This result suggests that tailings can be used for rust prevention and generally for pigmentation in water-based as well as oil-based carriers.

The reason that the tailings did not clump/settle in the 1-2-3 is likely attributable to the fact that the 1-2-3 used was a "tintable" white. This means that it contained sufficient dispersant to prevent clumping/settling of powdered additives such as the tailings. This suggests that problems experienced to date (clumping/settling) when tailings have been added to water-based carriers can likely be remedied by the addition of a dispersant. If so, a more accurate measure of the tailings performance in water-based carriers can be made and it is likely their overall performance will improve relative to results for these carriers to date.

ROOF COATING - FIBER REINFORCED ASPHALT

The same single-family residence in Kaneohe, Hawaii used for the rust/stain prevention experiment was also used to assess the efficacy of tailings as a filler in (Henry's) wet patch roof cement which is a heavy-bodied asphalt mastic reinforced with inert mineral fibers.

Experimental Procedure

The roof of the house had been previously coated with an elastomeric roof coating which had blistered on the flat areas of the roof. These areas were prepared by removing all edges and brushing away debris. The tailings were than mixed with the asphalt material at an approximate 50/50 rate and applied to the prepared spots.

Results

In the initial place where the tailings/asphalt mixture and straight asphalt mixtures were placed the following observations were made.

1. Neither of the formulations sagged, ran, blistered or peeled over an eight month period.
2. The tailings/asphalt mixture had less bubbling and cracking than the straight asphalt emulsion. The surface of the tailings/asphalt mixture was harder and appeared more durable.
3. Overall, the tailings/ asphalt mixture performed at least as well as the straight asphalt mixture.

These is are somewhat surprising results as the tailings caused significant thickening of the asphalt which one would think would have led to more cracking than the straight asphalt emulsion.

TERMITE RESISTANCE

One area of extensive interest has been the possibility of manganese tailings serving as a termite resistant coating. This was postulated for several reasons. First, tailings appear to have some anti-biofouling properties. Generally, this sort of effect is also applicable to insects. Termites are not accustomed to manganese in their environment and might be expected to avoid it. Second, the angular manganese grains are very hard and appear to interlock in coatings making a dense surface, difficult for an insect to get through.

Two experiments were conducted to assess this. The first was a preliminary experiment. It lasted six months. It involved two identical soft wood pieces of lumber about three feet long. One of these was coated in a tailings mix in an elastomer carrier (Oregon Research and Development Clear Sealer), the other was untreated lumber. They were both stuck in a termite nest and left for the six months. When recovered the manganese coated wood was in essentially perfect condition whereas the other piece of wood had been virtually totally eaten away. The contrast was dramatic!

On the basis of this result, a much more sophisticated experiment was devised with multiple controls for color, manganese alone (softwood slats sitting in manganese tailings but otherwise untreated) and carrier alone. This involved eight softwood slats put out in a heavily infested termite area. This experiment ran for one year. At the end of the year the experiment was pulled apart and the slats examined. To our surprise, no slats, including untreated controls, showed any termite damage. This result may be interpreted several ways. The first is that no termites were in the area or chose not to come to the experiment site. In our opinion, this is unlikely as the area was a known termite nesting ground in a protected banana patch. The second possibility is that the amount of manganese both covering the slats and in the ground where the unprotected slats were sitting, was sufficient to discourage the termites both from the treated and untreated slats which were within a few feet of each other. If this is the case, houses built on a pad of tailings several feet thick would probably be significantly protected from termite infestation. For the construction industry in the Pacific, which loses several billion dollars a year to termite damage, this could be a cheap and very important solution.

UNDERCOATS AND AUTOMOTIVE COATINGS

Manganese tailings coatings have been tried in two other applications: as undercoats and as automotive coatings. In both cases, the carrier used was an elastomer sealer. Several of these were tried. Oregon Research and Development Clear Seal was found to perform about the best. The tailings were suspended in the mix without dispersant. They tailings did tend to clump but could be thinned with water and spread.

The tailings value as an undercoat is that they sand very well to a high finish and fill any small nicks or cracks. This is due to the metallic nature of the tailings and the general grain hardness. This worked equally well on wood and metal. The same mixture was applied to an automobile exhaust pipe and engine block. The tailings coating withstood the high temperatures involved and actually seemed to bond and become an even harder coating. The relatively high melting temperature of the tailings at 1240 degrees centigrade contributed to the success of this coating. We were asked by an automotive body shop for a commercial source of this coating material after they observed the results. Manganese tailings have great potential in a range of coatings applications.

ECONOMIC EVALUATION

The value of tailings is highly dependent on the use to which they are put. A general ball park order of value is taken as $50 /ton (2.3 cents/pound or 5.8 cents /kilogram), an order of magnitude between sand at $5/ton and manganese at $500/ton. This value would place tailings at the low end of the range for fillers for coating applications. Clay fillers are on the order of 12 cents /kg. Fillers that impart specific properties can be considerably more expensive: ground limestone is 15 cents/kg, alumina trihydrate is 88 cents/kg and densified alumina is $1.10/kg. In most of the applications discussed in this paper, the manganese is imparting to the coating properties beyond those of an inert filler and could thus command a higher price. Exact prices are difficult to forecast as they are highly dependent on packaging, shipping parameters, marketing and market volume.

CONCLUSIONS

Manganese tailings have a considerable industrial future in a range of coating applications. After multiple year long trials of various manganese coating mixes, we recorded superior performance to commercially available products in the case of rust and stain inhibitors. Termite coating results are also very positive. Biofouling studies indicate there are clear antibiofouling properties but these have not yet been fully quantified. Ongoing research is using Atomic Force Microscopy (AFM) to investigate the detailed structure of the manganese coating surfaces to quantify the very positive but as yet qualitative results obtained to date. Our work shows that manganese tailings have a significant role to play in improving the properties of certain kinds of coatings. The fact that the manganese source is a waste material means that the cost of these coating materials should be substantially less than the cost of what is currently being used.

ACKNOWLEDGMENTS

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APPLICATION OF MAGNETIC MEASUREMENTS IN MONITORING OF CONTAMINATED SEA-FLOOR SEDIMENTS OF HONG KONG

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ABSTRACT

Rapid and non-destructive magnetic measurements have been made on fifty-one marine vibrocores taken from four locations within Hong Kong waters. Results of magnetic susceptibility (κ) measurement reveal a magnetic enrichment in more than 50% of the cores examined. Magnetic parameters including natural remanent magnetization (NRM), saturation isothermal remanent magnetization (SIRM), frequency-dependent susceptibility (κ_{fd}), 'hard' IRM (HIRM) and backfield S ratio were measured on selected cores. The κ, NRM and SIRM results show peak values in surficial sediments which drop off to a constant level at depth, revealing the presence of two magnetic remanence units. The results of κ_{fd}, HIRM and backfield S ratios indicate the presence of relatively coarse magnetic minerals in both remanence units. Varying concentrations in magnetic mineral are interpreted to be the cause for the observed variations in magnetic susceptibility in the cores. A positive correlation found between the magnetic susceptibility and concentrations of heavy metals in the sediments from one of the sites has suggested an anthropogenic origin of the minerals. Discharges from an abandoned power station, anchorage sites, shipping activities, and mine tailings nearby are thought to be the responsible factors. The present study shows that magnetic properties can be used to study contaminated marine sediments and to identify possible mechanisms of magnetic enrichment.

INTRODUCTION

Magnetic measurements have been applied in recent years to sedimentological studies (e.g. Oldfield et al., 1979; Scoullos & Zeri, 1993) and paleoclimatic reconstruction (e.g. Banerjee, 1994). Many recent studies have demostrated a causal relationship between magnetic parameters and contamination of sediments in gulfs (e.g. Scoullos et al., 1979; Oldfield & Scoullos, 1984), estuarine and coastal areas (e.g. Scoullos & Oldfield, 1986) and urban catchments (e.g. Beckwith et al., 1986). Magnetic enrichment observed in sediments has been attributed to industrial and urban discharges (e.g. Scoullos et al., 1979; Oldfield & Scoullos, 1984; Versteeg et al., 1995). These studies suggest that magnetic parameters such as magnetic susceptibility and saturation isothermal remanent magnetization can be used as indices of pollution. There have not been any previous attempts to study the relationship between magnetic properties and heavy metals in sea-floor sediments of Hong Kong. There are three objectives of the present paper: describe the variations in magnetic intensity and mineralogy of sea-floor sediments at selected sites; examine the statistical correlation between magnetic intensities and heavy metals; and determine the origin of magnetic particles.

STUDY AREAS

The vibrocores examined in the present study were collected from four areas in Hong Kong (Figure 1). Penny's Bay and West Lamma Channel are located in the Western Harbour Zone, while Green Island and Kwun Tong are located within Victoria Harbour. The list of cores from the four study sites, seabed levels, and their designations are given in Table 1. The sediments in the cores are generally a grey-green silty clay containing scattered shell fragments of the Holocene age. Since trawling and dredging are commonly practised in Hong Kong, the sediments may have been disturbed to a certain extent at all of the sites. The nature of the land use at the four sites is somewhat different, which allows us to compare the magnetic properties of the sediments deposited at varying proximity to contamination sources. Penny's Bay is situated near a deep-water channel which forms a navigation route for ships. A disused power station, ship repair yard, an abandoned quartz mine and an anchorage site are located on the eastern side of the site. The core from Kwun Tong is liable to contamination by discharges from nearby industrial and domestic land uses. Anchorage areas and sewage outlets are located at the eastern side of Green Island. A spoil ground used for the disposal of dredged spoil from Victoria Harbour is found at the western section of the Island. The cores from West Lamma Channel were located offshore, and away from major industrial sources.

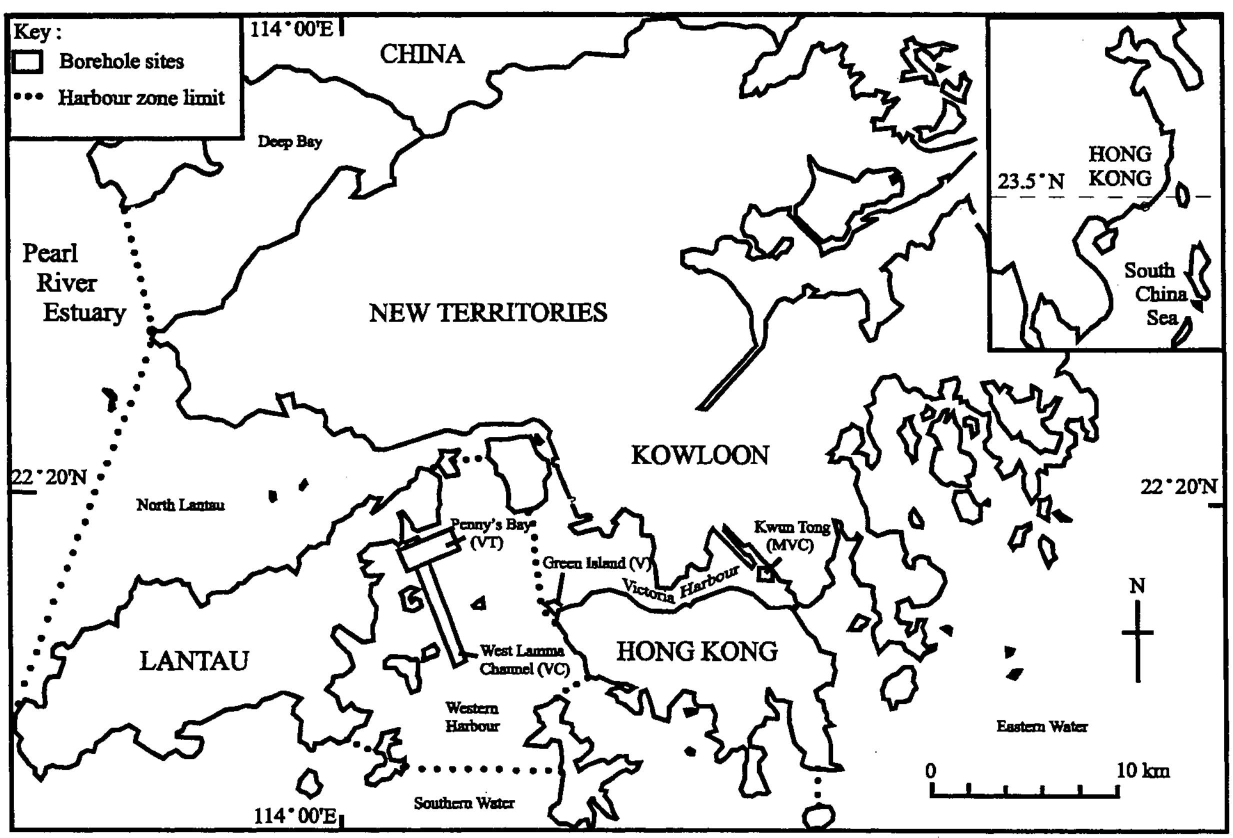

Figure 1. Location map of the study areas

MATERIALS AND METHODS

The cores were subjected to magnetic susceptibility measurements using a Bartington MS2 magnetic susceptibility meter equipped with a MS2C core-scanning sensor. Readings were taken at 1-cm intervals and background values were made to correct for any instrumental drift. The detection range used was 1.0 and the resolution 10^{-5} SI units. Readings obtained from edges of the cores were discarded. A magnetic enrichment index (MEI) was devised in the present study to depict the vertical variation in magnetic susceptibility in a semi-quantitative manner. MEI is defined as the vertical gradient of the logarithmic magnetic susceptibility. A strong magnetic enrichment is indicated by a high positive MEI. Little vertical variation in magnetic susceptibility yields a MEI close to zero, and a negative MEI implies an increase in magnetic susceptibility with depth.

Three cores, VT62, VC8 and V45 were chosen for measurements of the following magnetic parameters: κ_{fd}, NRM, SIRM, HIRM and S ratios. Samples were extracted at 10-cm intervals and κ_{fd} values were determined at 0.465 kHz and 4.65 kHz using a Bartington MS2 dual frequency sensor. NRM and IRM intensities were measured using a Minispin rock magnetometer. IRM measurements were made by imposing an applied field of one tesla using an impulse magnetizer. Determinations of HIRM and backfield S ratios are based on the methods given by King & Channell (1991).

Heavy metal concentrations of all cores except VC and MVC have been determined by MateriaLab (1994, 1995). Samples obtained at four depth intervals, 0.0-0.1 m, 0.9-1.0 m, 1.9-2.0 m and 2.9-3.0 m, were dried and digested with a mixture of nitric and hydrochloric acids for the chemical analyses. Atomic absorption spectrometry was used to determine the Cu, Cd, Cr, Pb, Ni and Zn content, and the cold vapour generation method for Hg content. Since the concentrations for both Cd and Hg were very low in all samples and in many cases below the detection limits (0.01 mg/kg for Hg and 0.2 mg/kg for Cd in both VT and V series), results for Hg and Cd have not been used for the analysis in the present study.

MAGNETIC RESULTS

Typical magnetic susceptibility profiles of the measured cores are shown in Figure 2. All profiles show peak values within the top meter which drop off to a constant level at depth. The highest magnetic susceptibility value was recorded in the top 20 cm of MVC 63/2. Core VC 8 shows only a slight enrichment in the top layers. The cores also show varying thickness of magnetic enrichment zones.

As shown in Table 1, strong MEIs are generally found in most of the vibrocores from Penny's Bay. The highest MEI (0.59) is found in the Kwun Tong core. High MEIs are observed in the eastern section of Penny's Bay in comparison to the western section. Most cores from West Lamma Channel show relatively low MEIs, while Green Island shows a variable pattern with cores showing both high and low enrichment.

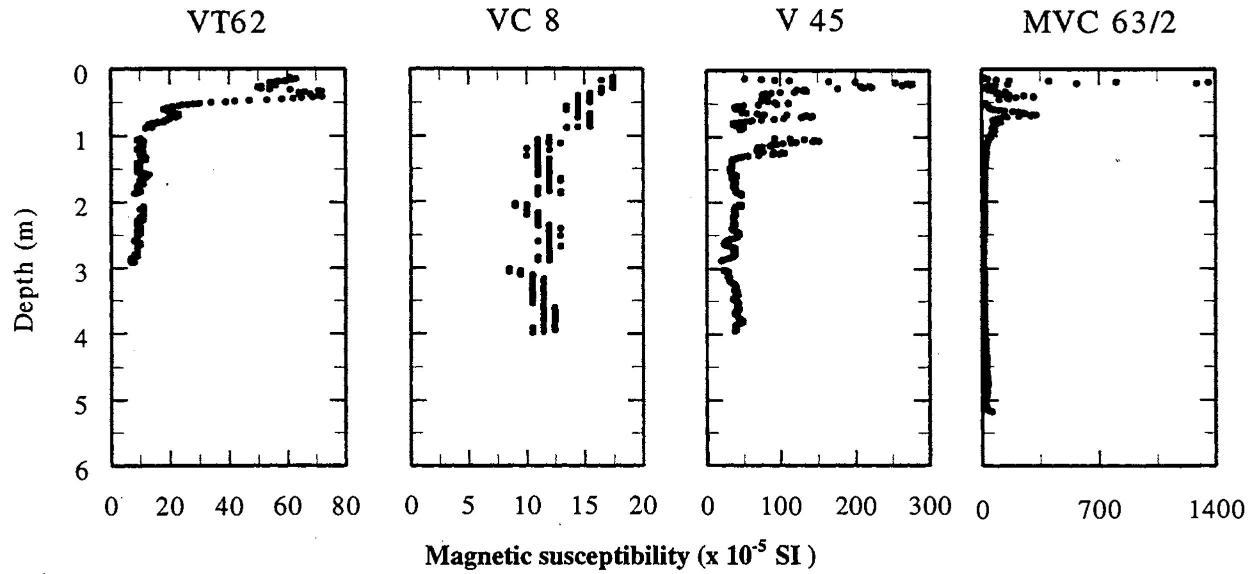

Figure 2. Magnetic susceptibility profiles of selected cores from Hong Kong waters

Table 1. Magnetic enrichment indexes (MEI) and seabed levels of vibrocores studied

Localities	Core	MEI	Seabed level (mPD)	Core	MEI	Seabed level (mPD)
Penny's Bay (Western section)	VT 1	0.21	-5.77	VT 10	0.02	-5.94
	VT 2	0.19	-5.34	VT 13	0.01	-5.96
	VT 3	0.09	-5.59	VT 17	0.01	-6.26
	VT 5	0.10	-5.48	VT 18	0.00	-6.57
	VT 6	0.14	-5.43	VT 20	0.01	-5.70
				VT 23	0.07	-6.30
Penny's Bay (Eastern section)	VT 38	0.28	-9.65	VT 51	0.15	-16.76
	VT 41	0.27	-8.85	VT 54	0.27	-9.59
	VT 42	0.27	-7.96	VT 60	0.26	-14.31
	VT 44	-0.08	-11.84	VT 62	0.27	-12.22
	VT 48	-0.14	-13.70	VT 63	0.37	-8.85
	VT 49	0.40	-10.54	VT 71	0.26	-15.31
				VT 74	0.35	-14.86
West Lamma Channel	VC 1	0.03	-6.10	VC 14	0.02	-7.03
	VC 2	0.02	-6.65	VC 15	0.00	-8.74
	VC 4	0.19	-7.00	VC 16	0.08	-9.58
	VC 5	0.04	-9.75	VC 17	0.10	-10.63
	VC 6	0.10	-10.34	VC 18	0.22	-9.93
	VC 8	0.06	-10.15	VC 19	0.05	-8.31
	VC 10	0.00	-6.34	VC 23	0.00	-7.56
	VC 11	0.11	-8.96	VC 26	-0.01	-7.89
	VC 12	0.10	-8.04	VC 32	-0.01	-8.99
	VC 13	0.27	-7.32	VC 34	0.07	-8.69
Green Island	V 2	-0.08	-16.16	V 45	0.23	-27.20
	V 3	0.06	-16.76	V 47	0.23	-27.20
	V 44	0.19	-21.45	V 48	-0.31	-17.56
Kwun Tong	MVC 63/2	0.59	-5.86			

Figure 3 shows the variations in magnetic parameters for the three selected cores. V45 from Green Island shows the highest magnetic concentrations, while VC8 from West Lamma Channel the lowest. Two magnetic remanence units can be identified in all three cores, with the top unit having relatively higher κ, NRM and SIRM values. All three cores show κ_{fd} values ranging from 0% to 6% with no obvious trend of variation, implying a negligible contribution from ultra-fine superparamagnetic grains. The computed S ratios are all close to unity and HIRM values close to zero, suggesting a dominance of magnetite as the magnetic carrier.

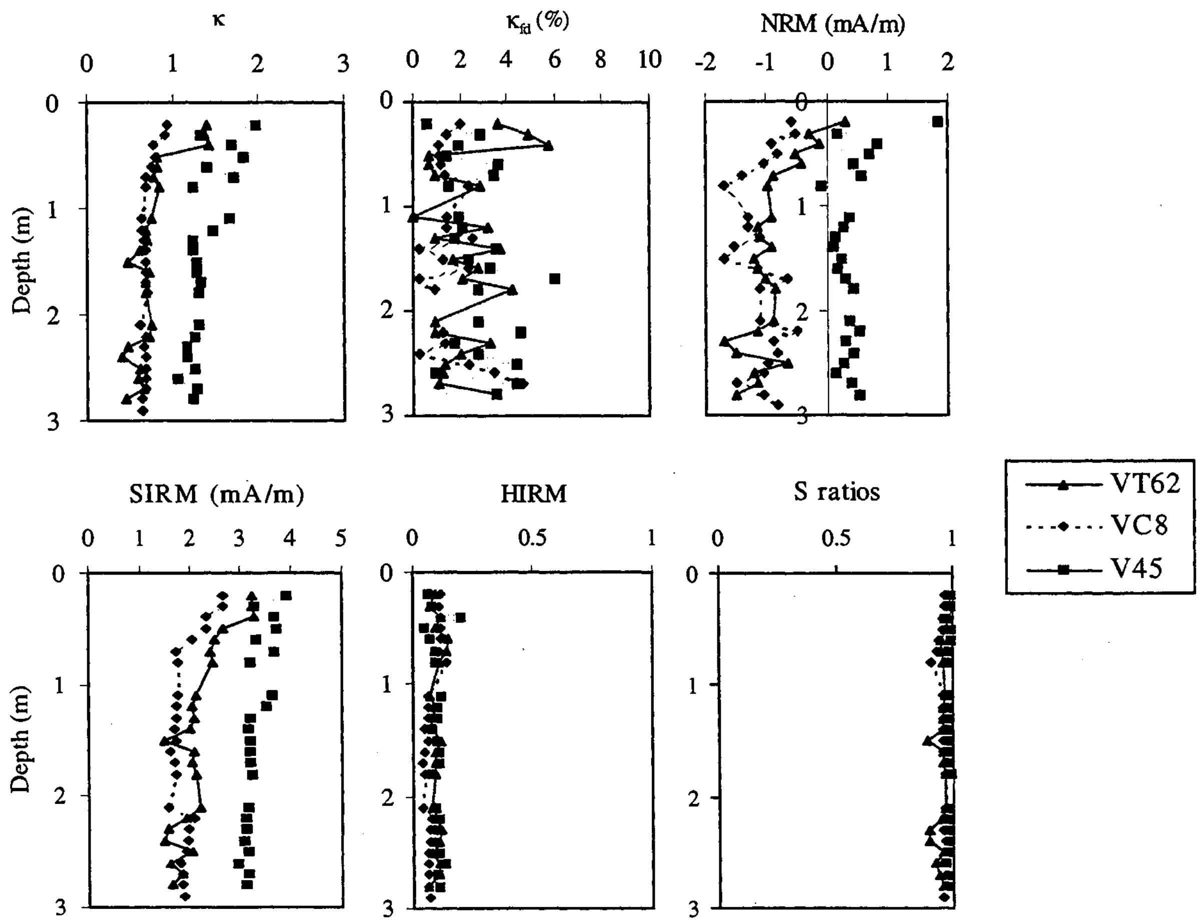

Figure 3. Magnetic parameters for three selected cores. Axes for κ, NRM and SIRM are presented on a logarithmic scale

Figure 4 shows the results of the IRM experiments for samples from various depths in cores VT62, VC8 and V45. The IRM intensities of the samples become saturated at an applied field of 0.1 tesla and remain constant above 0.1 tesla, implying the predominance of a coarse-grained magnetite in the sediments.

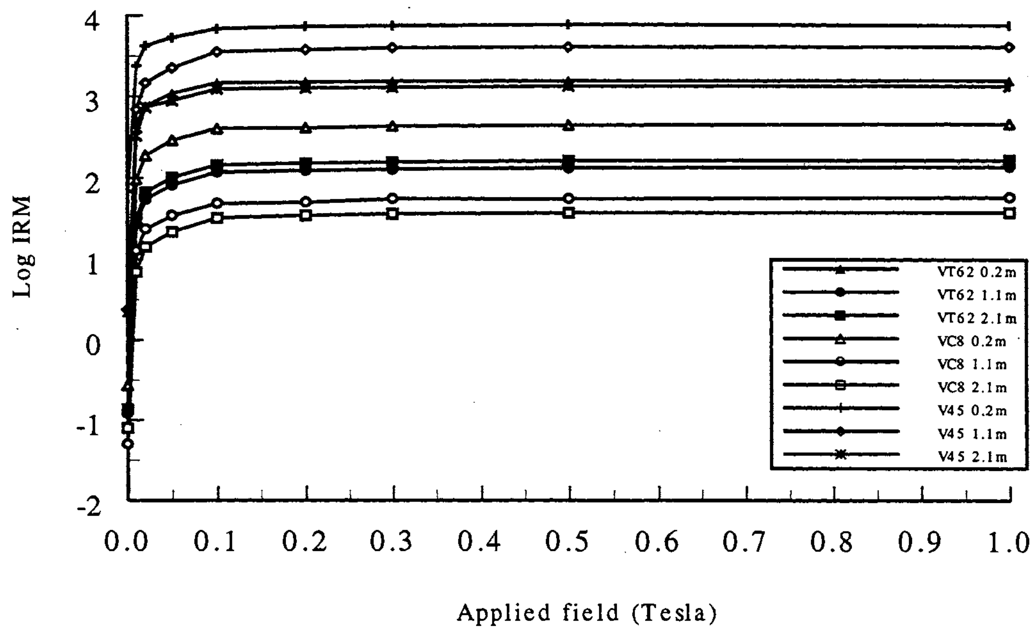

Figure 4. IRM acquisition curves for samples from the selected cores

DISCUSSIONS AND ANALYSIS

A strong positive correlation (r) is found between κ and heavy metal contents for Penny's Bay (Figure 5). Among the five heavy metals, Pb shows the highest r value, followed by Cu, Zn and Cr, and Ni shows the weakest correlation with κ. A weak statistical correlation between magnetic susceptibility and the heavy metal contents are observed in the Green Island cores.

The MEIs calculated for the cores suggest that enrichment of magnetic particles in surficial seabed sediments are a common phenomenon within the Hong Kong waters. The level of magnetic enrichment and the thickness of enrichment zone, however, are not identical for all localities (Table 1). The consistent HIRM and backfield S ratios show that the variations in magnetic intensity at the study areas are mainly caused by varying magnetic particle concentration. The variation in the thickness of the magnetic enrichment zone can be attributed to the different degree of dredging and dumping in the sites.

Magnetic particles in the marine sediments can be derived naturally (e.g. Thompson & Oldfield, 1986), or anthropogenically (e.g. Scoullos et al., 1979). In Penny's Bay, the coarse-grained nature of the magnetic carriers has suggested that the origin of the magnetic particles is not biogenic, which are often fine-grained in nature (Stolz et al., 1986; Chang et al., 1989). The strong statistical correlation between magnetic susceptibility and concentrations of such heavy metals as Pb, Cu and Zn also suggests an anthropogenic origin of the magnetic particles in the area.

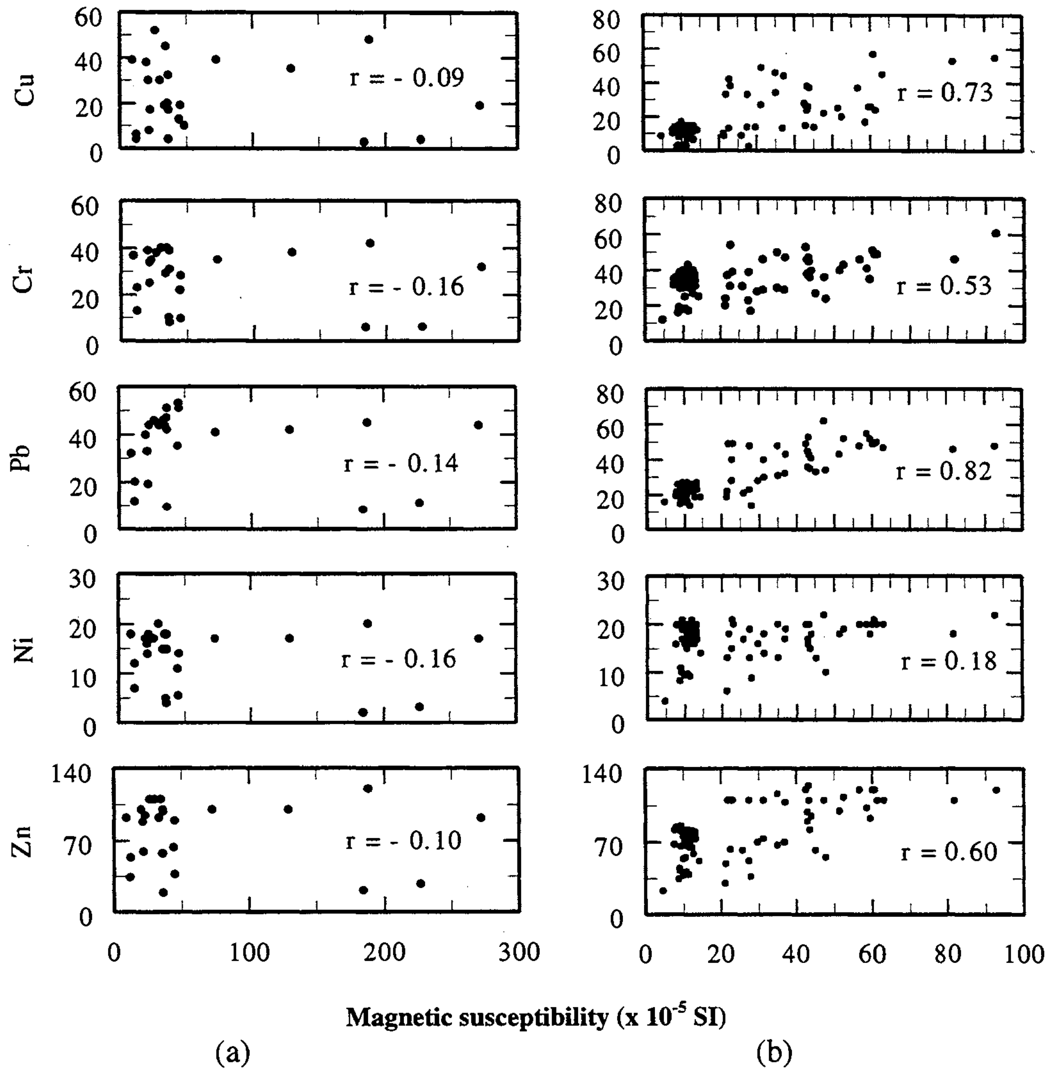

Figure 5. Correlations between magnetic susceptibility and heavy metals in Green Island (a) and Penny's Bay (b). Contents of heavy metals are in mg/kg, while 'r' is the correlation coefficient.

Higher MEI values in the eastern section of Penny's Bay (Table 1) have argued for a local source of the magnetic minerals. Fly ash produced by the power station, refuses and wastes from shipyard and anchorage sites, and disposed tailings from the quartz mine could all have contributed to the stronger magnetic and heavy metal enrichments in the eastern section. Ferrimagnetic iron oxides such as magnetite discharged from the contamination sources provide favourable surfaces for the absorption of some heavy metals such as Cd, Pb and Zn (Tessier et al., 1980; Lion et al., 1982). Lead-bearing paint scrapings from anchored vessels in both the shipyard and the anchorage areas could also have produced large amount of particulate lead, which may be absorbed onto the iron oxides. In addition, wastes and dusts discharged from passing ships and ferries in the navigating channel on the east may also contribute to the higher amounts of heavy metals and magnetic particles in the eastern section of the area.

The high magnetic susceptibility values in the surficial sediments of the Kwun Tong core can be attributed to pollutants in untreated industrial effluents from nearby factories, organic wastes, and nearby shipping activities. Poor tidal flushing as a result of increased reclamation work in the Victoria Harbour may have further promoted the magnetic and heavy metal enrichments in the area.

The low magnetic susceptibility and MEIs found in the cores from West Lamma Channel may be regarded as background values for the sediments. The magnetic results obtained, combined with the high dissolved oxygen level measured by Environmental Protection Department of Hong Kong (1995) have suggested that the area is the least polluted among the four study sites. Absence of nearby onshore contamination sources has accounted for the lower magnetic susceptibility and enrichment in the area.

The reasons for the weak correlation between the magnetic susceptibility and heavy metals concentrations at the Green Island site are unclear. The core samples of the area show inconsistent MEI values (Table 1). It is plausible that the deep water depth and the complex bottom current dynamics could have played an important role in determining the spatial distribution of magnetic minerals and heavy metals. More information about the bottom current hydraulics may be helpful in examining the relationship between magnetic susceptibility and heavy metal concentrations in the area.

CONCLUSIONS

The positive correlation found between magnetic susceptibility and heavy metal concentration in Penny's Bay suggests a genetic association of the two properties. The strong correlation found between magnetic susceptibility and lead has shown that lead-bearing scrapings released from shipping activities may be an important source of the heavy metals in the sediments. The magnetic results obtained from Kwun Tong and West Lamma Channel have emphasised the role of onshore contamination sources to the distribution of magnetic concentrations. The present study has provided a preliminary examination of magnetic-metal relationship of marine sea-floor sediments in Hong Kong waters. Being a rapid and non-destructive technique, magnetic measurements can provide an alternative means in future reconnaissance surveys of assessing seabed contamination in pollution-prone zones such as harbours and coastal cities.

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FEATURES OF GEOMORPHY AND ITS SUBMARINE SEDIMENT OF THE WEIZHOU ISLAND COAST IN THE BEIBU GUIF

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ABSTRACT

The Weizhou Island is piled up under the Water when Quaternary basalt magma gushed out.The erosion is the south and piling-up in the north are obvious geomorphic features from the coast.There are 12 geomorphic shapes longshore:volcanic clastic, tableands,destroyed ancient volcanic craters,sea cliffs,wave cut benches,sea stack, barriers,lagoons,intertide shoals,coral reefs,off-shore slope,submarine plains and artifocial morphology.

There are five types of sediment in Weizhou Sea Area:coral sand,clayey sand, clayey silt,sand-silt-clay,silty clay.Generally,sediment appear stripped distribution from coarse to fine and paralldl to the coast.Contents of heavy minerals in surface sediment tend to decrease from shore to sea with the increase of water depth,and the heavy minerals are namde as amphibole-glauconite-pyrite assemblage.Foraminifera and Ostracoda are abundant in the sediment.Species diversity and foramimifera number increase form inshor to offshore with the increase of water depth,two assemgblage zones can be divided:1)***Pararotalia amarta-Triloculina trigonula-Poroeponides cribroepondus*** assembiage zone,distributed from shore to water depth 15m;2)***Schackoinella globosa-Ammonia compressiuscula*** assemblage zone in the water depth 15-30m.

Alongshore sediments in the Weizhor Island originat mainly from the erosion of southern and western coastal bedrock,underwatercoral growing zone and reef falt in the north and eart.

INTRODUCTLON

Weizhou Island is in the north of Beibu Gulf, on the southern sea area of Beihai Peninsula, 48km as the crow flies from the Beihai City, GuangXi. The island is oval in shape, it extends 6km from north to south, 5km wide from west to east, coast lines of whole island extend 24.6KM, land arsa is 24.98km^2. intertide zone are 3.47km^2, it is a largest island in the Beibu Gulf. Authors have discussed features of geomorphy and its submarine sediment of the Island coast according to positive result on the spot investigation and indoor analyses early or late in 1983 to 1986 and 1989 to 1991 years, and discussed its regularity of sedimentary sourse and movement.

GEOLOGICA BACKGROUND

Weizhou island is in the northern marin of Midle Depression of the Beibu Gulf. Geologica tectonics have underwent very long and complicated evolutional course. Throghout the area, there are drilling and appear in Quaternary strata: silty-fine sand, clayey sand, clay, coarse sand with grevel in the Zhanjing Formation during Early Pleistoncene; olivine dolerite, basalt tuffite, basalt volcanic breccia in the Shimaoling Formation during Midl Pleistoneene; basalt tuffite, basalt volcanic breccia, agglomerat, olivine basalt in the Huguang Formation during Late Pleistocene. Holocene Formation is composed of the brownred sandy clay, clayey-sand with bioclastic, greyish-white bioclastic midfine sand, bioclastic beach-rock, cream-yellow bioclastic beachrock.

Neotectonise of the weizhou island is obvious, it displaies chiefly on the volcanic activities many times during Quaternary and vertical displacement of the earth crust. In the WeiZhou Island sea area, especially during Mid-pleistocene to Late Pleistocene, the earth's crust depression is in depressed sediment-environment inundated by seawater, magma activities frequently, submarine volcanic activilis happeded, basic volcanic eruption exceed five times, after the gushed outing every time, fromed all a inter-mittent period, during this the earth's crust quick vertical displacement emerged times. After Late Pleistocene, the globe came out general regression, WeiZhou island rose and emerged completely in the marine surface. Early Holocene, it is in the weathering environment, till Mid-Holoene, the globe climate warmed up, sea leved rose up quickly, corals was growing prosperously around the Weizhou Island, formed basic rock(volcanic breccia)and coral reef coast.

GEOMORPHIC MORPHOLOGIES AND ITS FEATRE

Weizhou Island since Quaternary Himalayas period volcanic erupted and is piled up underwater, it underwent a long ascension, weathering, denudation, under the erosion, carry, accmulation of the wind and wave and current, formed geomorphic morphologies of various description(Liu and Li 1991), such as Fig. 1 appeared.

1. Volcanic clastic talleland

Volcanic clastic tableland is distributed ovre the south and east and west of this island. It is composed of sed tuff and sed ruff pyroclastic rock, attitude of rock slopes gently. It is fromed by the shallow sea volcanic eruptive and deposit and underwent the erath's crust rising relatively. General trend of volcanic clastic tableland is south taller than north, the highest point is in the Qinqailing, 79.6m above sea level. From the highest point toward the west, north, east direcction lowers gradually, constituted geomorphic landscapes of the volc anic clastic tableland sloped gently. Owing to affection of the surface water, weathering and other exogenic force united action, volcanic clastric material turn into elurial-slope and weathered laterite, and formed small hills rising or falling mimutely.

2. Destroyed ancient craters

Because of this island belong to submarine volcanic eruption in the shallow sea, its shape of the crater and volcanic cone not as obvious as territorial volcanic eruption. According to investigation Nanwan Bay is a destroyed ancient crater. There is another ancient crater is northewest of Henglushan village.

Nanwan Bay crater It is in the Nanwan Bay harbour, a semicircle bay wich has a diameter of 2km and its bay mouth in the south links up with the sea; in its east, west, nouth formed sea cliff of 20-50m in height. Nanwan Bay is very similar to a remaining trace of destroyed

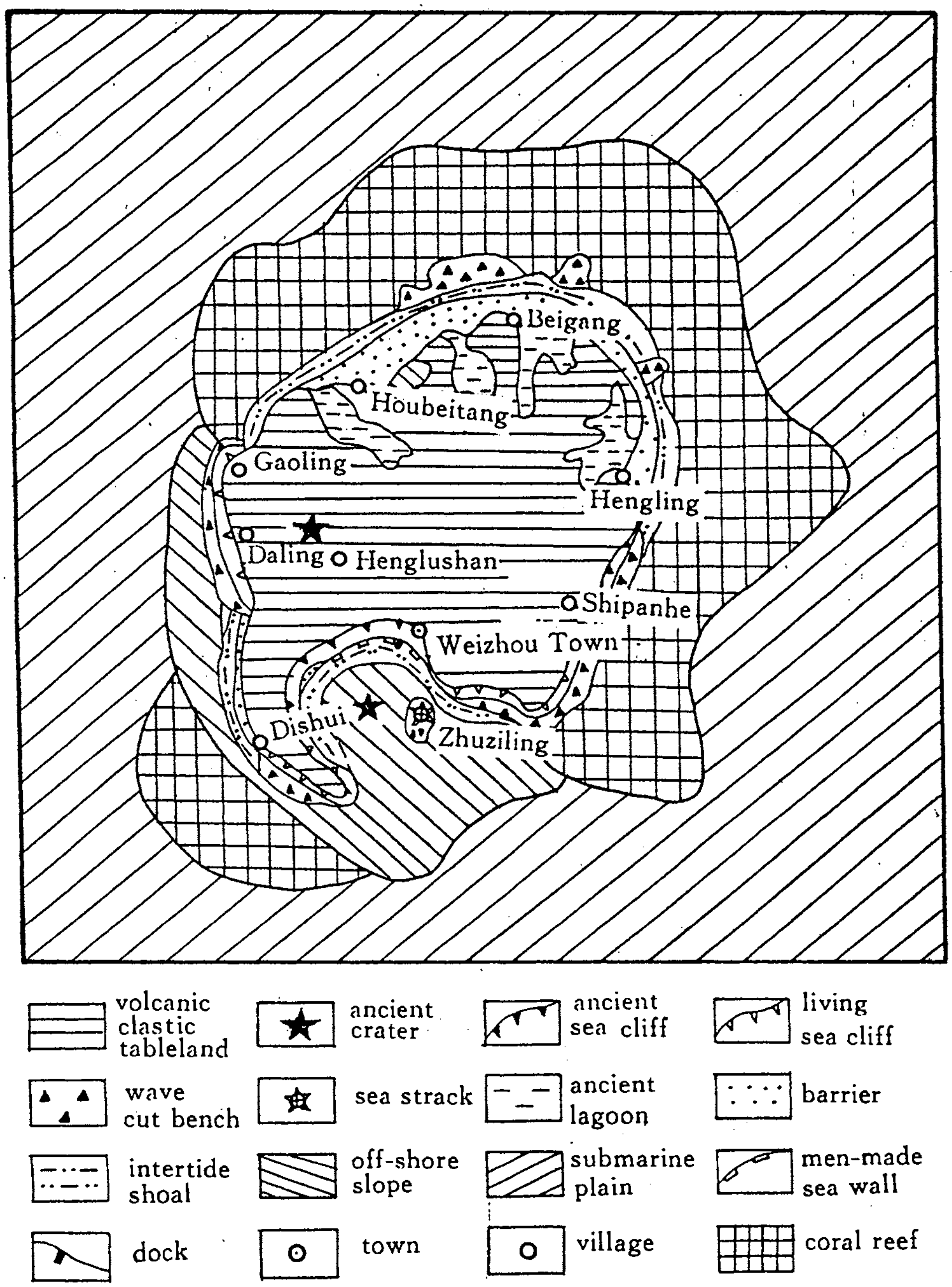

Fig. 1 Morphological types from the Weizhou Island

ancient crater by the erosion on the morphology. Because, grain size of the pyroclastic rock from Nanwan Bay coast is coarser than other area. In its sea chiff of the eastern side and western side, there is a layer agglonerate volcanic breccia and agglonerate with metres to tens metres in thickness. And a great quantity volcanic ash and volcanic bomb of various shapes is distributed in the steep and the beach. There fore, inferring a crater exists in the Nanwan Bay.

Henglushan Crater It is in small hill of 600m approximately in the northwest of the Henglushan, Weizhou Island. Topography of the hill is higher relatively, 52.6m above sea level; it exposed basalt of the second eruption in the third cycle, a circumference of 200m, geomorphology, it is similar to a shield volcanic cone. Owing to weathered denudation and vegetation covering, feature of the crater have been not obvious.

3. Sea cliffs

sea cliff may divided into two kind: the first, ancient sea cliff not suffered nowday erosion action by wave, the second, living sea cliff yet suffered nowday erosion action by wave.

Ancient sea chiff It is distributed in a zone of Nanwan street in the nouth shore from Nanwan Bay, the steep is 20-50m high, ext end2-3km length, cliff is generally stand erect, the part is a steep slope, top and feet of cliff turning gently. Traces of the marine erosion remained in the cliff, for example, distributing various big or small sea caves, the feet of ancient sea cliff linked with abrasion terrace, it has not suffered newday action by wave.

Living sea cliff It distributed in the coast of the Gaoling to Shiluobei, Dishui to Huashiju, Zhuziling to Wanzi, its steep is 10-50m high, genarally 20-30m, formed cliff stand erect and distributing various big or small sea cavse. Upper part grow cactuses and other plant, top and feet of cliff turning obviously, at present feet of cliff is eroded yet by the sea wave, appearing larger sea caves in scale (for excmpl, Tongtian cave), the part place collapssing phenomenon usually owing to gravitative process.

4. Sea stack

Sea stack is called also sea residual hill or an isolate peak. Zhuziling ridge in eastern side of Nanwan Bay is a large-scale sea stack. This stack is 27.8m high, on all around formed sea cliff, its height reaches 25m, under the southern steep due to long-term eroding by the wave and developed broad wave out bench of 70-80m wide. The top of sea stack grows cactuses and weeds and trees.

5. Wave cut benches

Wave cut benches form generally in the forward fringe of sea cliff. For example, under the steep of the Shipantan, Wanzijiao, Zhuziling, Jiaokong, Shiluobei, Gaoling and the others distribute all wave cut bench. In the south of the Shipantan, wave cut bench is wider, 200-300m wide. Owning to the bench surface is just level rock strata, therefore, wave cut bench of this a zone is comparatively smooth, there are not sediment is the bench, the southern bench is specially obvious. On the bench of the Shipantan, Zhuziling, Jiaokeng, and so on are piled all up large piece of rock from the sea cliff collaped down.

6. Lagoons

Lagoon distributed in the coast of the Weizhou Island are all ancient lagoon wich is without sea water to enter. They appeares mainly in the north and northeast of this island, such as Hengling, Beigang, Suniujiaokeng, Houbeitang, Xijiao and so on, its a side toward sea link generally with barrier, plane shape is in finger extend into inland and is bounded on the pyroclastic tabeland, the bounded place is offen steep bank. Ancient lagoon extends approximately 900-1500m long and 100-600m wide, 3-5m in height. Ancient lagoons have been opened all out cultivated land. Its sedimeut consist of sandy-clay and ages belong to the Mid-Late Holocene.

7. Barriers

Barrieres develop mainly in the coast of the Hengling-Suniujiaokeng-Beigang-Xijiao and so on, according to the bariers morphology and position and its formed ages may be divided into two kinds: old barriers and new ones.

Old barrieres They distribute mainly in the inside of new bariers of Suniujiaokeng, Houbeitang, Xijiao, Hengling and so on, such so forward margins of ancient lagoon link with the inner margin of new barriers. Old barrieres extend approximately 500-1600m long, 40-300m wide, 4-7m in height. Their surface due to the wind sways long thime, the barrier altered their original state, fomed uneven sand stacks and dunes, growing plant on the barrieres. The upper of old barrier is light-yellow, greyish-gellow midfine sand, mid-coarse sand, with a small amount shell stritus and coral clastic. The lower is greyish-white beach rock with fine sand coral clastic and shell setrilus. On the basis of C^{14} dating of coral clastic beach rock from the old barriers, their age is 6900±100a B.P. to 3100±166a B.P.. This proved old barriers to form in Mid-Holocene.

New barriers They distribute mainly in the coast of the east, north, Xiashiluo to Dishui of west etc. Their inner margins link with old barriers and even cover on them, out margins link closely with beaches. New barriers is generally 2-5m in height, and is often low gently ridges of smaller in scale, both sides slope gently, a side near sea are washed part by wave into steep bank. New barriers extends approximatly 50-1200m long, 20-250m wide. Its upper is white mid-fine sand, mid-coarse sand with a large number coral clastic and a small number shell; lower is bioclastic beach rock. On the basis of the C^{14} dating of coral clastic beach rock from the new barriers, their age is 2295±170a B.P. to 1290±80a B. P. . This proved new bvarriers to form in Late Hlolcene.

8. Intertide shoals

Intertide shoals develop mainly in the coast of east, north, south-west, Nanwan Bay etc. They are generally 50-200m wide, its widest places reach 400 to 700m, such as coast shoals in Beigang. The slope of intertide shoal is steeper near shore, 10°-15° slope toward sea change gently, 5°-6° slope. Sediment composition in the intertide shoal of the Nanwan Bay and southwest takes terrigenous clastics as the dominant factor, bioclastric comes second. In the coast of north and east, sediments of the intertide shoal take bioclastic as the dominant factor, terrigenous clastic cones second.

9. Coral Reef geomorphy

In the Weizhou Island, coral reef coast very develops. Coral is growing on well in the east and nouth and southwest, whereas, without coral reef distributes in the coast of west and Nanwan Bay. This island reef body is wider in the coast of northern Beigang to Houbeitang, reef flat reaches 1000m wide, coral growing zone 600m, belong to piled up coast. In a zone of Shipan river from the east, reef flat links with wave cut bench. In the coast of Daling of the west, due to wave erosion strongty is unfavourable to coral growing, reef flat outside the wave cut bench is only 10-20m wide, beling to eroded coast. In the southwest, Dishui coast lies whereas between two, belong to eroded and piled coast alternately, the seasonal change result from the wind direction and the strength of the wave and appear alternate phenomenon ofthe erosion and accumulution. Off-shore slope is approximately 200m wide, below it, there are reef flat and coral growing zone.

Reef flat of this island is in the water depth 2-4m of the toward shore side of coral growing zone(Wang et al 1987). Its toward land side is generally with sloping shape in a transition to beach, out margings of reef flat is gentl, without obvious a turn, reef flat without appears also water surface when low tide. Bottom of reef body consits of sandy sediment and with reef piece of original place growing. Coral growing zone distributes within the water depth 3.5-10.5m(Wang et al 1987). Its genuses or species have mainly: Acropora surculosa, A. prostrate, Monlipora ramosa, Porites, Goniastrea, Favites, povona etc.

10. Off-shore slope

Off-shore slope distributes in the low tide line to 15m water depth around the sea area of Weizhou Island, it is 200-1500m wide. In the north and east owing to develop coral reef but alterate off-shore slope into narrow, only 200-500m wide. In the south and west, it is wider, 500-1500m wide sediments of the surface lager in the off-shore slope is covered by mud-sand, toward sea side whereas turm into mud deposition.

11. Submarine Plain

Submarine plain distributes widely on the outside of water depth 15m or 20m sea area around the Weizhou Island, smooth and wide, with a slope of 0.1‰ to 1.0‰. surface sediment in the submarine plain consists of the grey, green-grey silty clay, clayey silt and sand-silt-clay.

12. Arlifocial morphology

Arlifocical morphologies appeare only in the coast of Nanwan, they have mainly men-made sea-walls and docks.

FEATURES OF THE SUBMARINE SEDIMENTARY COMPONENT

Features of the submarine sediment around the sea area of Weizhou Island aer passed through to analyse submarine surface sediment in the grain size, heavy mineral, micropateontology, and expounded its component characteristic and distributive regularity.

1. Sedimentary types

According to the grain size analytical result of submarine sediment, making known the submarine sediment types aroumd the sea area of Weizhou Island may be divided into five kinds:coralsand, clayey sand, clayey silt, Sand-Silt-Clay, silty clay, such as Fig. 2 appeared.

(1) Coral sand

Coral sand distributes in the eastern, northern, southwestern sea area of Weizhou Island, in the range of water depth 2-12m. Its rock reef is built on the basic bottom of volcanic rock. Most of the reefbuilding coral are massive colong which form the framework of the reef, and the branching corals only have a secondary position. Composition of the sedimentary coarse components from reef coral area cosists of the coral clastics, shell clastics, rock clastics, foraminiferal clastics, algae clastics, arthropod clastics and others. Among them, shell chastics take the first place, coral clastics second, rock clastics third, their content respectively for 41.5%, 35.11%, 18.50%, of the lotal quantity, the others are fewer very. But, in the reef rock faices of the original place, coral clastecs the first place, shell clastics second.

(2)Clayey sand

In the coast of west and Nanwan Bay, clayey sands distributes inshore betteew 0-15m water depth, there are odd pieces of distribution in the part region of the 15-20m water depth from the southeart and north. In this sediment, greyish-yellow, light grey mid-sand take the premier place. Its content is 35%-45%, clay second, 22%-38%, silt third, 11%, with a small amount grevel, coarse sand and shell sertritus.

(3)Clayey silt

Clayey sand distributes only in the marine region of the north of 15m or 20m water depth. This sediment assume greyish-green, bluegrey, contents of silt take 48%, clay 40%, sand 12%.

(4)Sand-Silt-Clay

This type distributes in the sea area betteew 15-20m isobath of the north and on the outside of 20m water depth of the east and south. Sediments with grey, light grey, greyish-yellow, contents of sand take 34%, silt 25%, clay 40%, and with a small amount complete shell and shell setritus.

(5)Silty Clay

Silty Clay distributes widely in the water bettew 15-20m isobath from te west and east and south east of Weizhou Island. This sediment assumes yellow-grey, light-grey, greyey-green, contents of clay is generally betteew 50%-60%, the highest reachs 65%, silt around 38%, sand about 5%.

2. Clastic heavy minerals

Contents of the clastic heavy mineral from the submarine sediment of Weizhou Island water according to anatysing and identifing result for two grain size grade of 0.25-0.125mm and 0.125-0.063mm, indicated seven kinds of the terrigenous clastic heavy minerals: ilmenite, fourmatine, zircon, marcasite, anatase, amphihole, epidote etc, three kinds of authigenic heavy mineral: glauconite, chlorite, pyrite etc.

Distribution of the terrigenous clastic heavy mineral parallels overall with coast, its content inshore water take 0.2-1.0%, toward offshore water

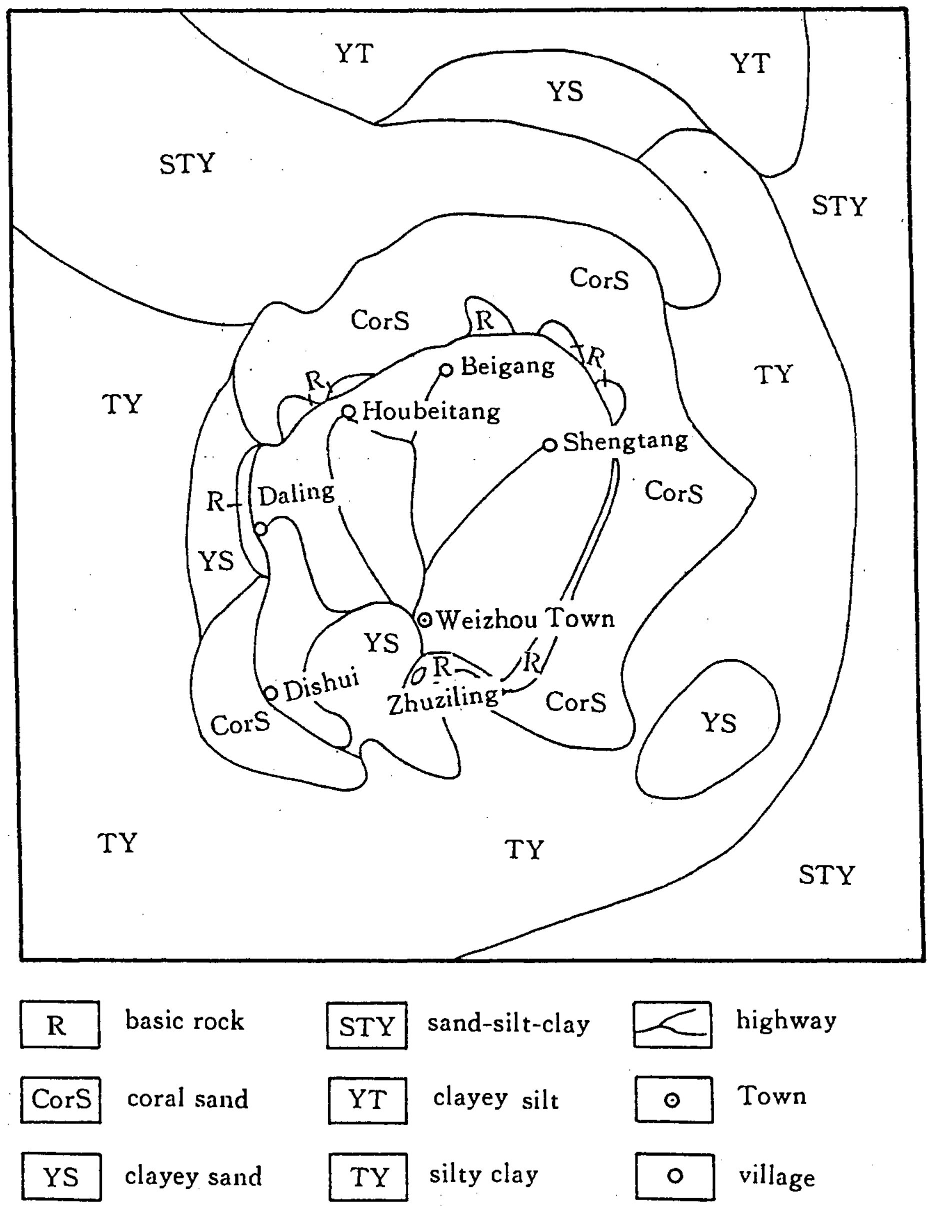

Fig. 2 Types of surface sediment from the Weizhou Island sea area

reduce gradually, shallow sea is less than 0.5%, formed feature inshor is high than offshor water. But, the part is some rise or fall, content of terrigenous clastic heavg mineral is no more than 1%. This has closely relations with terrigenous condition. Owing to the Weizhou Island encircle the water, its area only has 24.98km², without perennial river flows into sea, material originated from the terrigenous clastic is lesser, mainly from the material of wave eroding bedrock coast, terrigenous csastics is poor, kind of the clastic heavy mineral is monotonous, its content is lower. This is one of sedimentary compositional characters in the Weizhou Island warter.

Authigenic heavy mineral, glauconites distribute widely in Weizhou Island, its general trend of distribution is contrary to clastic heavy mineral, emerge content inshor water is low, offshore high, sandy sedimentary region is low, mud region is high. The rest, chlorite and pyrite distributed also very widely in the fine praticulate sediment region from Weizhou Island water. For this the heavy mineral from Weizhou Island water ae named as amphihole-glauconite-pyrite assemblage region.

3. Characteristic of foraminiferal distrilation

The coast water of Weizhou Island according to sedimentary environment, sediments, water depth and charactoristic of foraminifera abundance and assemblage, may be divided up two foraminifera assemblage zones.

(1) ***Pararotalia arata- Triloculina trigonula- Poroeponides cribroepondus*** assenblage zone

The assemblage distributed in the coral reef sedimentary enironmental area generally water depth below 15m, suffered effect by common action of the wave and tide and current, its sediments are bioclastic with sand, coral and shell castic take main composition, sand and rock clastic second. The number of foraminifera contained generally in 50g of dry sediment hundreds to thousands foraminifera tests, with more than 10000 tests in the individual location and with 6550 tests on average. The dominat species of the assemblage is obvious, the species number per sample with 15-60, with 35 on average, among them, genera or speies amounted to more than 10% of the tolal fauna have: Pararotalia amarta (d'Orbigny), ***Triloculina trigonuta*** (Lamarck), ***Poroeponides cribroepondus*** (Asano et vchioj), ***Ammonia beccorri vars, Schackoinella globosa*** (Millett), etc. Another important characteristic is with larger foraminitera of a certain number tropical species, generally take 1.64%-13.2% of the tolal fauna, 5.55% on averge, its genera or species are mainly ***Amphisteging sp.Heherostegina depressa, Peneroplis spanalas, Dendrilina sp*** etc. The assemblage is with characteristic of biocastic sedimentary environment of the tropical, subtropical coral reef.

(2) ***Schackoinella globora-Ammonia compressiuscula*** assemblage zone

This assemblage distributed in the shallow sea area of 15-30m water depth from the Weizhou Island coast, suffered effect by tide current and adverse hour hand circular current from the Beibu Gulf, Salinity is range of 30-33‰, sediment is silty mud. Content of foraminifera is rich quite, per 50g of dry sediment contains a few thousands to twenty thousands foraminiferal tests, with 9680 tests on average. Its dominant species is obvious, diversity is high, per 50g of sediment with 30-60 species, with 45 species on averge. ***Shackoinella globosa*** occupies dominator, takes 45.41% of the tolal fauna, the rest characteristic species have yet: ***Ammonia compressiuscula*** (Brady); ***A.pauciloculata*** (phleger and parker), ***Ephidium advenum*** Cushman, ***E.asiatium*** polski, ***E.magelanicum*** (Heron-Allen and Earland), ***Florilus decorus*** (Cushmanet Mc Culloch), ***Hanzawaia nipponica*** Asano, ***Brizalina stratala*** (Cushman), ***Cararotalia annectens*** (Parker and Jones), ***Lagena, Textularia foliace*** Heron-Allen et Earland, ***Bigenerina taiwanensis*** (Nokamura) and so on; yet ***Globigerinodes sacculifer*** of the small amount little individual. This assenblage reflects the feature of foraminifera fauna of the fine particulat sedimeut in shallow sea area from the Weizhou Island coast.

DISCUSSION OF THE SOURCE AND MOVEMENT OF SEDIMENTS

The movement of sediment depend on the source of sediment and hydrodynamic condition and topography, geomorphology, the weizhou Island is encircled by the water on all sides, around island without any screen. Therefor, southern to south western winds from the Beibu Gulf and its arousing wave are main dynamic modeled geomorphy. In the Nonwan Bay and Gaoling coast formed cliff reachs 50-60n high, constituted eroding strongly coast, in the coast of Houbeitang-Beigang-Gong-shanbei-Hengling of north to northeast, fromed sandy and bioclastic piled coast, slope gentle, beach rock develops relatively, toward sea incline, thickness 5-6m. This is typical coast of the erosion in the south and piling up in north. In the intertide zone of southeast, bedrock appeares yet belongs to eroding coast. In the coast of the Dishui Village to Xiashiluo of southwest, owing to seasonal change of the wind direction and wave strength enable the beach to appear superseding phenomenon of erosion and piling, by, named as eroding and piling coast.

As precedent relaled, there is no perennial river the Weizhou Island, only Shipan river, this a intermittent seasonal little river empties imto sea. The coast sediment originate mainly from the eroding coast of volcanic rock and coral growing zone and reef flat, but surface runoff carrying sediment is lesser. Thus it is seen that, in the south and west coast, sediment of the wave eroded down is transporsed to northern and eastern coast by the tide current, along the coast current. At the same time, bioclastic from the coral growing zone and reef flat zone of the northern and eastern coast is transported toward shore by the wave, current.

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METALS IN THE ATMOSPHERE OVER THE WESTERN TAIWAN STRAIT

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ABSTRACT

One hundred and eighty one aerosol samples, and two cascade impactor samples were collected in the atmosphere over the Xiamen waters from 1991 to 1993. Concentrations of Al, Fe, Cu, Pb, Cd, and Na were determined by an atomic absorption spectrophotometry.

The contents of Fe, Cu, Pb, Cd in the atmosphere over the Xiamen waters are lower than those over inland cities in China, in Europe or in North America. Annual and seasonal variations of concentrations of the metals can be primarily attributed to washout or monsoon for non sea salt metals. Fe presents in bimodel distributions with size around 3.6μm and 0.52μm, Al was chiefly distributed on the particles with size > 2.1μm, Na on the particles with size ≥3.6μm, and the size distribution of Cu, Pb, Cd were presented in small particles, chiefly on the particles with size ≤ 0.52μm.

INTRODUCTION

The attention to the study of metals in the marine aerosol particulates is increasing due to their environmental ecological effect and contribution to the biogeochemical cycle. In the aspect and the environmental ecological effect, first, on the side of climate, aerosols with metals can act as cloud condensation or ice nuclei, absorb and scatter solar radiation, affect the radiation budget on the earth. The relatively high iron content (5%) of the dust can absorb the short wave length radiation efficiently. Second, on the side of ecological effect, dissolved Al serves itself as toxicant to fish in some concentration range, and its content and distribution is associated with the action of marine organism (Chen G. Z., 1990). Iron limitation of phytoplankton was postulated as the reason for the high nutrient (N, P), but low phytoplankton concentrations offshore in the subarctic and equatorial Pacific as well as the circumpolar southern ocean (Martine 1990).

The atmosphere over coastal regions is a transition zone between the Continent and the ocean, which is regard as a good site to study the processes of air-sea exchange. The sampling site is located at Xiamen, western Taiwan Strait, China. The concentrations of Fe, Cu, Pb, Cd, Na, Al in area 200 aerosol samples collected from 1991 to 1993 were determined. Long-term sampling and the analysis of the large quantities of the aerosols are beneficial to better understand the metals in the atmosphere over the western Taiwan Strait: their contents, pollution indexes, sources, transportation and the effect of the air-sea exchange.

EXPERIMENTAL

Site and Method

Site

The sampling station was located on the southeastern coast of Xiamen Island at 24°16'14"N and 18°5'25"E(Chen et al.,1993). A model 241 high volume air particle sampler with wind control was used to collect aerosols in the marine atmosphere. The sampling head was 10M above the sea level. The average collected time for each sample was about 35.8 h, and the average sampling volume was $1500M^3$. The effective annual sampling duration was 2639h, which covers 30% of the year duration. A Sierra 235 cascade impactor was also used to seasonally collect size-separated particles samples. A size separated sample has 7 stages. The medium of particles size for each stage is: stage 1=17 µm, stage 2=9.8µm, stage 3=3.6 µm, stage 4=2.1 µm, stage 5=1.0 µm, stage 6=0.5 µm, stage 7=0.52 µm . The effecting period was from 1991 to 1993, and the filter was Whatman 41.

Chemical Analysis

The dissolution of the solid matrixes was carried out in Tefflon digestion vessels. A quantitative area of a filter sample were inserted into the vessel. Concentrated suprapure HNO_3 and HF were used to digested the metals completely. After digestion, the coarserate colloid is dissolved with 1% HNO_3 to a fixed volume. The digested solution was used to determine Al, Pb, Cu, Fe, and Cd by Graphite Furnace Atomic Absorption Spectrometry (Yu, 1990,1991). Then, the digested solution with CsCl matrix compressor was used to determine Na by Flame Atomic Absorption spectrometry (Wei and Qu 1988).

RESULTS AND DISCUSSION

Concentration and variations of trace metals

Concentrations of the trace metals

The ranges and averages of the concentration of the trace metals in the atmosphere over Xiamen were calculated based on 181 aerosol samples from 1991 to 1993. The results are presented in Table 1 with the data of other regions for comparison.

Table 1. Concentrations of Atmospheric Metals in Xiamen and Other Regions for Comparison*, **

Site	Fe $\mu g/m^3$	Cu ng/m^3	Pb ng/m^3	Cd ng/m^3	Al $\mu g/m^3$	NA $\mu g/m^3$
Xiamen	0.76 (0.030-2.18)	9.63 (0.11-26.64)	67.4 (0.53-245.6)	0.83 (0.016-3.7)	2.95 (0.19-13.3)	15.3 (2.04-38.4)
Beijing	8.9	34	560	1-3	19	
North America	3.6	280	2700	<1-41	2	
Europe	1.4	340	120	0.5-620	0.6	
Antarctic	0.00084	0.036	0.5	<0.015	0.00008	

* Data of other regions from Liao (1992)
** Data in parenthesis is the concentration range of metals

The contents of Fe, Cu, Pb, Cd in the atmosphere over Xiamen were lower than those in inland cities in China and those in Europe and North America. The content of Al was higher than that in North America and Europe, but lower than that in inland cities in China. The lower contents of Pb, Cd, Fe, Cu in the atmosphere over Xiamen would indicate their from the relatively low sources. As Asia is being eroded much more rapidly than the other continents (Holland 1978), and Al is the major component of soil, the content of atmospheric Al in Xiamen is higher than those in Europe and America but Xiamen is far from the loess regions in China, so the concentration of atmospheric Al in Xiamen was lower than that in inland cities in China.

Trend of concentration changes for 3 years

Fe, Cd, and Na in annual mean values showed no remarkable change in annual mean concentrations for 3 year observations. The content of Al increased with year. The reason for it may be from two aspects. One is pollution with the development of Al industry. The other is soil erosion from Xiamen and dust transportation from North China. The strengths of crustal weathering and dust transport changed from year to year (Duce 1980, Hitoshi et al 1989). The increasement of soil weathering with the development of construction industry and dust transport from inland may result in the increasement of Al. Pb had a tendency to increase, the peak value was in 1992. Pb is primarily from automotive exhaust and coal combustion (Maring et al 1990, Liao 1992). The increase of the number of automobile in Xiamen and uncompleted combustion made the increase of Pb to peak value in 1992, and with the use of liquefied petroleum gases, coal gas and non-leaded petroleum, the content of Pb decreased remarkably in 1993. Cu showed no great change, but with a peak value in 1992, which may be related to the fuel conversion.

Characteristics of seasonal variations

Like annual variation, Na in monthly mean values did not change seasonally so much. But, Al, Fe, Cu, Pb, Cd in May, June, July, Aug, and Sep were lower than those in other months, and the curves in May, June, July and Aug, and Sep are down convex.

The contents of Al, Fe, Cu, Pb and Cd in the months with high concentrations rose and fell unsteadily. In General, the concentrations of Al, Fe, Cu, Pb and Cd in marine aerosols over the Xiamen waters appear seasonal variations, with a sequence of winter > spring and autumn > summer. The reasons for the metals characteristics of seasonal variation will be discussed in more detail in the following section.

Size distribution

The distributions of the concentration percentage in each size stage are listed in Table 2. For Fe, there are two peaks at stage 7 and stage 3, and no much difference between the concentration percentage of large particles and small particles that would suggest that Fe was not only from natural source, but also pollution. The high value of 60.9% occupied by small particles in winter sample reflects the source of pollution for Fe.

Table 2. Distributions of Concentration Percentage

Sample	Fe			Cu			Pb			Cd			Na			Al		
No	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
91.1	60.9	10.2	28.9	74.6	2.6	22.4	96.5	2.3	4.1	97.1	1.7	1.2	40.7	5.8	56.5	43.6	14.0	42.5
91.7	46.6	16.9	36.3	68.7	6.8	24.5	86.3	3.9	9.8	95.8	1.8	2.5	18.6	6.4	75.0			

S: Small particles with size < 2.1 μm
M:Medial particles with size = 2.1μm
L: Large particles with size > 2.1 μm.

In dry season, curves of the distribution of the concentration percentage fro Cu go gently on stage 1 to 6 with abrupt peak values for Cu on stage 7. The content of Cu with size ≤ 0.52μm greater than 60% indicate large amount of pollutant source. But, in wet season there is a small peak appearing on stage 3, suggesting that portion of Cu in the marine aerosol over Xiamen waters would derive from mineral dust. Based on the EF_{Cu} to EF_{Al} is within the range of 1 to 10 in the non-size-separated samples. Apparently, the value of EF is related to the size-separated sampling. The values of EF for an element in the aerosol depend not only on the chemical factor of the pollution air but also on the physical condition of sampling.

The distribution of the concentration percentage for Pb was similar to that for Cu with much low values in stage 1-6, and a remarkable peak values in stage 7. The content of Pb in small particles was greater than 80%, and 90% for Cd. Majority of Pb, Cd distributed at the range of size ≤1.0 μm, chiefly at range of size ≤0.52μm.

Na was mainly distributed on stage 1 to 3 with size ≥3.6 μm. Al was mainly distributed in stage 1-6 with the minimum lower than 5% on stage 7. The content in large particles was nearly equal to that in small particles. If we consider the transition zone between the large particles and the small particles, the contents of small particle rise as the large particles deposit and remove from the air during the long term transportation.

In general, the size distribution of Fe was present in double mode, Al was chiefly distribution on stage 2-5, Na was chiefly distributed on the particles with size ≥3.6μm, Cu, Pb, Cd were chiefly distributed on the particles with size ≤ 0.52 μm.

Reasons for features of seasonal variations

Meteorology

Meteorology is a significant factor which affects the distribution and transportation of metals in the atmosphere. The rainfall from May to Sep accounts for the major part of the annual rainfall, and in June the rainfall reach its maximum. Corresponding to the rainfall variation, the contents of heavy metals had low level during the period of May to Sep, high level during the period of Oct to Feb next year, and reached their minimum in June. Apparently, rain washout is the important factor which affects the contents of heavy metals in the atmosphere over Xiamen waters. Based on the feature of precipitation in Xiamen as well as Taiwan Strait, dry season begins in October and ends in March next year, rain season begin in April and ends in September. Therefore, the heavy metals the atmosphere over Xiamen waters have the remarkable characteristics of dry and wet seasonal variation. So, we think the concentrations of the heavy metals Fe, Cu, Pb, Cd, and Al in the atmosphere over Xiamen have the feature of dry and wet seasonal variation with the contents in dry season higher than those in wet season.

Rain washout removes the metals from the atmosphere. Air currents accelerate the diffusion and redistribution of the metals in aerosols. Wind speed and wind direction reflect the strength and source of the wind. The wind direction in Xiamen has the remarkable feature of seasonal variation as the result of monsoon and the effect of the topography of the Taiwan Strait. In winter and autumn, wind is primarily from the north to east sector, with the northeast wind as the prevailing wind. In summer wind is primarily from the SE-SSW sector, with the southeast wind as the prevailing wind. Spring is the transitional season between winter and summer, southeast wind and northeast wind are the prevailing wind and present alternately as the result of the interaction between the south and north climate system (Cai 1994, A survey of Chinese gulfs 1993). In the aspect of the air mass trajectories, as the effect of cold high pressure in the north of

Asia in autumn and winter, air masses travel through the large areas of North China, then move eastward over the whole east sea. take the form of pipe-shape in the specific topography of the Taiwan Strait, at least, the western Taiwan Strait with E-E sector, and northeast as the prevailing wind direction(Chen W. M., 1990). Cold air masses in autumn and winter carried the loess dust and anthropogenic pollution emitted from the industry and living areas to Xiamen by long range transportation of pollutants, reach Xiamen primarily with southeast direction. This is another reason for the low concentrations of Al, Fe, Cu, Pb, Cd in the atmosphere over Xiamen waters.

The content of Na in the marine aerosol is related to the wind direction and velocity. As illustrated in Table 3 average monthly wind speeds show no great change with a little low level in summer. Wind whether from northeast or southeast, reach Xiamen over the sea. In the aspect of the large scale of the climate system, oceanic air currents carried by the southeast wind make up its low level wind speed. On the other hand, marine sources is the strong source for Na, thus the atmospheric Na shows no great seasonal variation.

Table 3. Average Monthly Wind Speed (m/s)*

Month	1	2	3	4	5	6	7	8	9	10	11	12
Mean	3.5	3.5	3.3	3.1	2.9	2.9	3.1	3.0	3.5	4.2	4.0	3.6

* Data from A survey of Chinese Gulfs, 1993

Effect of source

The anthropogenic pollution of Fe, Al are primarily from corresponding industry, but there are no big corresponding enterprises in Xiamen. The industries of chemistry, pharmacy, paint and synthetic rubber produce limited Al pollutant. Rust washing produces limited Fe pollutant, mineral dust from crustal weathering is the main source for atmospheric Fe, Al(Tang, 1989). Fe and Al in the atmosphere over Xiamen are not only from crustal weathering and the input of industrial pollutants in the Xiamen region, but also carried by the cold air masses in North China which bring about products of weathering and pollutants from industry and living.

Crustal weathering is the main natural source for Cu, metal processing and machine production bring about anthropogenic pollution.

Pb, Cd have low level abundance in crust, their sources are chiefly from human emission. The combustion of coal and oil will cause the increasement of Pb, Cd in the atmosphere. In winter, fuel exhaust leads to the high concentration of heavy metals in the atmosphere. The proportion between the contribution to atmospheric metals from the Xiamen region and the long range transportation over the western Taiwan Strait needs to be studied in the future.

CONCLUSIONS

The average contents of the metals in the atmosphere over Xiamen waters were: Fe, 0.76μg/m^3, Cu, 9.63ng/m^3 ,Pb, 67.4ng/m^3, Cd, 0.83ng/m^3, Al, 2.95μg/m^3, Na, 15.2μg/m^3. The concentrations of Pb, Cd, Fe, Cu were lower than those in inland cities in China and those in Europe and North America. The concentration of Al was lower than that in inland cities in China and similar to North America, but higher than that in Europe . There are no remarkable feature of Fe, Cd, Cu in the annual mean concentration changes for 3 years. The concentrations of Pb, Al have the tendency to increase.

The concentrations of Fe, Cu, Pb, Cd, and Al have the characteristics of seasonal variation in the sequence of winter>autumn and spring >summer, and dry season >wet season. The effects of rain washout and monsoon are the primary factors which result in the seasonal variation of these metals. The contents of Na shows no seasonal variation, wind direction and wind speed are the main factors which affecting the content of Na in the coastal area.

The size distribution of Fe was present in bimodel form, Al was chiefly distributed on the particles with size > 2.1μm, Na on the particles with size ≥3.6μm, and the size distribution of Cu, Pb, Cd were presented in small particles, chiefly on the particles with size ≤ 0.52μm.

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EROSION AND ACCUMULATION OF HUANGHE DELTA AND HUMAN IMPACT ON THEM

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ABSTRACT

The course of the Yellow River (Huanghe) has shifted 10 times since it migrated from the south of Shandong province to the North, discharging into the Bohai Sea in 1855. The latest shift of the river course happened in 1976. The new formed subdelta or delta lobe prograds seawards very fast and has protrudes seawards about 30 km. The abandoned subdeltas of 1953-1976 period have been roded strongly under sea waves and currents.

The coast erosion and accumulation is estimated by processing bathymetrie data of the near shore survey of 12 years. 3 major erosion centers and 1 major accumulation center are found. All of them correspond to the abandoned river mouths or current river mouth, respectively. About 100 km^2 of land has been eroded away. A fast prograding subdelta of about 300km^2 is accumulated.

Water and sediment discharges of the Yellow River to the sea are constantly decreasing in recent years, mostly due to increasing water consuming and water conservation constructions. No-waterflow days has increased from 2 days in 1971 to 133 days in 1996. Models for prediction of recent subdelta evolution are made, indicating the delta prograding rate will be decreasing in near future. The coast will get eroded stronger. A new minor change of the end channel was made in 1996 artificially Human impact on the Yellow River Delta Coast is enormous.

1. INTRODUCTION

The Yellow River (Huanghe) is the 2nd largest river in the world in terms of the sediment load into the sea with world highest suspended sediment concentration in its turbid water and highest deposition rate in its delta area. Huge amount of Huanghe sediment rapidly accumulates along the river channel of its downstream, especially in the estuary, creates fast prograding deltas and fills in the end channels as well as the river mouth. Therefore, the river course has to shift

Historically the Yellow river course has shifted many times (Fig.1). The latest major shift occurred in 1855, when he Yellow River course shifted from the south of Shandong province to its northern part into the Bohai Sea. Since then major shift of the river course happened 10 times, and a recent Yellow River Delta has formed (Fig. 2).

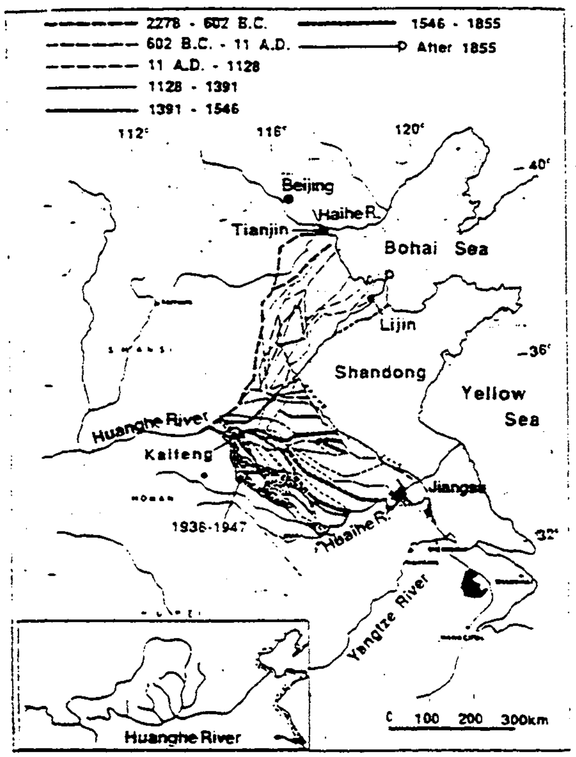

Fig. 1 Historical Shift of the Yellow River (Huanghe) course. After Y. Saito and Z-s Yang (1994).

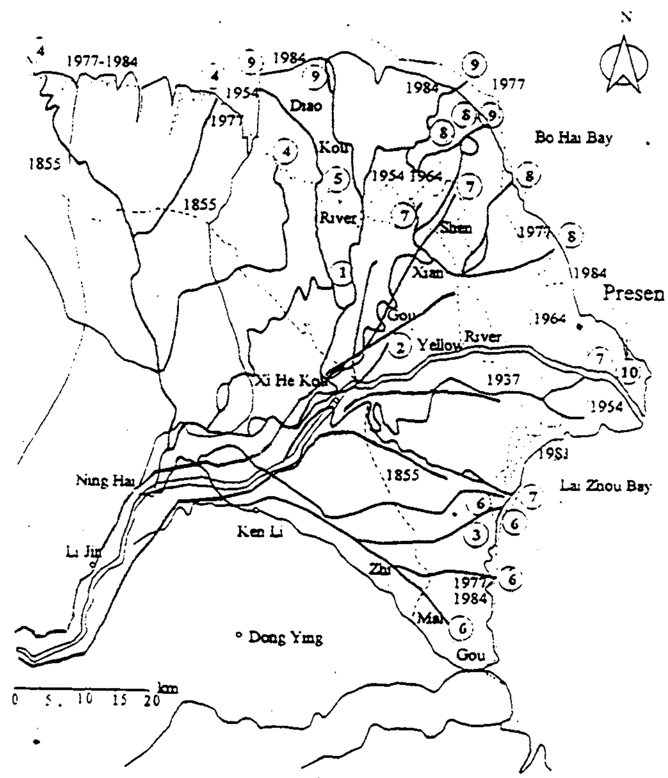

Fig. 2 Recent Yellow River (Huanghe) Delta and shifts of the river channel since 1855.

The latest minor shift happened in 1976 when the river course has changed from the northeast part to the east part of the Delta into the Laizhou bay. A new subdelta or delta lobe has formed by sediment accumulation around the Huanghe River mouth. It protrudes seaward about 30km with a prograding rate of about 1.5km/a (Fig. 3), while the abandoned sudeltas of 1953-1976 period have been eroded strongly under sea waves and currents. About 100km^2 of coastal land has been eroded away.

2. EVALUATION AND PREDICTION OF EROSION AND ACCUMULATION

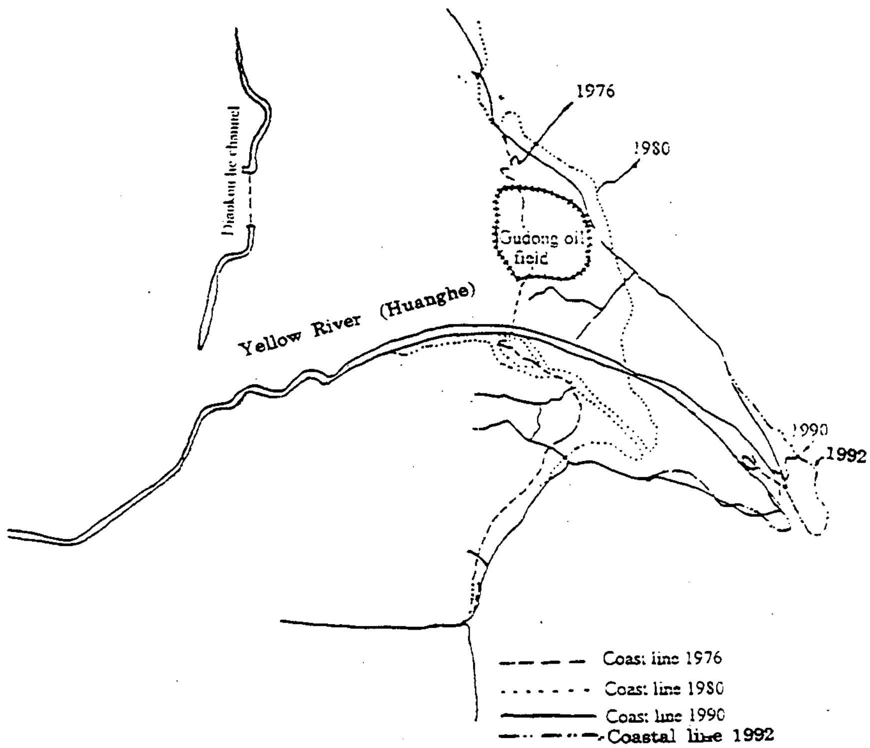

Fig. 3 Prograding of the modern Huanghe Delta from 1976–1992

Such strong erosion and fast accumulation of the Huanghe Delta coast is very unique for the coastal science and attract attention of many scientists. The annual average sediment discharge for over 50 years is about 1×10^9t. Pang and Shi (1980) indicated that about 2/3 of one billion ton of the Huanghe sediment was accumulated in the serial delta area and one 1/3 of it gets into the sea Bornhold et al. (1980), based on subbottom profile data, calculated that about 90% of Huanghe sediment to the seas is accumulated within 20 km from the Yellow River mouth. Chen (1990) according to the structure of strata of the subaerial delta and sediment discharge concluded that about 90% of sediment is accumulated for building the delta itself. Thus, they explained the reason of such fast prograding of the Delta. Qian et al. (1992) calculated sedimentation ratio of the Yellow River in the delta area during different period of the channel shift from 1953-1976. Fan and Guo (1992) used satellite images to evaluate the delta evolution and its prediction. Saito et al. (1994) calculated the sediment remained on land and the portion to the seas. Zhang et al. (1996, 1997), calculated the sediment portion carried to the seas based on its grain size and marine dynamic factors.

We used bathymetric data of 36 survey sections perpendicular to the coastal line of the Huanghe Delta in 12 years from 1976-1988 to evaluate the erosion and accumulation of the Yellow River Delta dynamically and quantitatively. For the 12 years sine the last minor shift of the Yellow river channel 3 erosion centers with score depth of more than 5 m have been formed in the northeast off the Delta. These 3 erosion centers are coincident to 3 river mouth bars or subdeltas of the river channel course in 1964, 1972 and 1976, respectively (Fig. 3 and Fig. 4). Totally, 4.733×10^9t of sediment has been eroded away. An accumulation center is formed the present river mouth area. The maximum thickness of the accumulation center is over 13 m. The accumulation center originally was in the North of present river mouth, but gradually moved southward, forming a new delta lobe sharper in its north side and larger in its south side (Fig. 4). The accumulation amount of sediment in the subaqueous area is 4.453×10^{9}t, totally, that means about 86% of the Yellow River sediment discharge is deposited in the subaerial Delta and its nearshore area.

A prediction of the Delta evolution bathymetric topography to 2000 year was made based on the erosion-accumulation process from 1976-1965 by neural network method. The prediction shows that 3 erosion centers will continually be eroded to depth of 6 m. The accumulation center with

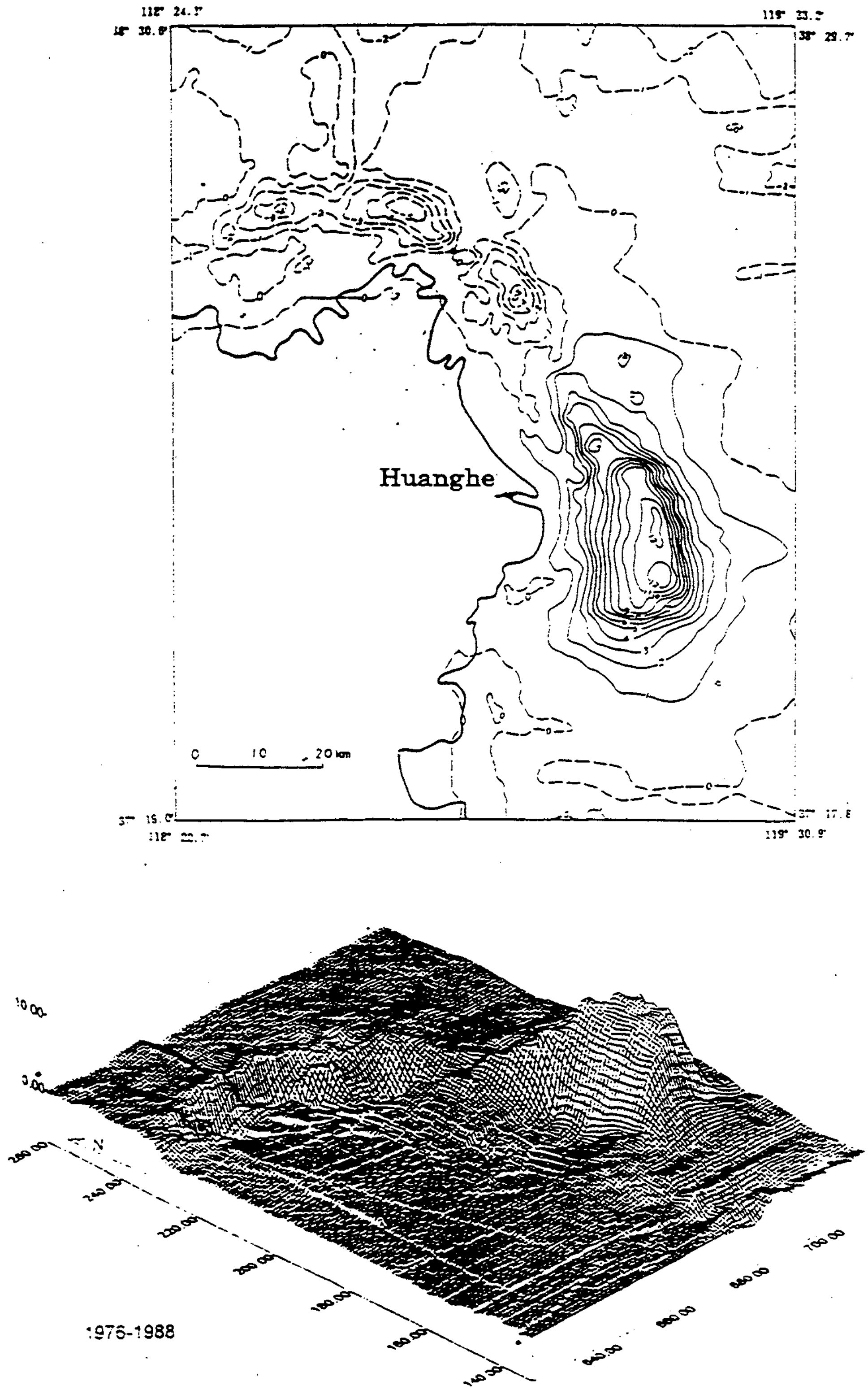

Fig. 4 Erosion and accumulation thickness of the Yellow River (Huanghe) Delta from 1976–1988.

maximum depth of more than 14 m will become larger and extend seawards more than 4 meters. This prediction shows the erosion and accumulation rate is decreasing.

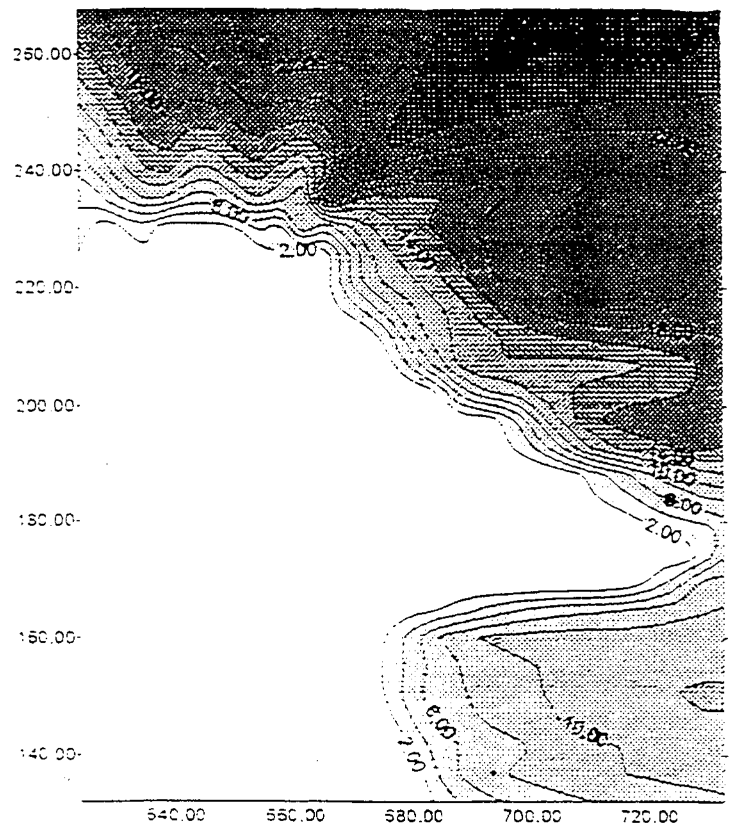

Fig. 5 Predicted isopath of bathymetry in 2000 in the Subagueous Yellow River (Huanghe) Delta by neural network method based on the bathymetric data from 1976–1988 in the area

3.HUMAN IMPACT ON DELTA EROSION AND ACCUMULATION

Water sediment discharges of the Yellow River Delta to the seas have constantly decreasing in recent years (Fig. 6, table 1). The increasing water consuming and water conservation construction are the main reasons (table 2). No-water discharges days has increased from 12 days in 1972 to 133 day in 1996 (Fig. 7). Therefore, the erosion rate will increase and accumulation rate will decrease. A prediction of coast line evolution based on sediment discharge statistics taken at Lijin gauge station of different period is made by gray system method. The prediction coast line based on sediment discharge from 1980-1989 has a lowest accumulation rate than that based on the statistic sediment data from previous years (Fig. 7). A new minor change of end channel near to the river mouth was made by human activities in 1996 for creating some long for oil drilling. Now the river mouth is directed northeastwards, but not southeastward as it was before. Therefore the erosion-accumulation pattern of the Yellow River Delta has been changed significantly. Human impact on the erosion and accumulation of the Yellow River Delta is enormous.

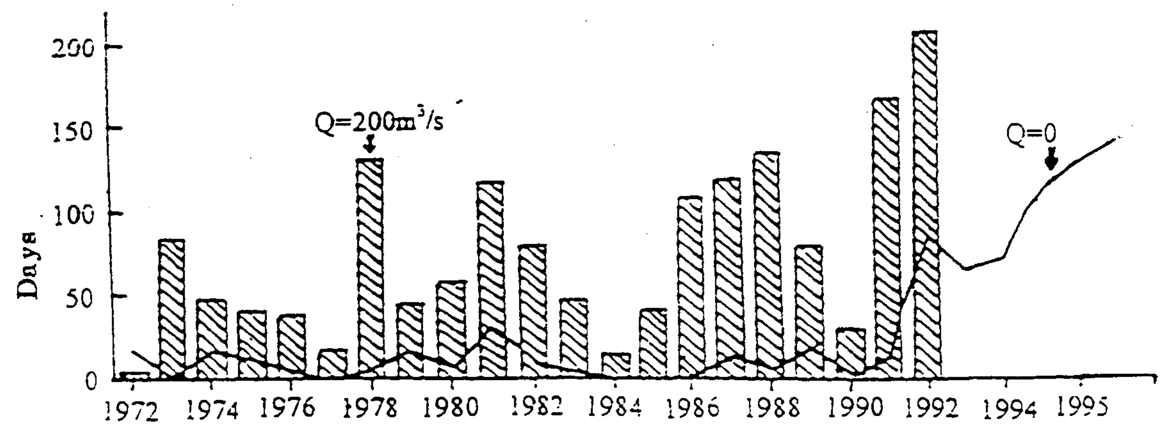

Fig. 6 No–waterdischarge–days (Q=0) and low–waterdischarge–days (Q<200m^3/s) at Lijin gauge station. Modified after Q–s Zhang

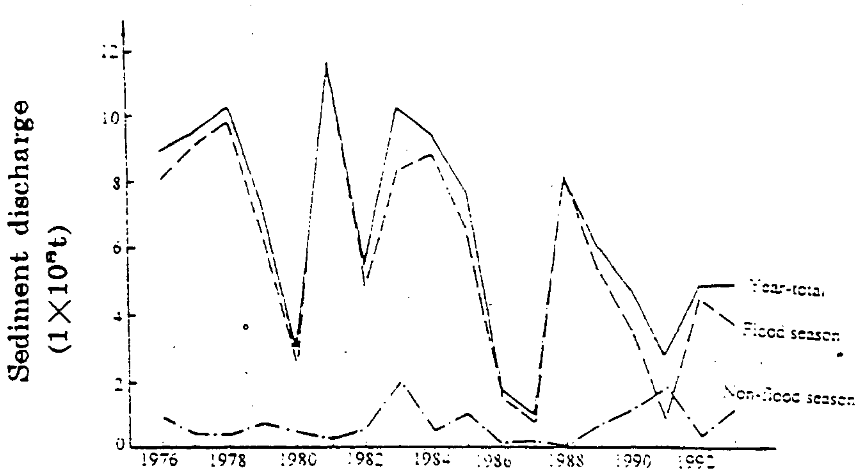

Fig. 7 Variation of sediment discharge of the Yellow River (Huanghe) into the Delta area since 1976 based on the data taking at Lijin gauge station.

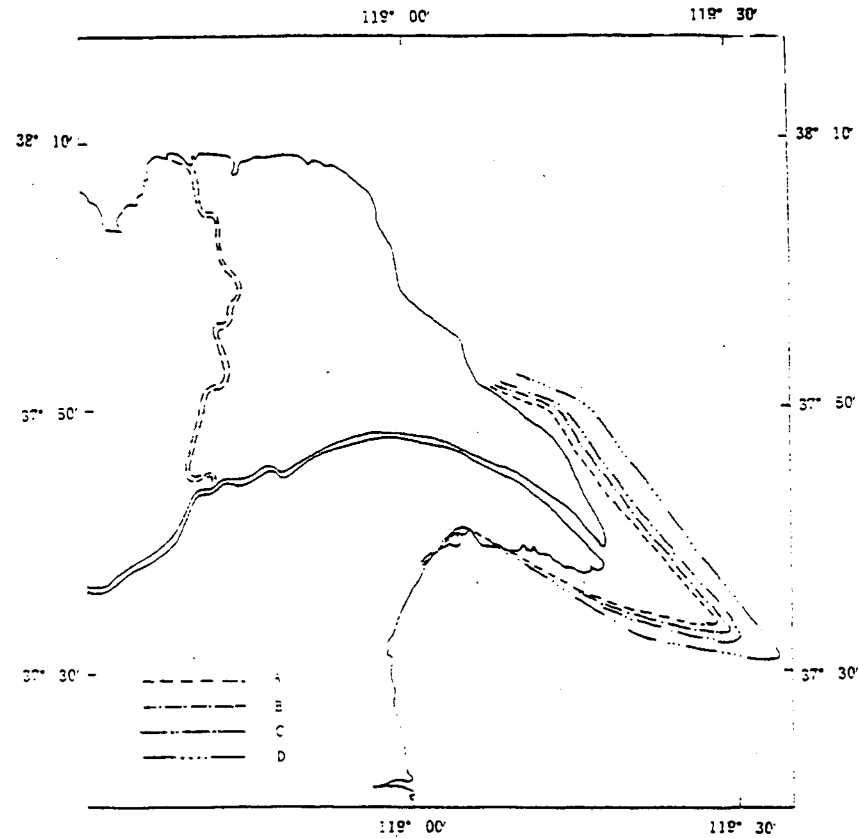

Fig. 8 Prediction of coastal line evolution of the modern Huanghe Delta to 2000y, based on average annual sediment discharge at Lijin station taken in different period.
A. 1980–1989 B. 1979–1989
C. 1970–1989 D. 1950–1989

Table 1 Allocation of the Yellow River Water Resources

Provinces (Autonomous regions)	Quota (billion m^3)	Water consumption (present level) (billion m^3)
Qinghai	1.41	
Sichuan	0.04	
Gansu	3.04	1.76
Ningxia	4.00	3.70
Inner Mongolia	5.86	6.00
Shanxi	3.30	2.50
Shaanxi	4.81	2.00
Henan	5.54	3.50
Shandong	7.00	8.00
Hebei and Tianjin	2.00	0.50
Total	37.00	27.96

Table 2 Sediment and water discharges of the Yellow River to its Delta area at different period of different period of different river course channel to the sea. Statistics at Lijin gauge station.

Name of channel	Period	Sediment load (1×10^9t/a)	Water runoff (1×10^9 m^3/a)
Shenxiangou channel	1953-1963 11 years	1.20	47.2
Diaokouhe	1964-1973 12 years	1.10	41.9
Qingshuigou (Recent)	1976-1992 17 years	0.66	26.7
(Qingshuigou)	1986-1992 7 years	0.41	17.0

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ARTIFICIAL REEF PLAN IN HARMONY WITH ECOSYSTEM AS A COASTAL CONSERVASION MEASURE -IN NAKABAYASHI FISHING PORT

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ABSTRACT

The coast of Nakabayashi fishing port is located in the northern-most of Murotoanan Kaigan National Park and is one of the best beach resorts in this area.

Although shoreline retreat is recently declining, submarine erosion is so active. Storm surge disasters due to bottom section decrease are, therefore, seriously concerned.

To cope with this problem, the integrated shore protection system as a counter measure against erosion was applied and the artificial reef plan in harmony with ecosystem was proposed, while this type of reef has no record yet in actual execution.

INTRODUCTION

1. Location:

The coast of Nakabayashi fishing port is located in the eastern part of Shikoku, facing Kisuidoh and in the northern-most of Murotoanan Kaigan National Park.

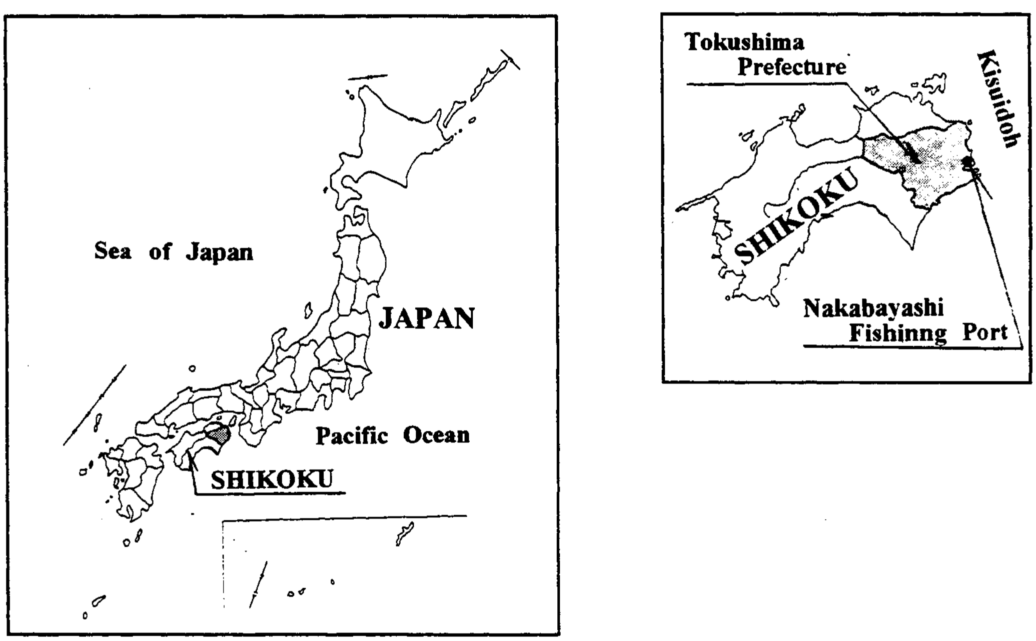


Fig.-1: Location Map

2. Topographic features;

(1) Curvature of coastline;

The coast as Project Site is a northern half part, 690m long out of Pocket Beach (Kitanowaki Kaigan) stretched to about 1,320m length. The radius of curvature is approximately 920m.

(2) Width of beach;

The sandy beach is about 30m wide on an average.

(3)Bottom slope, particle diameter of sediment;

The bottom slope is about 1/30 as far as 4m in water depth, and about 1/50 beyond that depth. The average particle diameter of sediments is 0.02 mm.

3. Beach utilization;

The coast of Nakayabashi fishing port is so familiar as one of the beast beach resorts in Tokushima Prefecture, characterizing the following points;

(1)The visitors are estimated to be 150,000 to 300,000 per year and mostly from Kei-Hanshin area.

(2)This beach resort area is most enjoyable by people for swimming and beautiful landscape, located in Murotoana Kaigan National Park.

(3) This resort is well equipped with the facilities such as parking lot, rest rooms, shower rooms, stands or shopping center and tourist homes.

4. Beach erosion;

Shoreline retreat shows max 12m during 43 years, and retreat phenomenon is not so remarkable along the whole shoreline. Bottom erosion is however, in progress as shown in Fig.-2, and shoreline position is deemed to be retreated after all in future.

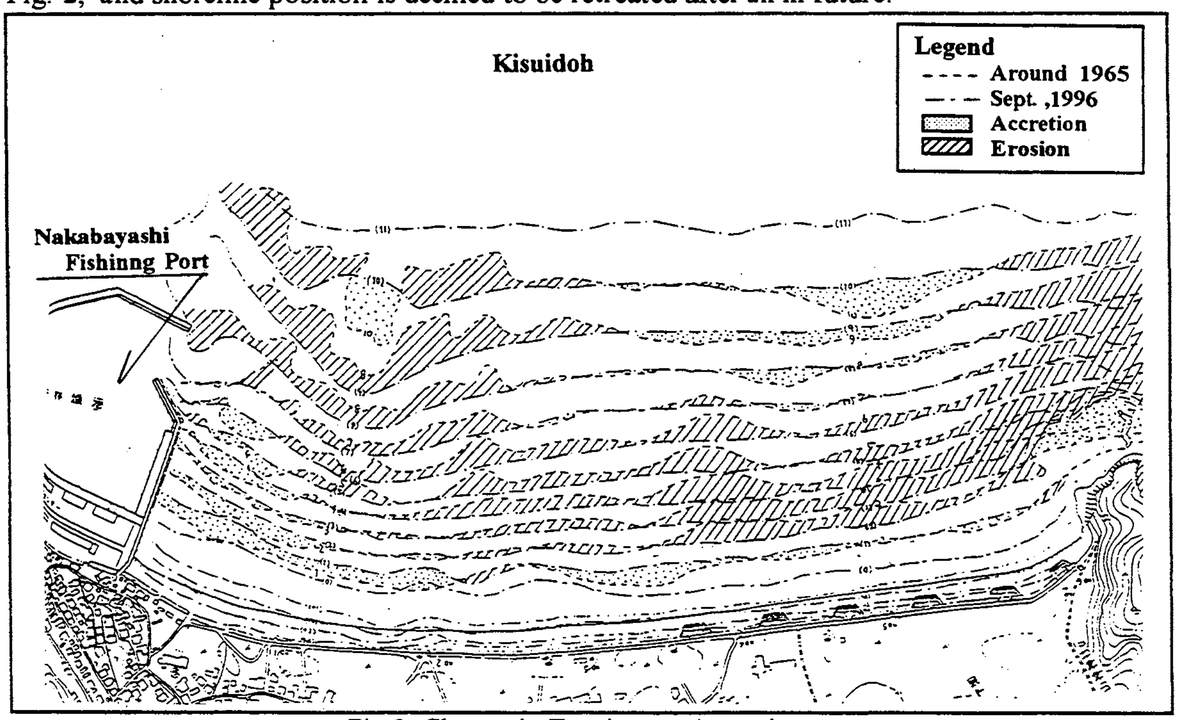


Fig.2: Change in Erosion • Accretion

Now, in order to cope with the problems of shoreline retreat caused by erosion on bottom section and shortage of crown height on the existing seawall, the planning for the coastal protection facility was carried out, and artificial reef in harmony with fisheries was proposed taking into consideration the importance of landscape as well as the request of local fishery workers for environmental conservation.

OUTLINE OF PLAN

1. Concept;

(1) Artificial reef is selected as a competent protection facility not to damage landscape, as the structure is designed to be built entirely under seawater.

(2) Artificial reef plays a role in mitigation of beach erosion developing accretion in the backwater through diminishing the combe ring seawaves.

(3) Artificial reef should have enough crown width to enable crown height of the existing seawall to match with wave runup height.

(4)Artificial reef has the structure in harmony with fisheries where seaweed and so on can easily attach.

2. Specifications;

(1)Offshore distance;

Since the coast as project site involves the bathing beach, the artificial reef is to be installed in the offing outside the water area now in use. However, considering the waterway of the fishing boats calling the fishing port and the reflected waves, the offshore distance up to the offing of the artificial reef is 210m from the seawall.

(2)Submerged depth of crown;

It is, in general, recognized that the deeper the submerged depth of crown, the wider the crown width and the bigger the construction cost.

Accordingly it is theoretically better to make the submerged depth of crown shallow as much as possible, but the submerged depth of crown is D.L.-0.6m, considering the growth of seaweed, etc.

(3) Crown width;

Crown width is 20m, in order to let wave runup height match with crown height of the existing seawall.

(4) Layout;

The length of artificial reef is 110m per one unit considering the extension of site beach and offshore distance. Also the opening width is 50m, and the layout is as shown in Fig.-3.

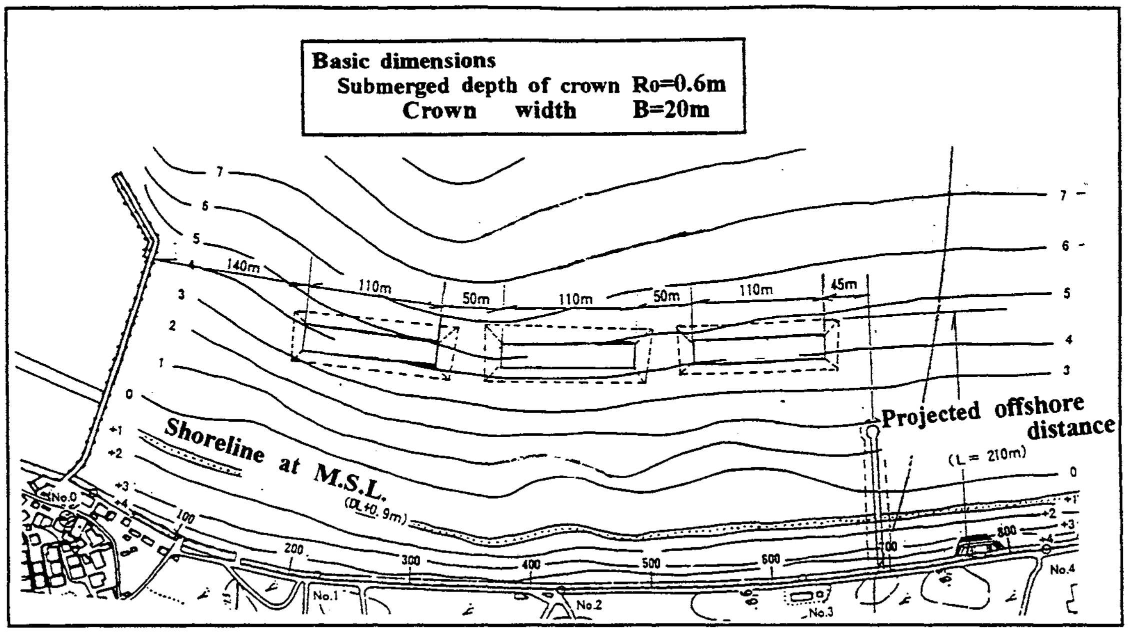


Fig.3: Layout

3. Study on the cross-section of artificial reef in harmoney with fisheries:

The coast selected is a sandy beach, but the installation of artificial reef functions as the formation of reef water area and also meets the expectation of propagation effect for reef creatures. With regard to the cross-section of artificial reef, it was requested by the local fishery workers to design the cross-section to enable seaweed to easily attach and to check in details the materials of armor block. For that purpose, the cross-section profile of artificial reef in harmoney with fisheries was studied and also the armor materials were reviewed.

(1)Cross-section profile:

The cross-section profiles are classified into 5 types according to the shape crown surface.

Type A: To maintaine crown surface constantly flat. Conventional type with lots of execution records.

Type B: To arrange the dent spots at several points on crown surface.

Type C: To set level difference against on shore crown surface, making offshore crown portion shallow.

(Wave absorption in offshore side is to be seriously considered)

Type D: To set level difference against offshore crown surface, making onshore crown portion shallow.

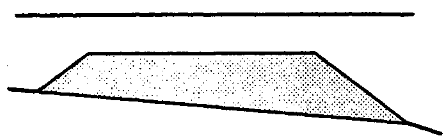
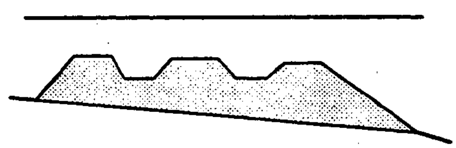
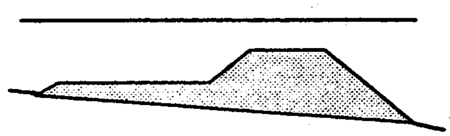
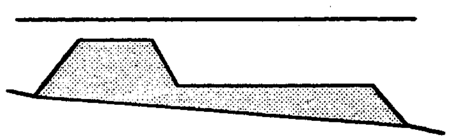
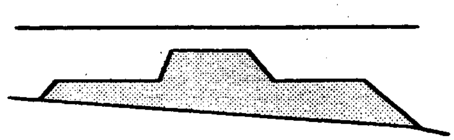
(Wave absorption in onshore side is to be seriously considered)

Type E: To set level difference against both onshore and offshore crown surface,making central crown portion shallow.

(Wave absorption in the center is to be seriously considered)

The fishing industry related feature by type is as shown in Table-1

Table-1: Features of artificial reef by cross-section profile

Type	Profile	Feature
A		• Diversification of seaweed is expected due to long in slope offshore side.
B		• Drifting seaweed easily accumulates due to whir pool. • Diverse space is available for fishes. • Diversification of seaweed is expected due to long slope in offshore side.
C		• Drifting seaweed easily accumulates in on shore side. • Stability of floating larva is expected due to tranquility in onshore side. • Diversification of seaweed is expected due to long slop in offshore side.
D		• Growth of large-scale seaweed is expected due to deep submerged depth of crown in offshore side
E		• Diversification of seaweed is expected due to level difference among onshore, central and offshore crown portions. • Stability of floating larva is expected due to tranquility in on shore side.

The requirements for the site area in view of the fishing industry development are as follows;

To form seaweed bed as the habitat for fish and shell.

To promote stability of larva and juvenile by creating tranquility area around artificial reef.

Taking into consideration the above-mentioned needs and required crown width (20m), the competent cross-section of artificial reef was studied.

① Type B and E are not applicable because of the crown width being comparatively shorter.

② Type A and D are deemed to be not so effective to stability of larva and juvenile.

Consequently Type C was selected as the optimum cross-section in harmony with fisheries in the coast of Nakabayashi fishing port.

(2)Armor materials:

The selection of armor materials is also important to ensure attaching of seaweed and stability of juvenile shell.

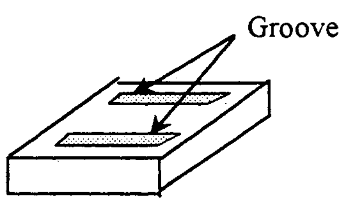
There are stone, concrete and steel as the general armor materials, and the respective characteristics are as follows;

Stone ---------- Due to field stones, a variety of surface shape and space are formed. Due to light weight this stone is used in the area where wave height is low.

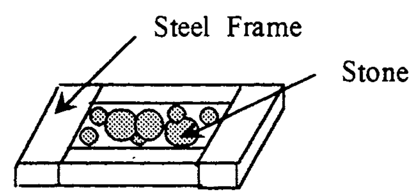
Concrete block ------ This block is generally used as the armor materials for artificial reef.
Just reveting by the rectangular blocks makes the reef surface so monotonous.
So the technical development has been promoted; for instance, the block profile is designed to be more complicated one or the block surface is grooved, etc.

Steel ---------- Steel rust causes the uneven spots on the surface, and also in the sea area where Fe Ion is being the limiting factor for growth of seaweed, the elution of Fe Ion is deemed to be so effective to growing seaweed.

Besides the new armor materials have been developed with the concept to integrate together both stone and steel advantages; that is the armor material stuffing steel frame with stones.



Grooved Concrete Block



Steel Frame • Stone Stuff Type Armor Material

Fig-4: Diagram of Armor Materials

(3)Cross-section of artificial reef:

The cross-section profile is shown in Fig.-5; based on Type C cross-section and steel frame stone stuff type armor material. The construction cost in this case is more expensive than concrete block type reef, on assumption of total length being 330m with 3 units of artificial reef.

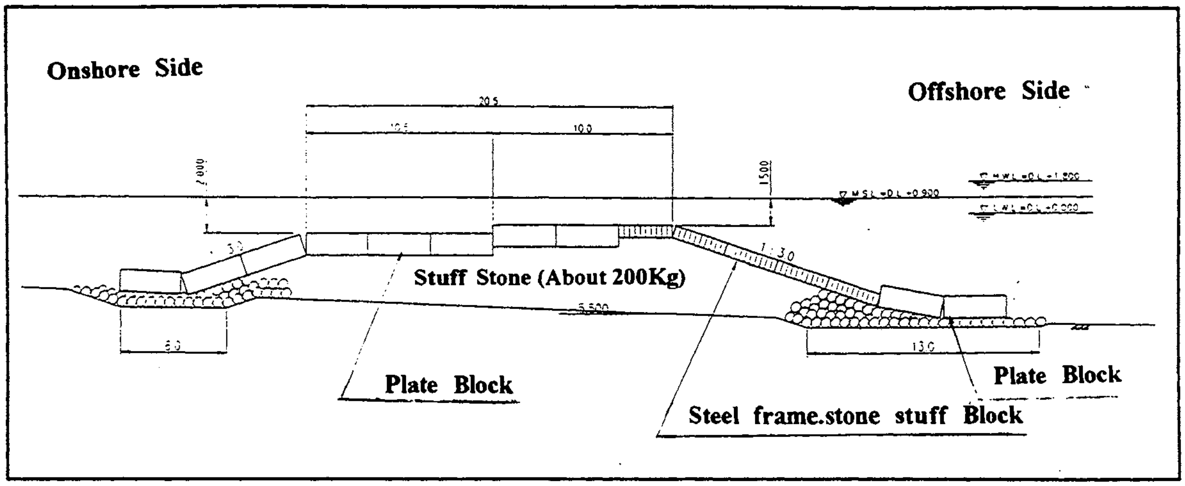


Fig-5: Cross-section of Artificial Reef

SUMMARY

The functional aim of artificial reef in harmoney with fisheries are to diminish the energy of waves beating to the beach and to develop the reef itself as the habitat optimum to growing of seaweed, various small fishes, abalone and top shell, etc.

For that purpose, it was planned to raise the bottom upto the reasonable waterdepth supplying plenty of stones (approx. 200kg) on the existing bottom of about 5m waterdepth and to revet the surface by armor materials to form the complicated uneven spots and various space.

The current trial estimate of construction cost vary by 30 percent depending on the shape and property of armor materials.

Now from an economic point of view the cost reduction of expensive materials is under consideration and also another technical subject under examination is how to develop such armor materials as contributive to wave force mitigation and seaweed growth..

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COMBINATION SEA ENVIRONMENTAL DESIGN CRITERIA FOR MARINE STRUCTURES

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ABSTRACT

Extreme sea statistics and combinations of environmental events or response for structures are very important problem in performance evaluation and design of coastal and Offshore structures . A probabilistic method is developed that leads to the combination of Typhoon (Hurricane)or winter storm induces winds, waves, currents and surge for a generic site. The traditional recommendation for the fixed structures is a combination of the 100 years maximum wave height with the 100 years wind and current. This approach is, however, unduly conservative, since the largest wind, wave and current values in 100 years are not expected to occur at precisely the same time .

Previous studies of combinations of extreme sea environmental conditions fall into two categories: first, the generic load model defines a surface in the multivariate space of meteorological-oceanic variables, such as the joint probability of waves, currents, winds and storm surges; second, use the structural response to combine the environmental variables, such as overturning moment (OTM), base shear forces and etc. While the great majority of publications are concentrated in combinations of responses, although 100 years response is not corresponding to wave, wind and current with 100 years joint probability.

Since the combination design criteria is considered with extreme statistics of individual environmental events and their joint probability, in this paper some new concept for mentioned above problems is proposed .

INTRODUCTION

It is well known that the design loads with the different return period of 50 or 100 a were used as design criteria in the calculation of design loads for the ocean engineering structures before the probability design method or the reliability analysis method instead of the traditional safety coefficient method . Thus, the research of design criteria of ocean environmental conditions is developed with the great investments while the research of reliability analysis for ocean engineering structures is spread in the world .

The traditional design environmental criteria for marine structures is a combination of the 100 yr. maximum wave height with the 100 yr . wind and 100 yr. current. This appproach is, however,unduly conservative, since the largest wind, wave and current in 100 yr. ruturn period are not expected to occur at precisely the same time.

Previous studies of combinations of extreme sea environmental conditions fall into two categories: first, the generic load model defines a surface in the multivariate space of meteorological-oceanic variables, such as the joint probability of waves, currents, winds and storm surges(Liu. 1994 , 1995 ; Bitner-Gregersen.1988); second, use the structural response to combine the environmental variables such as overturning moment, baes shear forces and etc.(Forristal. 1991, Wen 1990, 1991).

Study of the design environmental criteria for a template platform in South China Sea shows, that wave current and wind corresponding to 100 yr. return period response (for example, OTM)are more than combination of wave, current and wind with joint probability of 100 yr. return period. Both exteme response method and joint probability method of environmental combination criteria can not give unique solution, because fifferent combinations of wave, current and wind can obtain 100 yr . response or 100yr . joint probability.

Proposed in this paper method based on of the stochastic simulation of joint probability with 4 types data samplings and exteme response analysis for 4 types of structures .

PREDICTION OF EXTREME SEA ENVIROMENTAL EVENTS

In the engineering design practice three statistical models (Gumbel,Weibull and Log-normal distribution)are widely used for prediction of 100 (or 50)years wave, wind, current and storm surge.

The new statistical model is proposed based on the following consideration: a discrete distribution P_k (K=1,2,...,n) — as Typhoon frequency acting on certain sea area, and a continue distribution $G(x)$ — as Typhoon wave height , wind , current or surge , can form a new distribution — Compound Extreme Value Distribution $F(x)$

$$F(x) = \sum_{k=0}^{\infty} P_k |G(x)|^k \qquad (1)$$

Observed and hindcast Typhoon and Hurricane data show that n is fitting to Poisson distribution ,and Typhoon or Hurricane characteristics are fitting to Gumbel or Weibull distribution (Liu, 1980, 1982). So that two statistical models are derived as :

Poisson-Gumbel Compound Extreme Value Distribution :

$$X_P = -\ln\{-\ln[1+\frac{1}{\lambda}\ln(1-p)]\}\alpha + u \qquad (2)$$

Poisson-Weibull Compound Extreme Value Distribution :

$$Xp = \{-\ln[-\frac{1}{\lambda}\ln(1-p)]\}^{\frac{1}{v}} b \tag{3}$$

Where Xp is the design extreme value with return period $T(=1/p)$, λ the mean value of Typhoon or Hurricane frequencies , α and u the parameters of Gumbel distribution , and v and b the parameters of Weibull distribution .

Formulae (2),(3) can be used for wave ,wind , current and surge prediction . Some American researchers indicate that mentioned above new formulae also can be used for flood frequency analysis. In North Bohai Bay where some sea areas are covered by ice for diffrernt days which varies from year to year , number of observed wave data is fitting to Binomial distribution, and observed daily maximum wave heights are fitting to Log-normal distribution. Therefore, for North Bohai Bay the Binomial-Log-normal Compound Extreme Value Distribution can be derived as follows :

$$\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{Xp} e^{-\frac{t^2}{2}}dt = 1-\frac{365}{\bar{n}}[1-(1-p)^{\frac{1}{365}}] \tag{4}$$

$$Hp = b_0 + \exp(a+\sigma \cdot Xp) \tag{5}$$

where Hp —— extreme wave height with design probability p.

$$a = \frac{1}{N}\sum_{i=1}^{N}\ln(Hi - b_0) \tag{6}$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[\ln(Hi-b_0)-a]^2} \tag{7}$$

b_0 —— parameter.

N —— total number of wave data highter than b_0.

JOINT PROBABILITY OF SEA ENVIRONMENTAL EVENTS

Joint probability of multidimensional variables can be expressed as

$$P = \iint_{\Omega}\cdots\int f(x_1,x_2,\cdots,x_n)dx_1dx_2\cdots dx_n \tag{8}$$

where Ω is the domain of integration in the multivariate space and f $(x_1,x_2,\ldots,x_n)$the joint probability density function of variables.

Analytical solution for joint probability of non-Gaussian , correlated multidimensional variables are very complexity and it can not find practical use.

The stochastic simulation techniques are efficient for estimation of joint probability. Different methods have been developed to reduce the number of simulations , among them Important Sampling Procedure (Bourtant , 1986)is used in this paper.

This method is used to determine the design environmental criteria for templet platform at 145m depth Lufun sea area of South China Sea. 20 years hindcast Typhoon wave , wind and current data are used for simulation. Simulated results shown in Table 1.

Table 1. Joint Probability of Wave, Wind and Current

Return period	Wave	Current	Wind
(years)	(m)	(m/s)	(m/s)
100	14.2	2.18	53.7
50	13.7	2.12	50.2
20	12.9	1.91	45.0
10	12.2	1.69	42.0

Difference between simulated joint probability and calculated results by OTM method are shown in Table 2.

Table 2. Comparison of Calculated Results

Method	Wave(m)	Current(m/s)	Wind(m/s)
Individual 100 years value	15.6	2.77	55.9
OTM method	14.3	2.31	54.7
ISP method	14.2	2.18	53.7

DATA SAMPLING FOR JOINT PROBABILITY AND CORRESPONDING DESIGN CRITERIA FOR DIFFERENT STRUCTURES

Both extreme response method and joint probability method for environmental combination criteria can not give unique solution , because different combinations of wave , current and wind can obtain 100 years response or 100 years joint probability . Proposed in this paper method consists of two steps : frist ,use stochastic simulation method to get different combinations of wave , current and wind with 100 years joint probability ; second , caculate response to structures , and choose the extreme value from them . 100 years return period combination of wave , current and wind corresponding to extreme response is an unique solution. Therefore, for different type of structures data sampling from Typhoon hindcast process must be different . There are four cases of joint probability with diffrerent data sampling corresponding to different type of structures :

Maximum wave with simultaneous current and wind ;
Maximum wind with simultaneous wave and current ;
Maximum current with simultaneous wave and wind ;
Maximum surge with simultaneous wave and current ;

For instance , in the case of fixed structure, dominated load is wave load , hence the data sampling have to take case 1. For some moored structure, sometimes the wind load is dominated and the maximum wind with simultaneous wave and current can be taken as data sampling. In case of some coastal structures (for example, man-made island , dam), data sampling have to take case 4. For riser ,some cables the maximum current and simultaneous wave and surge can be used as data sampling.

CONCLUSION

1. Proposed statistcal models for extreme prediction of Typhoon parameters can be used in China Sea are or other sea areas and give satisfying results as shown in comparison by (Langley R. Muir . 1986.)

2. Combined joint probability of meteo-ocean parameters and extreme responses distribution with different data samplings of Typhoon parameters for four kinds of structures can be used as environmental design criteria for marine structures .

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THE APPLICATION OF WAVELET TRANSFORM TO WAVE BREAKING

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ABSTRACT

The wavelet transform is particularly well adapted to characterize transient phenomena, such as wave breaking, because it decomposes signals (such as, a set of measured wind waves data) into building blocks a set of measured that are well localized in space and frequency. For many different types of signals, particularly wave breaking, the important information is carried by singularities and sharp variation points. In this paper, wavelet transform is used to the set of measured wind waves data. The results reveal significantly new and previously unexplored on wave breaking.

1. Introduction

In deep water, the most dramatic breakers are plunging breakers where the breaking commences by the wave overturning and forming a forward moving sheet of water which plunges down into the water in front causing splashes, air entainment, and eddies. Most other breakers are described as spilling breakers. From their initiation, "white water "falls down the front face of the wave. The falling water appears white because of entrained air bubbles and drops created at the surface. This kind breaking seen as whitecaps(Monahan 1971). It is visible from the appearance of the whitecaps, yet it can not be readily measured with customary instruments. Breaking waves are suggested to play an important role in all aspects of sir-sea exchange processes, including momentum, heat and mass. So waves breaking are an important component in many fields of study, such as the process of air-sea interaction, ocean wave dynamics, oceanic remote sensing and ocean engineering. However in both breaking waves' theoritical study and its practical measurement , the first problem we encountered is how to detect the breaking of waves.

In this paper our investigation is of the surface elevation $\zeta(t)$ measured at a fixed point. As we know , wave breaking may well result in localized singularities in $\zeta(t)$. However when applying a Fourier transform to $\zeta(t)$, these localized singularities will be completely delocalized throughout the frequency spectrum $S(\omega)$. The wavelet transform has the advantage over conventional Fourier analysis in that information is localised in both physical and wavenumber space. The wavelet analysis provides a two-dimensional unfolding of one-dimensional signals, resolving both position. It has been shown that the continuous wavelet transform is well adapted for investgating the coherent structures in turbulent flows(Farge 1992). For analyzing purposes the continuous wavelet transform is better suited because its redundancy allows good legibility of the signal's information content. With the using of wavelet transfrom , we have expanded the investigation by using local variables as a tool for detection and quantification of breaking waves and give a new breaking criteria. We have also compared , on the basis of experimental results, breaking characteristics determined with different breaking criteria. The results give some new viewpoits concerning our understanding of wind waves.

2. Wavelet transform

First of all, we introduce here a family of functions, the so-called analyzing wavelets, $\psi_{ab}(t)$, that are generated by dilations a and translations b from a mother wavelet $\psi(t)$ as

$$\psi_{ab}(t)=\frac{1}{\sqrt{|a|}}\psi\left(\frac{t-b}{a}\right) \qquad (1)\backslash$$

where $a>0, b\in R$, and $\psi(t)\in L^1\cap L^2$ and satisfies the following admissible condition :

$$C_\psi=\int\left|\hat{\psi}(\omega)\right|^2|\omega|^{-1}d\omega<+\infty \qquad (2)$$

where $\hat{\psi}(\omega)$ is the Fourier transform of $\psi(t)$; that is,

$$\hat{\psi}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{+\infty}\psi(t)e^{-i\omega t}dt \tag{3}$$

The continuous wavelet transform of a time-series $f(t)$(For any $f(t)\in L^2$) is then defined as the inner product of ψ_{ab} and f as

$$\tilde{f}(a,b) = \langle\psi_{ab}, f\rangle = \int_{-\infty}^{+\infty} f(t)\psi^*_{ab}(t)dt \tag{4}$$

where an asterisk superscript indicates the complex conjugate. In essence the wavelet transform takes a one-dimensional function of time into a two dimensional function of time and scale. To summarize, the wavelet transform may be compared to a mathematical microscope, for which ψ characterizes the optics, $1/a$ is resolution, b the position.

We now list some of the basic properties of the continuous wavelet transform. We denote the continuous wavelet transform of a function $f(t)$ by the operator notation $W[f](t)$ and the resulting wavelet coefficients by $\tilde{f}(a,b)$.

(1). The wavelet transform is linear, because it is an inner product between the signal f and wavelet ψ.

(2). The continuous wavelet transform is covariant under any translation t_0 and any dilation T_0 of the signal; namely,

$$W[f](t-t_0) = \tilde{f}(a, b-t_0), \tag{5}$$

$$W[f](T_0 t) = T_0^{-1}\tilde{f}(T_0 a, T_0 b), \tag{6}$$

A consequence of the translation covariance (5) is the fact that the frequency of a monochromatic signal can be obtained from the phase of the wavelet coefficients. A consequence of the dilation covariance (6) is the fact that the wavelet transform of a power-law function is fully determined by its restriction to any line l =constant. The lines of constant phase point out the possible singularties of the function(Farge, M 1992). So it is very easy to localized the possible singularities of f by looking at the phase of its wavelet coefficients: The lines of constant phase converge on the singularities. This property will be used in the following section to test singularities in wind wave datasets.

In this paper , we also rely on the fact that the wavelet coefficents completetly characterize the time-series data.

In practical applications, the wavelets can be conveniently discretized by setting $a = 2^s$ and $b = \tau 2^s$, so we obtain

$$\psi_{s\tau}(t) = 2^{-s/2}\psi\left(2^{-s}t - \tau\right) \tag{7}$$

where s and τ are integers. Then the continuous wavelet transforms for time series data $f(t)$ become

$$\tilde{f}(s,\tau) = \frac{1}{\sqrt{2^s}}\int_{-\infty}^{+\infty} f(t)\psi^*\left(\frac{t}{2^s} - \tau\right)dt \tag{8}$$

In analogy with Fourier energy density spectrum, we can readily define a a wavelet spectrum for a data series $f(t)$ as

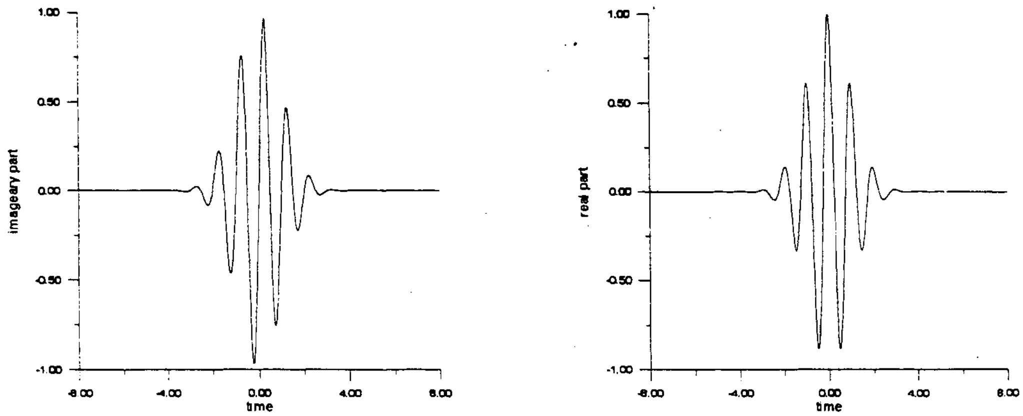
$$W_f(s,\tau) = \tilde{f}(s,\tau)\tilde{f}^*(s,\tau) = \left|\tilde{f}(s,\tau)\right|^2 \tag{9}$$

Since in practice the scale , s , and translation, τ , can be associated with a corresponding frequency, ω , and time, t , (9) can be considered as a representation of the time-varying, localized energy spectrum for a given time series.

In this paper, we choose to use the complex-valued , modulated Gaussian analyzing wavelet known as the Morlet wavelet,

$$\psi(t) = e^{i2\pi t}e^{-t^2/2} \tag{10}$$

This wavelet originally proposed by Morlet(Morlet , 1982) et al. and has been widely used in signal analysis. As shown in Fig.1 , the standard Morlet wavelet is a plane wave of frequency $\omega_g = 2\pi$ modulated by a Gaussian envelope of unit width. For all practical purposes, the Morlet wavelet is admissible and progressive.



(a) (b)

Figures 1 The standard Morlet wavelet g(t) defined in Eq. (10): (a) the imaginary part of $\psi(t)$, (b) the real part of $\psi(t)$.

3. Detecting of breaking waves by wavelet transform

a. Principle

In order to obtain information of breaking waves, local(i.e. instantaneous) wave properties including angular frequency(σ) ,phase velocity (c), and the horizontal velocity component (u) are needed. These parameters can be deduced through the Hilbert transform (Melville 1983; Bitner-Gregersen& Gran 1983), in which the surface fluctuations are denoted by the following complex representation:

$$\eta(x,t) = \zeta(x,t) + i\xi(x,t), \tag{11}$$

where $\zeta(x,t)$ and $\xi(x,t)$ are respectively the measured and conjugate signals of vertical fluctuations of the water surface; x and t are the space and time coordinates, respectively. The quantities $\zeta(x,t)$ and $\xi(x,t)$ are uniquely defined by the Hilbert transform:

$$\zeta(x,t) = \frac{p}{\pi}\int_{-\infty}^{\infty}\frac{\xi(x,\tau)}{\tau - t}d\tau, \tag{12}$$

$$\xi(x,t) = \frac{p}{\pi}\int_{-\infty}^{\infty}\frac{\zeta(x,\tau)}{\tau - t}d\tau, \tag{13}$$

where p is the Cauchy principle value of intergration evaluated at $\tau = t$. From the convolution theorem, we have

$$F(\xi) = iF(\zeta) \tag{14}$$

where F denotes the Fourier transform. The complex signal in (11) can be expressed in the polar form as

$$\eta(x,t) = a(x,t)e^{i\phi(x,t)}, \tag{15}$$

where $$a(x,t) = \left[\xi^2(x,t) + \zeta^2(x,t)\right]^{\frac{1}{2}} \tag{16}$$

is the local wave amplitude, and

$$\phi(x,t) = \tan^{-1}\left[\zeta(x,t)/\xi(x,t)\right] \tag{17}$$

is the local phase function. The local wavenumber and angular frequency can then be obtained, respectively, from the following definitions:

$$k(x,t) = \frac{\partial\phi(x,t)}{\partial x}, \tag{18}$$

$$\sigma(x,t) = \frac{\partial\phi(x,t)}{\partial t}. \tag{19}$$

The local wave phase velocity is defined by

$$c(x,t)=\frac{\sigma(x,t)}{k(x,t)} \tag{20}$$

where $\sigma(x,t)$, $k(x,t)$ are respectively local angular frequency and local wavenumber. Alternatively, Melville(1983) showed that the phase velocity of a narrow-band process obtained from

$$c(x,t)=\left[g/\sigma(x,t)\right]\left[1+\left(a\sigma(x,t)^2/g\right)^2\right] \tag{21}$$

Although (21) was derived for narrow-band processes, its application to ocean waves appears to result in resonable success(Bitner-Gregersen,E.M., 1983).

Through (11) and (15), we can also get :

$$\zeta(x,t)=a(x,t)\cos\phi(x,t), \tag{22}$$

$$\xi(x,t)=a(x,t)\sin\phi(x,t). \tag{23}$$

Then the local vertical and horizontal velocity components at the free surface can be approximated to first order by finite differencing

$$w(x,t)=\frac{\partial\zeta(x,t)}{\partial t}, \tag{24}$$

$$\begin{aligned} u(x,t)&=\frac{\partial\xi(x,t)}{\partial t}=\frac{\partial H(\zeta)}{\partial t}=\frac{\partial(a\sin\phi)}{\partial t}\\ &=\sigma a\cos\phi+\frac{\partial a}{\partial t}\sin\phi=\sigma\zeta+\frac{1}{a}\frac{\partial a}{\partial t}\sqrt{a^2-\zeta^2}. \end{aligned} \tag{25}$$

In the following, we will give the new form of local variables on the bases of the wavelet energy spectrum , through (9), we get (1) The wavelet spectrum of $\zeta(t)$:

$$E(\omega,t)=W_\zeta(\omega,t)=\tilde{\zeta}(\omega,t)\tilde{\zeta}^*(\omega,t)=\left|\tilde{\zeta}(\omega,t)\right|^2 \tag{26}$$

We think $W_\zeta(\omega,t)$ is an equivalent time-frequency spectrum for $\zeta(t)$. then there is a localized frequency spectrum at each data point $\zeta(t_i)$, given by

$$\Phi_i(\omega)=E(\omega,t_i)=\left[W_\zeta(\omega,t)\right]_{t=t_i} \tag{27}$$

It is not immediately clear which frequency should be used for σ in calculating $a\sigma^2$. Because breaking events are generally associated with the high frequency part of the spectrum, for each $\zeta(t_i)$ we chose to define a σ_i as the average frequency over the high frequency range $\lambda\omega_p:\omega_n$, of the localized spectrum at $t=t_i$ as

(2) The local angular frequency

$$\sigma_i=\left[\frac{\int_{\lambda\omega_p}^{\omega_n}\omega^2\Phi_i(\omega)d\omega}{\int_{\lambda\omega_p}^{\omega_n}\Phi_i(\omega)d\omega}\right]^{1/2}=\left[\frac{\int_{\lambda\omega_p}^{\omega_n}\omega^2E(\omega,t_i)d\omega}{\int_{\lambda\omega_p}^{\omega_n}E(\omega,t_i)d\omega}\right]^{1/2} \tag{28}$$

where ω_p is the localized frequency at the energy peak, ω_n is the cut-offfrequency, and λ is a number greater than 1 that denotes the start of the high frequency range beyond ω_p. The exact location of high frequency range has not been clearly defined. Considering this range as corresponding to the familiar equilibrium range, one frequently used value of λ has been 1.35. Here we choose $\lambda=1.35$

(3) The local amplitude

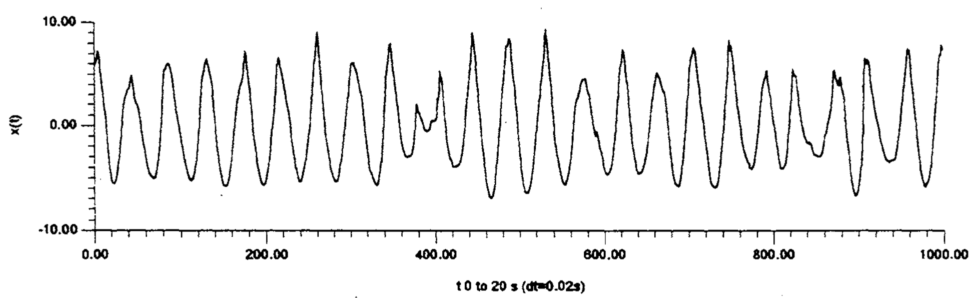
$$a_i=\left[\int_{\lambda\omega_p}^{\omega_n}\Phi_i(\omega)d\omega\right]^{1/2}=\left[\int_{\lambda\omega_p}^{\omega_n}E(\omega,t_i)d\omega\right]^{1/2} \tag{29}$$

b. Experiments

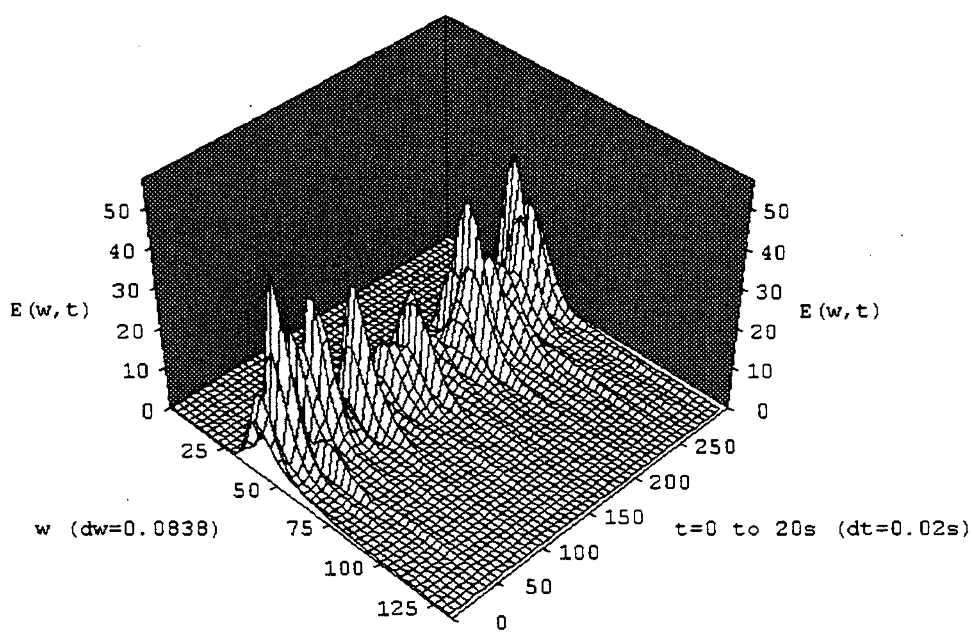
The wave data used in the present paper were obtained from laboratory simulations. The experiments of simulation were conducted in the Wind-Wave-Current Research Facility- the large flume of Physical Oceanography Laboratory, Ocean University of Qingdao. The tank's effective length is 46m , wideth is 1.2m; the water was 74cm deep, and the wind tunnel 60cm high. A capacitance-type gauge was used to measure the surface displacement at fetches 0f 10.0 , 15.1 and 20.4m under wind velocities from 2 to 14m/s. A typical wave record at the wind velocity of U=14m/s and fetch of L=31 m is shown in Fig.2c. In order to preserve features of the breaking , a sampling rate of 50hz was used for digitizing.

The wave data that we selected satisfy the following criteria: 1) Waves are generated by an approximately constant wind of long duration ; 2) predominantly generated by wind.

Segments of time series of at the wind velocity of 14m/s are shown in figure 2a; Figures 2b and 2c show typical examples of the three dimensional display of the modulus of the wavelet spectrum $E(\omega,t)$ from different angle.



(a)



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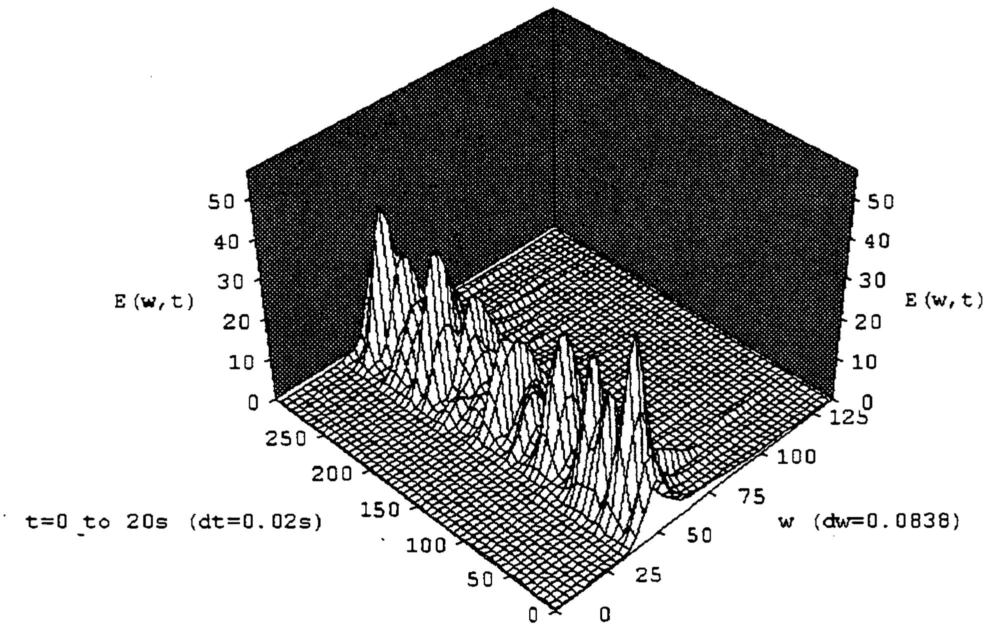


(c)

Figure 2 The wavelet spectrum of laboratory dataset c:(a) the corresponding wave elevation ;(b) Three-dimensional display of the spectrum of dataset c (Form 0-6 s); (c) Three-dimensional display of the spectrum of dataset c from different angle;

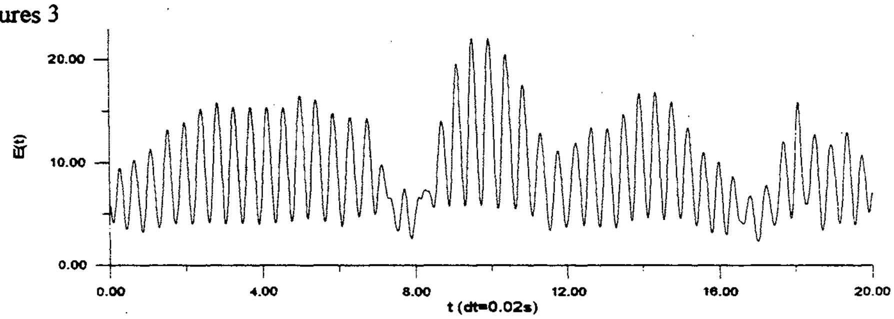
It is found that wavelet spectrum of the wave components at high frequencies (corresponding to small T) are remarkably inhomogeneous, with very sharp peaks sporadically distributed along the time axis t. In the following analysis, we suggest that the sharp peaks correspond to wave singularities resulting from nonlinear advection, where wave breaking generally occurs.

Integrating Eq.(26) with respect to ω , t, gives

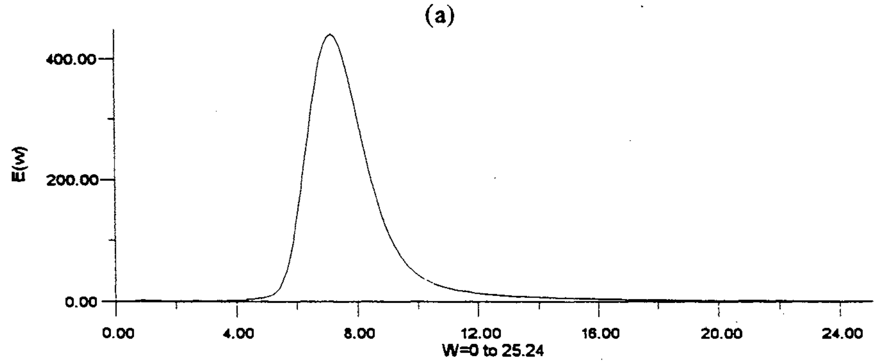
$$E(t) = \int_{-\infty}^{+\infty} E(\omega, t) d\omega, \tag{30}$$

$$E(\omega) = \int_{-\infty}^{+\infty} E(\omega, t) dt. \tag{31}$$

as shown in Figures 3



(a)



(b)

Figures 3 (a) The energy of dataset versus time - E(t). (b)The energy of dataset versus frequency - E(w).

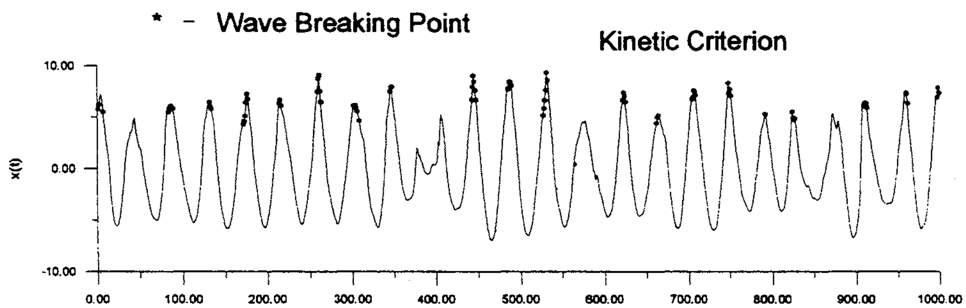
So the total energy can be defined as

$$E_{total} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} E(\omega,t)dtd\omega \qquad (32)$$

First of all, we adopt the kinetic critterion: The wave breaks when the longitudinal particale velocity exceeds the wave phase velocity, i.e $u \geq c$. Since we are interested in large-scale breaking, effects of surface drift currents on breaking will not be considered (Banner & Phillips 1974; Phillips & banner 1974). From (21) and (25) we have

$$\sigma\zeta + \frac{1}{a}\frac{\partial a}{\partial t}\sqrt{a^2-\zeta^2} \geq g/\sigma\left[1+\left(a\sigma^2/g\right)^2\right] \qquad (33)$$

here , the local amplitude a_i and local angular frequency σ_i are used in computing $u \geq c$. Figure 4a presents an illustration of the analysis where estimated breaking waves are marked on the same time series segment given in Figure 2.c. The value of λ is important here. The different λ are not always recognizing the same breaking waves. In general with the same cut-off frequency, ω_n, the lower end of the frequency range farther away from the local peak frequency, i.e. large λ value, wouild yield higher local average frequency σ and more breaking waves.



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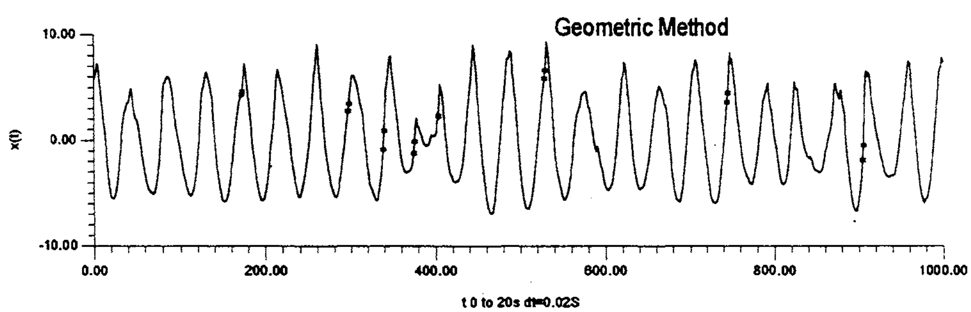

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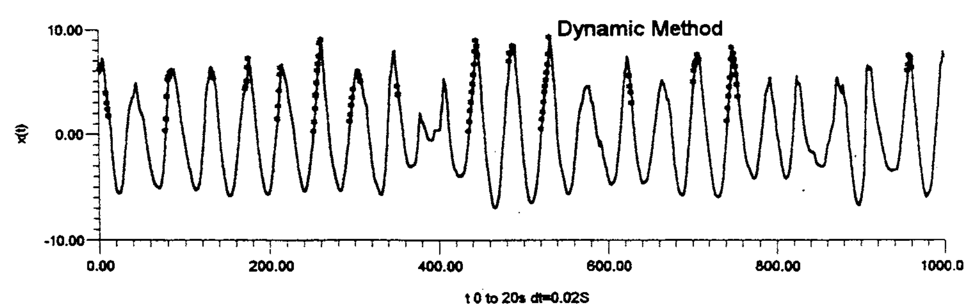
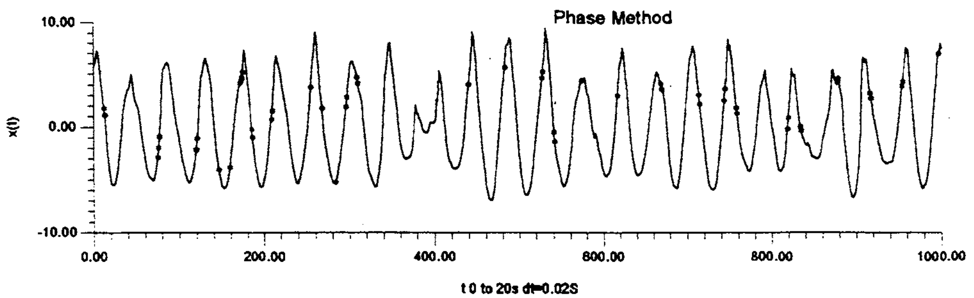


(c)



(d)

Figures 4 The breaking waves detected by different Criterions : (a) Detected by Kinetic Criterion ; (b)Detected by Geometric criterion ; (c) Detected by Dynamic criterion.; (d) Detected by phase method.

There is generally only one breaking event per wave; occasionally, two or more breakings occurring at different phases were observed. The significance of this is not clear at this stage, but is useful in comparing different breaking criteria. Because the wave profile is very complicated at the breaking point, some of the multiple-breaking events occurring inclose proximity may be due to the difficulty of measurements. Therefore, when two or more events were detected in a same wave, they were cosidered as one event.

We also adopt the geometric criterion and the dynamic criterion here.

Geometric criterion. Breaking occurs when the surface inclination exceeds 30.37° (Longuet-Higgins & Fox 1977). Following a treatment of rendering local steadiness of wave motions, the surface inclination can be approximated by $\partial\zeta/\partial x = c^{-1}\,\partial\zeta/\partial t$ (Longuet-Higgins & Smith 1983). The waves with the break points are shown in Figure 4b.

Dynamic criterion. The acceleration of fluid particles exceeds a portion of the gravitational acceleration when the wave breaks. The proportionality constant ranges from 0.388 near the wave crest, based on numerical calculations of Longuet-Higgins & Fox(1977), to the classical value of 0.5(Stokes 1880). Here we choose the value of 0.39 . Figure 4c shows display of the breaking waves. Longuet-Higgins studied the acceleration field in steep gravity waves. It was shown that the apparent acceleration (Euler acceleration)measured by a fixed wave gauge differs greatly from the real acceleration of fluid particles measured by a Lagrangian device. And for a more complicated sea, Longuet-Higgins proved that the downward true acceleration can be as great as $-g$. So we only use the dynamic criterion as a reference here.

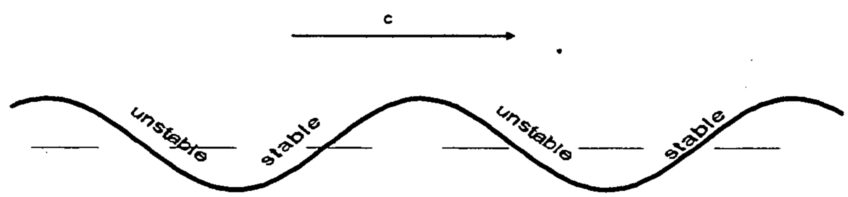
We applied the above methods to measurements of breaking waves with using the segments of time series at the wind velocityof 4m/s, 6m/s, 8m/s, 10m/s and 12m/s, and obtained results on the probability of wave breaking in table 1.

Table 1. Occurrence frequencies of wind -wave breaking obtained by the three criteria

Wind speed	Record length	Number of waves	Criterion of wave breaking					
			Geometric		Dynamic		Kinematic	
(m/s)	(s)	(N)	Number of breaking waves(n)	Occurrence frequency (n/N)(%)	Number of breaking waves(n)	Occurrence frequency (n/N)(%)	Number of breaking waves(n)	Occurrence frequency (n/N)(%)
4	60	136	0	0	0	0	5	3.6
6	60	121	0	0	3	2.47	17	14
8	60	93	0	0	15	16.1	25	28
10	60	90	7	7.8	48	53.3	50	55.6
12	60	85	9	10.6	50	58.8	64	75.2
14	60	75	24	32	48	64	56	78

As can be seen in the firgure 4, it is evident that there were significant portions of events detectable by one criterion but not by the other. The breaking waves classified by the kinematic criterion are also identified by the geometric criterion. So it maybe show that the kinematic criterion is less than sensitive than the geometric criterion, especially at lower wind velocities(Paul A.Hwang 1989).

The table1 and figure 5 show that in temporal wave measurements the surface profile steepens beyond the critical level (the geometric criterion) earlier than when the particale velocity exceeds the phase velocity(the kinematic criterion). If based on the geometric criterion, the breaking inception is on the upwind side of the wave crest, while the kinematic criterion indicates inception on the downwind side. In a progressive wave(see Fig. 5) the surface is contracting on the forward face(downwind side) of the wave, and stretching horizontally on the rear face(upwind side). Thus, the forward face of the wave is unstable to short-wave disturbances, and the rear face isstable(Longuet-Higgins,M.S. 1994). So we think the breaking inception on the downwind side is more reasonable than on the upwind side.

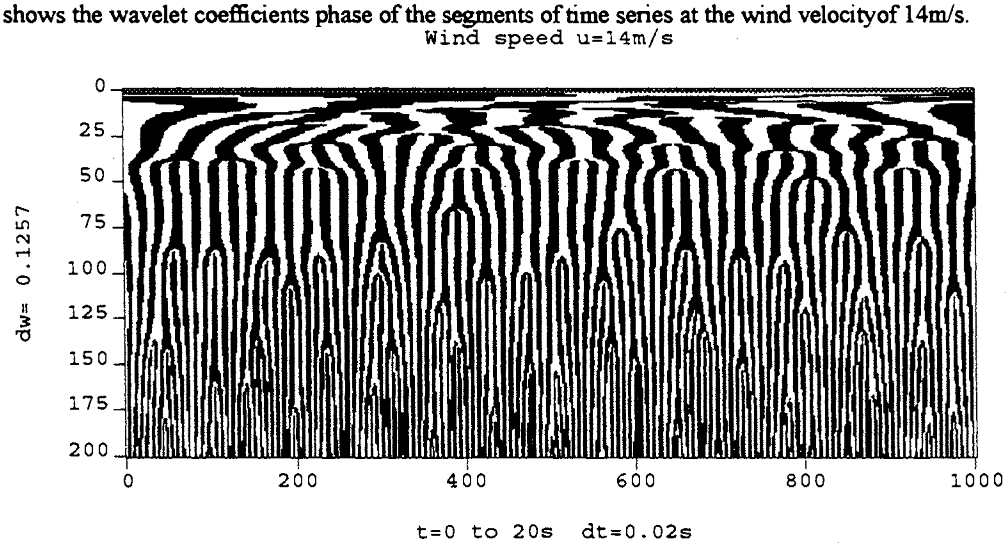


Figures 5 Stable and unstable phases in a progressive gravity wave

Now we attempt to adopt a new method to detect the breaking waves. Here we rely on the fact that the points of breaking inception are just correspond to the singular points of the time-series $f(t)$. To find the singular points, we should procedd as follows. First, we plot the phase of the wavelet coefficients to locate singularities — for the iso-phase lines will point towards singular points. Second, we should verify that the singular point detected at t_0 is isolated, namely that

$$\tilde{f}(a \to 0, t_0) < \tilde{f}(a \to 0, t_0 \pm \varepsilon), \text{ with } |\varepsilon| \text{ vey small} \qquad (34)$$

Figures 6 shows the wavelet coefficients phase of the segments of time series at the wind velocityof 14m/s.



Figures 6 The phase of wavelet spectrum .

Black : Phase >0 ; White: Phase<0; Grey : Phase=0

Figures 4.d shows the waves with the break points detected by method of singularities .

4. Energy Loss by Breaking Waves

Wind waves breaking in deep water are an important component in the process of air-sea interaction. Breaking waves cast off clouds of spray into the atmosphere, this mechanism greatly enhances the net water vapor flux into atmosphere. By estimating the energy loss , we can infer the exchange of waters between the atmosphere and the ocean.

Ducan (1981) made laboratory measurements of the rate of loss of energy per unit crest length, E, from a quasi-steady breaking wave produced by a subsurface hydrofoil. The estimated energy loss increases rapidly with the phase speed of the breaking wave, c_b ,

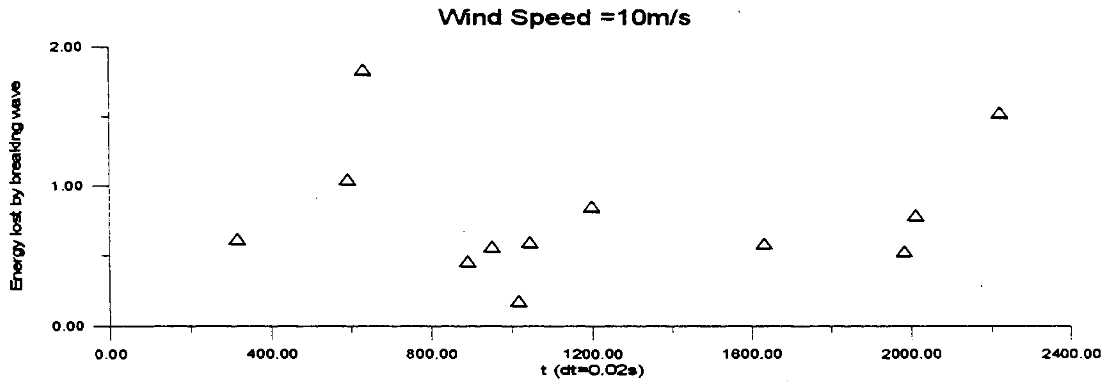
$$\Delta E = (0.044 \pm 0.008)\rho C_b^5 g^{-1}, \quad (35)$$

where ρ is density of the water and g is the acceleration due to gravity. Because the wavelet transform has excellent localized property, we adapt a simple method — we think the energy loss is

$$\Delta E(t^*) = \int_0^\infty [E(\omega,t_1) - E(\omega,t_2)]d\omega \quad (36)$$

Here t_1 and t_2 are the times before and after wave breaking.

The following figure is the result of computing the Eq (36) .



Figures 7 Energy Lost by Breaking Waves

5. Conclusions

The derivation and application of wavelet transform has been described. Just as the Fourier transform has acted as a common language between theory and experiment, the wavelet analysis provides a common basis for comparison, but now more easy to interpret in physical space. Therefore, the wavelet transform approach that leads to above results is useful,convenient, and also exploratory. The wavelet transform provides a feasible and reasonable way of calculating local properties such as phase and particle velocities, particle accelerations,etc. from a single-point measurement of surface elevations. We applied this technique to detecting breaking waves, and obtained useful results. For the wind wave studies, wavelets certainly ample oppportunities for data analysis.

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EXPERIMENTAL STUDY ON MODAL ANALYSIS OF FLOATING ELASTIC PLATE

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ABSTRACT

Floating structures, such as floating airport can be constructed by plate-type structure system. This structure system has a great deal of potential to apply to oceanic structures like a artificial ground. The pursuing of hydroelastic interaction problem have attracted the attention of researchers.

As to interaction problem, most of published research papers are relating to the theoretical analysis, but the experimental studies are a few except response analysis of floating structures by ocean wave.

The experimental study which authors have known as of now is conducted only beam-type model, which has been imaged as large scale floating structure.

As theoretical approach is being studied for nearly three years as interaction problem in our laboratory, the grounds for the validity of our theoretical analysis have been required. Therefore, an experiment was carried out by elastic plate models, which three types of models were made of silicone rubber. The experiments were performed in air and in water. The experimental apparatus for modal analysis were water tank, FFT Analyzer, STAR System, etc..

This paper presents mainly some views obtained by the discussion through comparison of the data by experiment and calculation results.

INTRODUCTION

Our research laboratory is continuing to study dynamic behavior problem of elastic floating plate for around three years under the research subjects relating to oceanic architectural structures surrounding by water. As theoretical development of plate with regard to natural frequency analysis was completed by some structural assumption, and also the computer programming for numerical calculations was made. Actual data collection by water tank experiment was done in order to verify the validity of theoretical developments.

This paper reports a part of contents of experiment carrying out at present and states some views obtained by the discussion.

EXPERIMENT

1. Property of testing model

Testing models were made of Shin-Etsu silicone rubber and two catalysts. The combination of these materials has following merits. An arbitrary shape of model can be formed freely by the mold. The clear phenomenon of coupled vibration between fluid and elastic plate occurred from water motion can be simulated. Stable and linear elastic range of the model materials is obtained widely in order to decide Young's modules. The silicone rubber has a water proof character.

Testing models were prepared three types shown in Table 1. Fig.1 and Fig.2 show the drawing of model, the supporting frame, the arrangement of hitting points of plates by impulse hummer and attaching point of miniature accelerometer.

Table 1 Properties of elastic plate models

Model	Length (a)	Width (b)	Thickness (t)	Material	Young's Modulus	Poisson's Ratio	Density
	[mm]						
T-1(25)	250	250	10	silicon KE-112	31.03 [kg/cm^2]	0.47	1.20×10^{-6} [$kgsec^2/cm^4$]
T-2(25)	250	250	20				
T-2(50)	500	500	20				

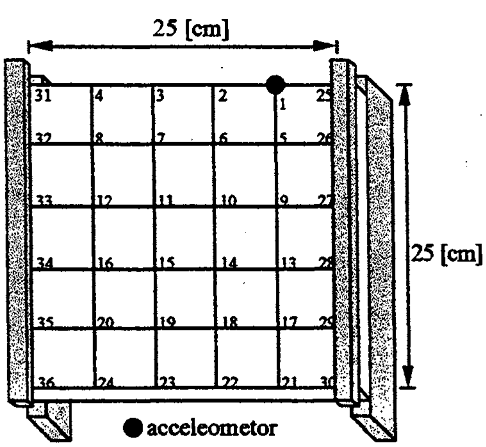

Fig.1 Schematic Model T–1(25) & T–2(25)

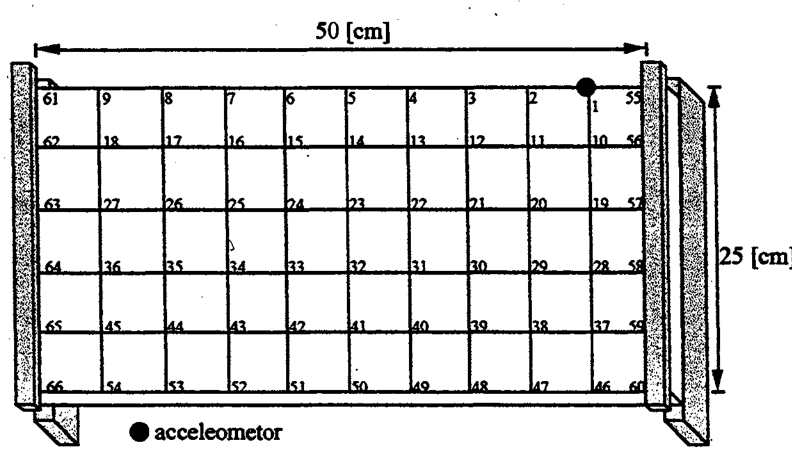

Fig.2 Schematic Model T–2(50)

The model materials and experimental apparatuses are shown in Table 2, the model number and maker also are shown.

Table 2 Testing model materials and the makers

FFT Analyzer	CF-360Z	Ono Sokki Co., Ltd	Japan
Impulse Hummer	5850A	Dytran Instruments, Inc.	U.S.A
Miniature Accelerometer	3115A	Dytran Instruments, Inc.	U.S.A
Silicone Rubber	KE-112,CAT-112,CAT-RM	Shin-Etsu Chemical Co., Ltd	Japan
STAR System	Ver.5.1	Structural Measurement System, Inc.	U.S.A

2. Experimental method and the procedure

Fig.3 shows experimental system by apparatuses schematically, and the flowchart of modal analysis by FFT Analyzer and STAR System is drawn in Fig.4.

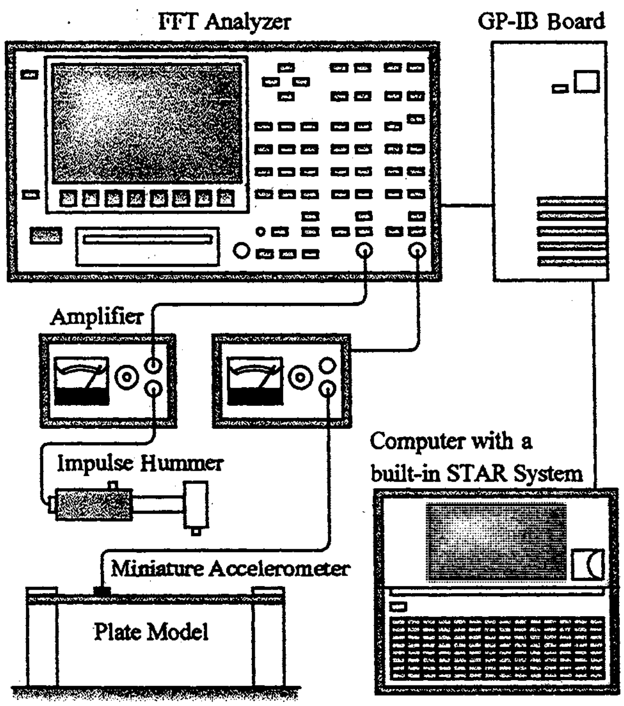

Fig. 3 System of Experiment

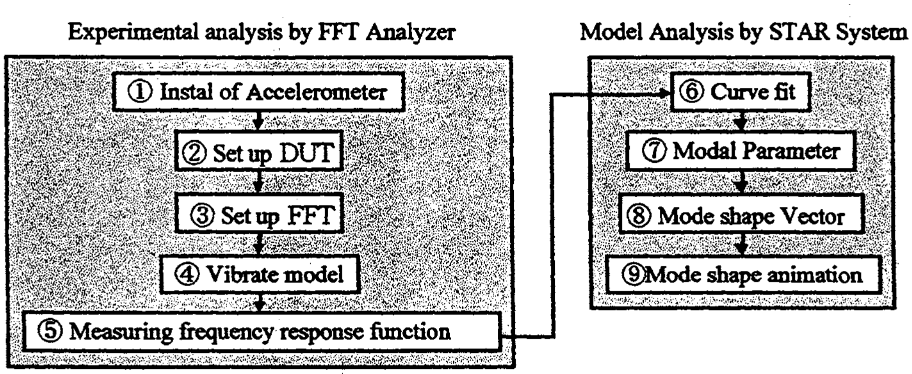

Fig. 4 Flowchart of Modal Experimental Analysis

DISCUSSION OF RESULTS

In Fig.5 up to Fig.6, comparisons of vibrational mode shapes obtained from modal experiment of two models and numerical calculations are demonstrated when plates exist under the condition

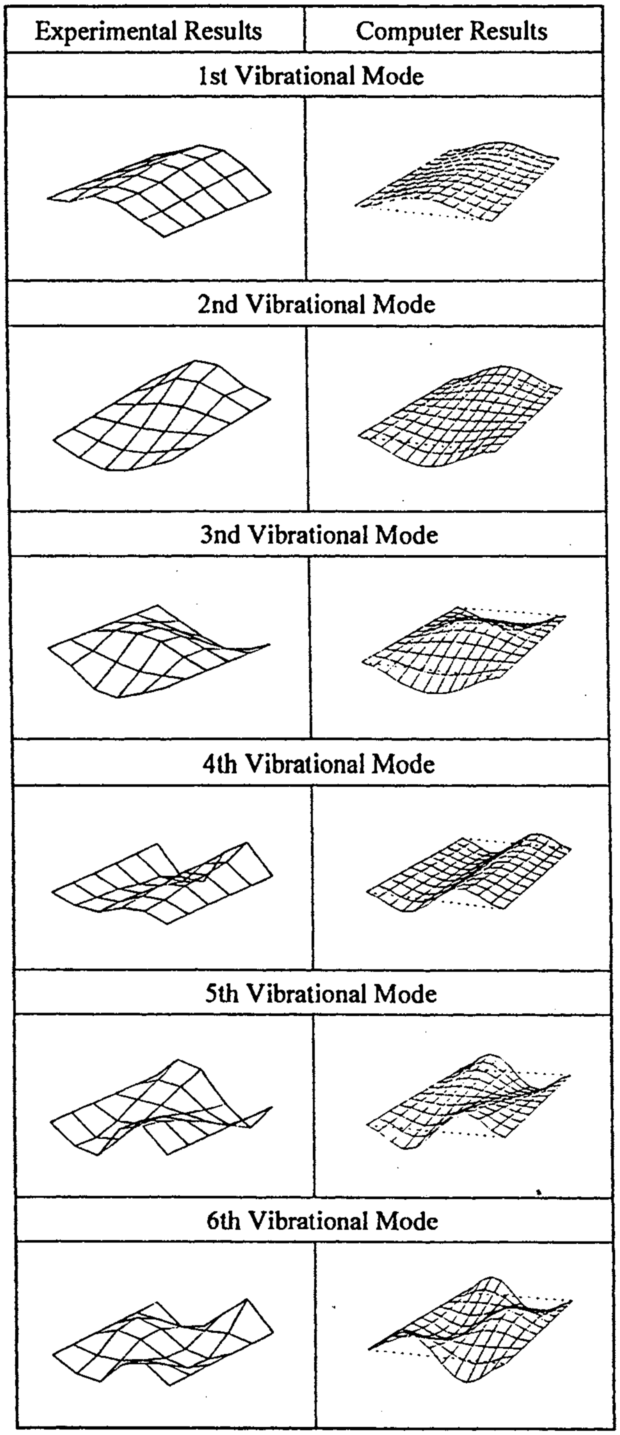

Fig.5 Comparison of vibrational mode between experiment and calculation (Model T-2(25))

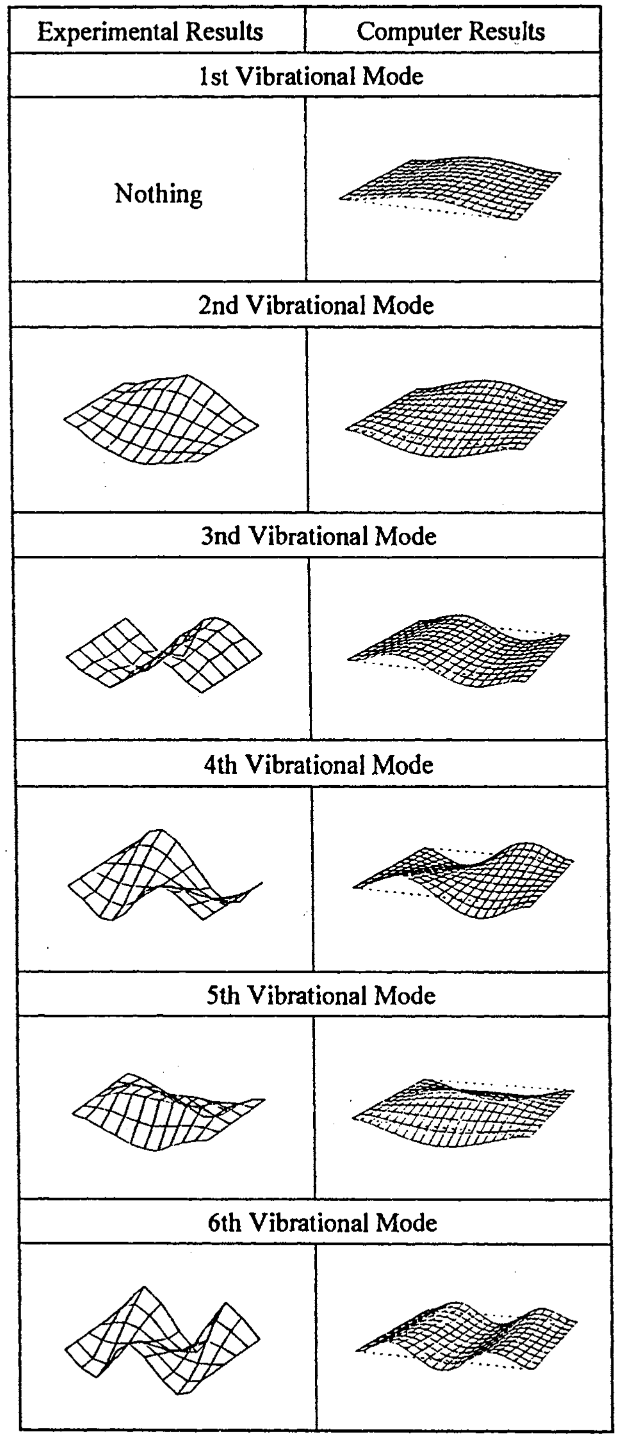

Fig.6 Comparison of vibrational mode between experiment and calculation (Model T-2(50))

of in-water, respectively. Two opposite edges built-in, two other edges free supporting conditions were employed for all testing models alike. In this paper, the results from only Model T-2(25) is shown as a reference, since other models show same or quite similar tendency. Here, it was confirmed that mode shape was decided of varying aspect ratio. In Table 3 up to Table 5, 1st vibrational natural frequencies from the experiment are omitted. The reason occurs from the analyzing capacity of own FFT apparatus. It can be presumed that frequency less than 5 Hz is not suitable for analysis judging from the other experiment. Comparing the both results by the each mode, respectively, mode shape of experimental results comes to agree to computer mode shape totally, but some differences and error are observed from computer results. Besides, it was

Table 3 Comparison of present experimental results with Computer results (Model T-1(25)) [Hz]

	In Air			InWater		
Vibrational Mode Order	Experimental Results	Computer Resuluts	error (%)	Experimental Results	Computer Resuluts	error (%)
1st	12.97	10.32	0.26	—	7.34	—
2nd	14.41	11.95	0.21	7.30	8.49	0.14
3rd	23.74	19.68	0.21	13.25	13.83	0.04
4th	32.63	28.63	0.14	15.88	20.16	0.21
5th	34.55	30.97	0.12	18.74	21.83	0.14
6th	43.45	36.52	0.19	26.61	25.26	0.05

Table 4 Comparison of present experimental results with Computer results (Model T-2(25)) [Hz]

	In Air			InWater		
Vibrational Mode Order	Experimental Results	Computer Resuluts	error (%)	Experimental Results	Computer Resuluts	error (%)
1st	17.30	19.90	0.13	8.54	14.07	0.39
2nd	20.20	23.17	0.13	12.85	16.31	0.21
3rd	35.31	37.20	0.05	23.59	25.19	0.06
4th	47.49	55.47	0.14	28.09	38.20	0.26
5th	51.05	60.14	0.15	34.05	41.58	0.18
6th	67.32	68.65	0.02	46.82	43.76	0.07

Table 5 Comparison of present experimental results with Computer results (Model T-2(50)) [Hz]

	In Air			InWater		
Vibrational Mode Order	Experimental Results	Computer Resuluts	error (%)	Experimental Results	Computer Resuluts	error (%)
1st	7.54	5.07	0.49	—	4.06	—
2nd	9.93	7.78	0.28	6.01	6.24	0.04
3rd	17.79	14.00	0.27	8.79	11.20	0.22
4th	22.00	18.21	0.21	13.53	14.59	0.07
5th	28.72	25.13	0.14	19.07	20.06	0.05
6th	33.00	27.68	0.19	24.63	22.10	0.11

observed that as 6th mode shape in modal experimental analysis had skipped, 6 mode shape drawn by the experiment coincided with 7th mode shape given by calculation results. Here, Mesh division is different number in experimental analysis and numerical calculations. At first stage, same number of facets and same size (2.5 cm x 2.5 cm) were adopted, but good results were not obtained in the experiment. Therefor, the size of facet in the experiment was employed different size from the calculation as shown in Fig.1 and Fig.2. It was found that good results would not be obtained by increasing number of facets in the experiments.

In Fig.7, all values of natural frequency in air show greater than the case of in-water. This is natural results occurred by added mass effect. Comparing Model T-1(25) with Model T-2(25) by the thickness of plate, Model T-2(25) shows higher frequency than Model T-1(25). The reason is Model T-2(25) has higher rigidity. In comparison of varying aspect ratios of Model T-2(25)

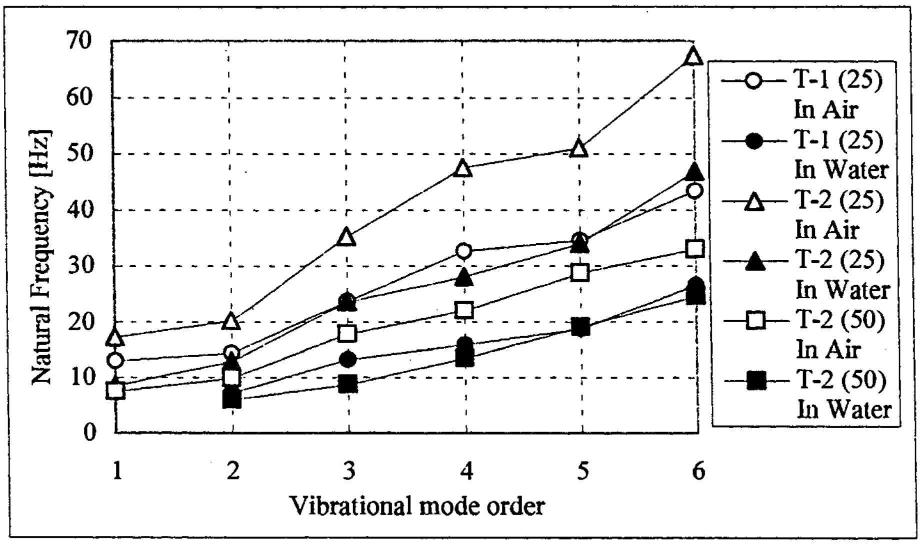

Fig.7 Comparison of natural frequency by modal experiment in air and in water

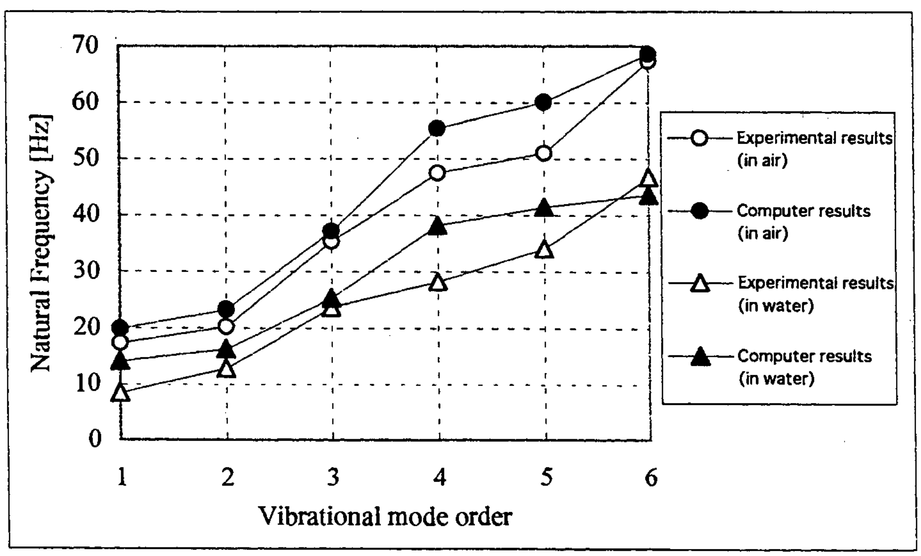

Fig.8 Comparison of natural frequency of model T-2(25)

and Model T-2(50), Model T-2(25) having higher rigidity shows natural frequency becomes higher. From our modal experiment, it is confirmed firmly that natural frequency was affected by the rigidity of plate as prediction by theoretical development.

Fig.8 shows comparison of natural frequencies of Model T-2(25) obtained by experiment and numerical calculation in the case of in-air and in-water. From this comparison, experimental results are obtained smaller values than computer results. Maximum error denotes 15%. This case shows a satisfactory agreement. Results of natural frequency on Model T-1(25) and Model T-2(50) in this paper are shown in Table 3 to Table 5 in stead of figures. It is found that experimental results are larger than computer results in air. As the testing model has a structural damping, the experimental values must become smaller than results obtained from theoretical development. Complete opposite feature is shown in comparison with Model T-2(25), in this point there exists inconsistent which can not be explained. Lager errors appear at lower mode in both models, and these data are not reliable. With regard to the unreliable data obtained by modal experimental analysis and computer results, the following causes are considered;

- The rigidity of Model T-1(25) and T-2(50) are lower than that of Model T-2(25). It is inferred the cause is relating to the capacity of own FFT Analyzer.
- The supporting condition was assumed two opposite edges built-in, two other edges free conditions in the theory, but there might be error that this condition satisfying the assumption was Not simulated in model testing. There is a possibility that natural frequency included the supporting frame as total system.
- The estimation of added mass was not validity, the follow-up model test and theoretical development simultaneously have to be being continued. So far, the case of in-air has been described.

In the case of in-water, Table 3 to Table 5. 1st up to 5th mode of all testing models show that experimental results are smaller than computer results, but the inversion phenomenon at 6th mode occurs between experimental and computer results. In the case of in-air, though the results with regard to Model T-2(25) come to good agreement, other models did not obtain satisfactory results. Therefore the results in the case of in-water were not reliable, and it is utterly impossible to give any comment by that reasons as above. Feature compiled to add here is that same tendency are observed in vibrational mode shapes by experiment.

CONCLUSIONS

Following conclusions are addressed by the above studied.

- In the experiment and calculation, values of natural frequency in air are larger than those in water as natural conclusion. It is found that water effects are estimated.
- Properties of testing models which will be used in next experiment had to be considered carefully by the capacity of own FFT Analyzer. Using of silicone rubber, some views for preparing the testing model have been obtained.
- Model-2(25) has the highest rigidity among three models. It can be judged from properties of model and from inspiration that natural frequency greater than 5 Hz should be set up to 1st vibrational mode.
- A Firm supporting frame excluding the vibrational system completely has to be arranged for the experiment.

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MODAL EXPERIMENTAL STUDY ON ELASTIC VERTICAL CIRCULAR CYLINDRICAL SHELL IN WATER

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ABSTRACT

To analyze natural frequency of structures surrounding by water based on the fluid-structure coupled vibration problem, there is an assumption to make it possible by the proper estimation the added mass of structure. Surveying past published papers until just recently, the greater part of them are only related to the theoretical developments, and the experimental study exists little except response analysis of marine structures by ocean wave. Since water motion shows complicate behavior even though linear wave theory is applied in water tank test, it cannot be stated as yet that advanced and highly theoretical analysis given by researchers the other years has verified the validity of natural frequency existing in actual phenomena.

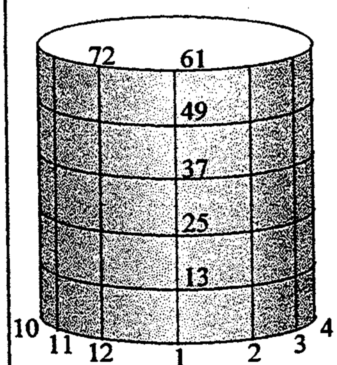
This paper reports the discussions of natural frequency analysis of clamped-free elastic cylindrical shell in water through the comparison between data obtained by modal experiment and numerical calculation.

INTRODUCTION

The subject of fluid-structure interaction analysis arouses much interest to researches and structural designers in ocean engineering field. In our research laboratory, the coupled vibration as one of interaction problems has been studied by theoretical approach and water tank experiment to present time. If added mass of submerged portion of oceanic structures is estimated properly, the structural design will become possible by combining the added mass into structural mass as well as buildings on the land. The goal of our research work carried out is to propose a method of calculation of added mass with regard to elastic body such as shell, plate, etc. surrounding by water. Since Finite Element Method(FEM) program for structural analysis is being used widely in common with most engineering fields, added mass analysis is aimed at combination with FEM. The purpose of this paper is to obtain natural frequency of clamped-free cylindrical shell in water by modal experiment. If the comparison between experimental results and computer results comes to good agreement, it verifies that the assumption is validity and calculation method of added mass should be correct. Cylindrical shell has two types of vibrational mode, which are longitudinal axial mode(m) and circumferential mode(n). In order to obtain natural frequency depending on m and n mode order, modal analyzer system is necessary device in the experiment, which system is composed of STAR System, FFT analyzer, impulse hummer, miniature accelerometer, etc. (see Table 1). As the observation of coupled vibration phenomenon in water tank test could be seen well and the simulation of elastic vibration came possible, the testing models were made of silicone rubber. The experiments of two models were carried out by changing water-depth systematically. The discussions and conclusions are described from the views obtained by experimental results and comparisons with computer results.

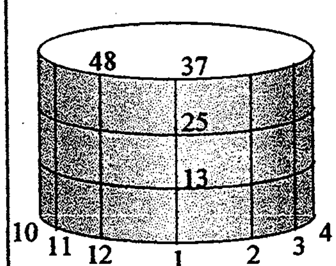
MODEL TESTS

Cylindrical shell models were prepared two types for testing. Those models were made of silicone rubber(KE-112), which were hardened by two kinds of catalyst(CAT-112 and CAT-RM). Schematic of two models, properties and arrangement of measuring points are shown in Fig.1 and Fig.2, respectively. Ratios between water-depth and overall length of model employed 0.0, 0.2, 0.4, 0.6, 0.8 to Model 1 and also 0.0, 0.33, 0.66 to Model 2.



Overall Length (BH)	38.5 cm
Radius (R)	20.25 cm
Thickness (t)	1.0 cm
Elastic Modulus (E)	38.52 kg / cm^2
Poisson's Ratio	0.47
Density	1.20 $\times 10^6$ kg sec^2 / cm^4
Measuring Point	NO.46 (Total 72 points)

Fig.1 Outline of Model 1



Overall Length (BH)	23.4 cm
Radius (R)	20.25 cm
Thickness (t)	1.0 cm
Elastic Modulus (E)	38.52 kg / cm^2
Poisson's Ratio	0.47
Density	1.20 $\times 10^6$ kg sec^2/ cm^4
Measuring Point	NO.26 (Total 48 point)

Fig.2 Outline of Model 2

Regarding to the experiment and its procedure, after those models were installed in air and in water under the clamped-free supporting condition, the impulse hummer made the models vibrate. Transmitted acceleration between measuring point and hitting point were measured by a miniature accelerometer. The miniature accelerometer was fixed at one point on the model. Hitting point by the hummer were moved along measuring points. Each point was hit by 8 times, respectively. This becomes equivalent to what hitting points are fixed on one point and miniature accelerometer moves around among measuring points. Frequency response function were obtained by FFT analyzer. The STAR System gave modal parameter by the frequency response obtained from FFT analyzer and drew mode shape animation. The relation among longitudinal axial and circumferential mode order judging from animation and natural frequency can be clear, and added mass depending on mode orders can be examined. The purpose of this research is to obtain natural frequency in longitudinal(=m) and circumferential mode orders(=n). The model materials and experimental apparatuses are shown in Table 1, and the model number and its maker also are shown.

Table 1 Testing model materials and the makers

FFT Analyzer	CF-360Z	Ono Sokki Co., Ltd	Japan
Impulse Hummer	5850A	Dytran Instruments, Inc.	U.S.A
Miniature Accelerometer	3115A	Dytran Instruments, Inc.	U.S.A
Silicone Rubber	KE-112, CAT-112, CAT-RM	Shin-Etsu Chemical Co., Ltd	Japan
STAR System	Ver.5.1	Structural Measurement System, Inc.	U.S.A

DISCUSSION OF RESULTS

Experimental results obtained by modal analysis are shown in Fig.3 to Fig.16. Fig. 3 up to Fig.10 show natural frequencies of Model 1 and Model 2, respectively, in the variations of water-depth. Fig.11 - Fig. 16 also show natural frequencies under fixed m mode.

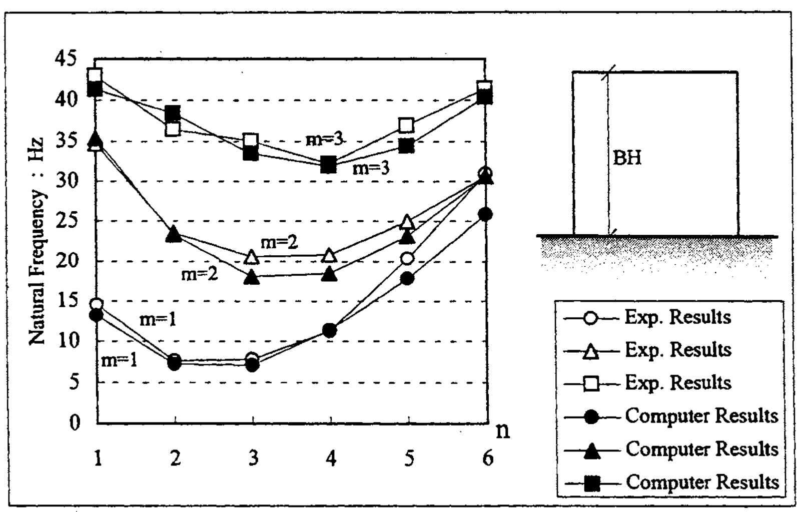


Fig.3 Comparison with Computer Results
of Natural Frequency on Model 1 (h/BH=0.0)

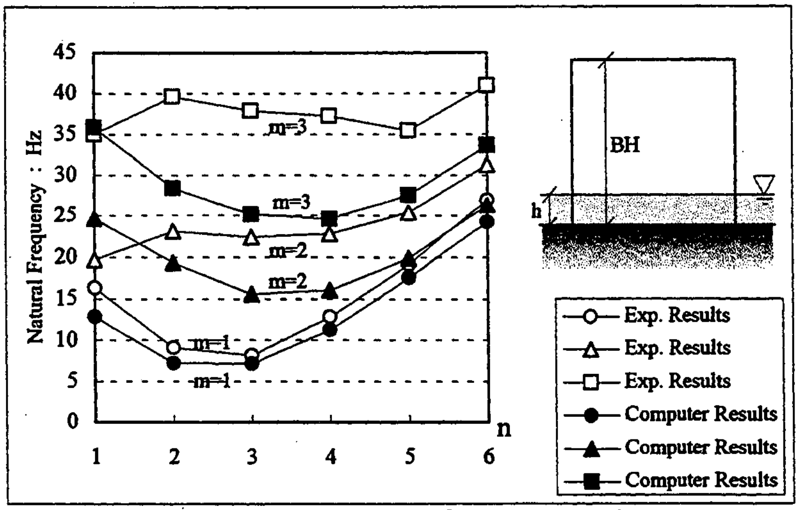


Fig.4 Comparison with Computer Results
of Natural Frequency on Model 1 (h/BH=0.2)

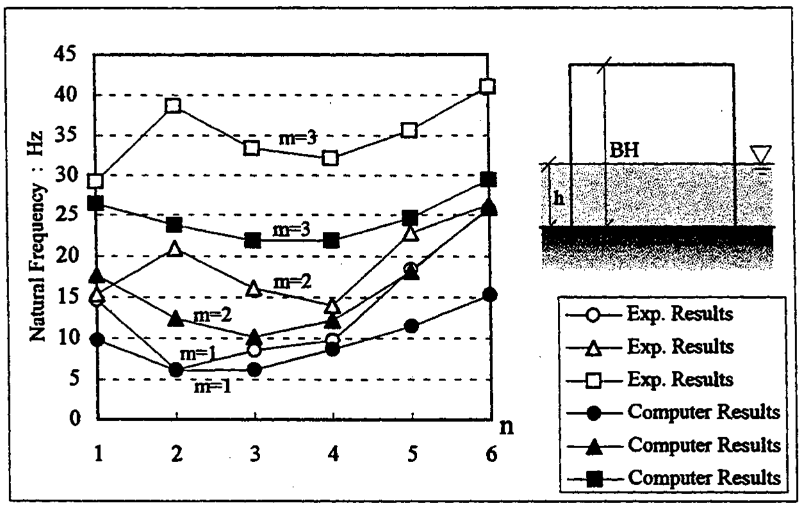


Fig.5 Comparison with Computer Results
of Natural Frequency on Model 1 (h/BH=0.4)

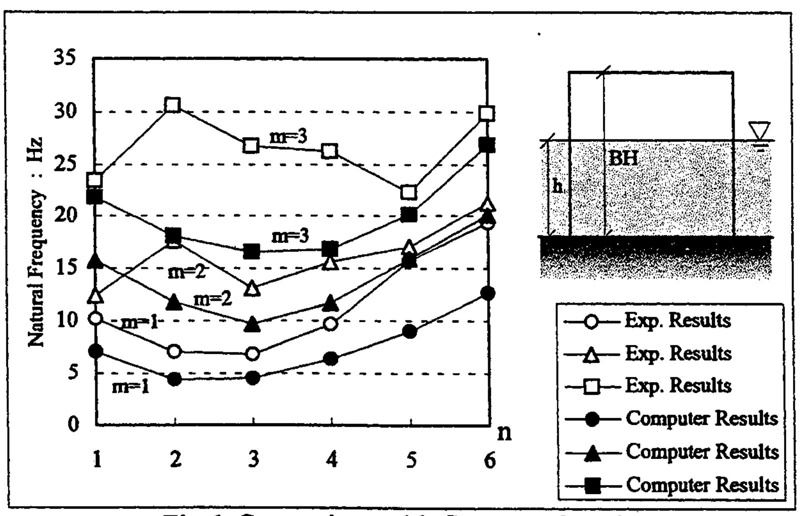


Fig.6 Comparison with Computer Results
of Natural Frequency on Model 1 (h/BH=0.6)

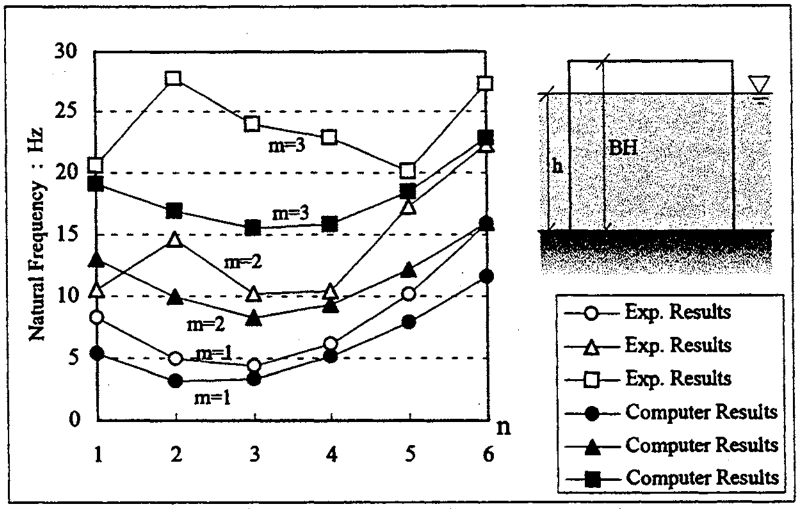


Fig.7 Comparison with Computer Results
of Natural Frequency on Model 1 (h/BH=0.8)

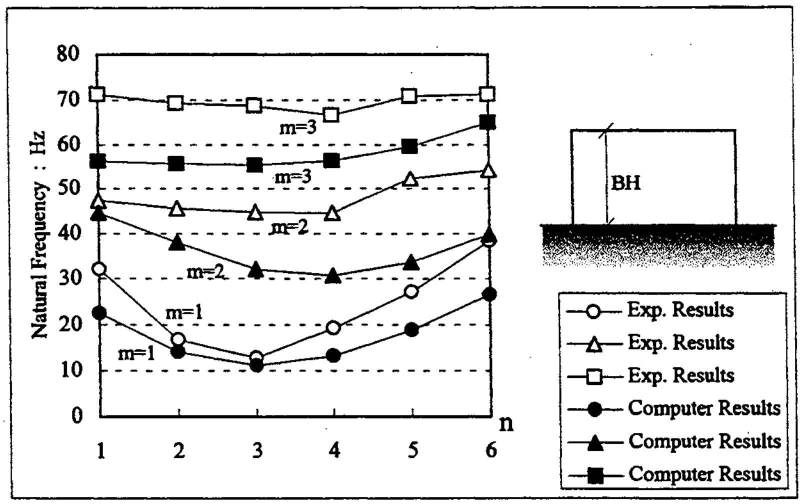


Fig.8 Comparison with Computer Results
of Natural Frequency on Model 2 (h/BH=0.0)

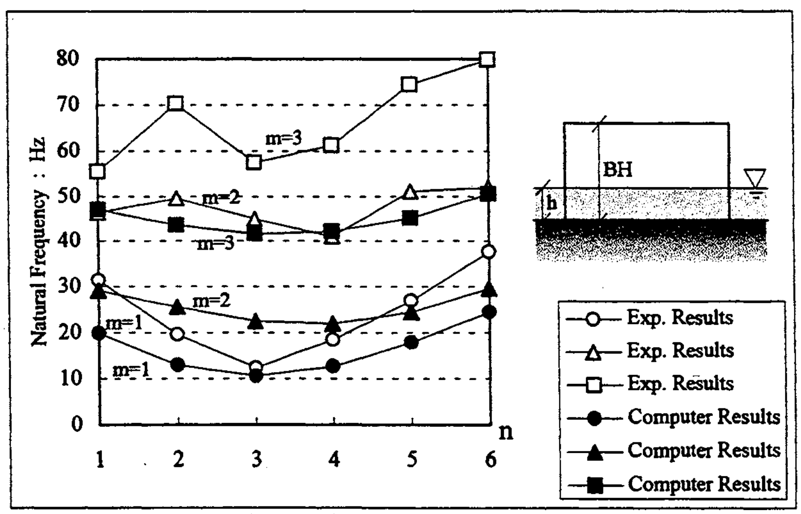


Fig.9 Comparison with Computer Results
of Natural Frequency on Model 2 (h/BH=0.33)

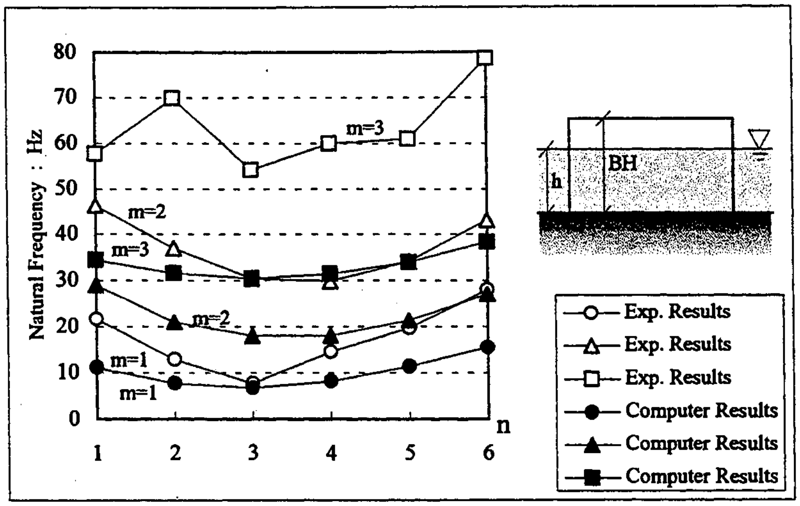


Fig.10 Comparison with Computer Results
of Natural Frequency on Model2(h/BH=0.66)

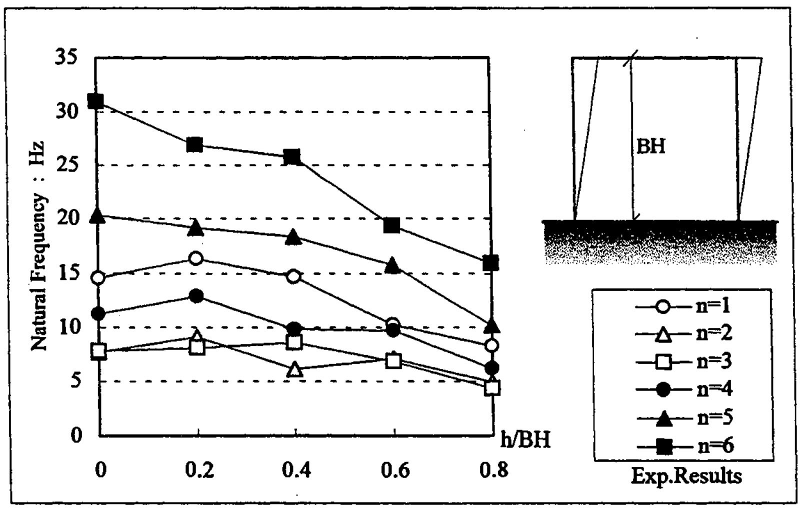


Fig.11 Natural Frequency of Model 1 by Variations of Water-Depth
under the Fixed Longitudinal Axial Vibrational Mode Order , m=1

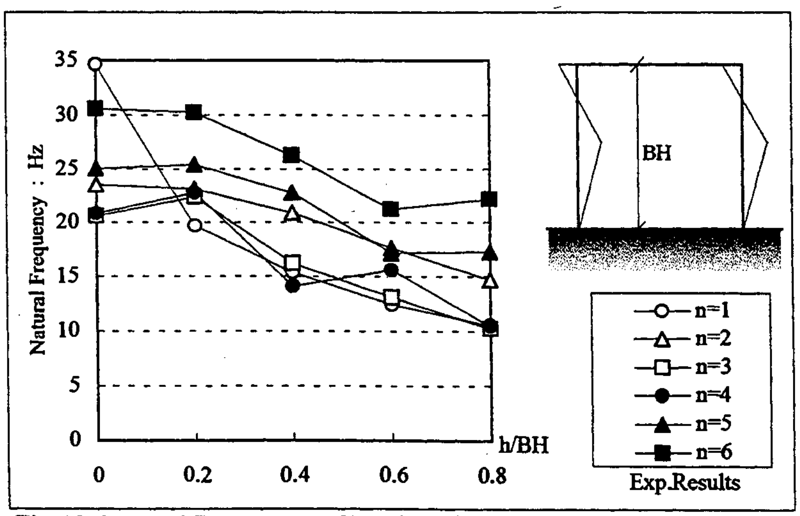


Fig.12 Natural Frequency of Model 1 by Variations of Water-Depth
under the Fixed Longitudinal Axial Vibrational Mode Order , m=2

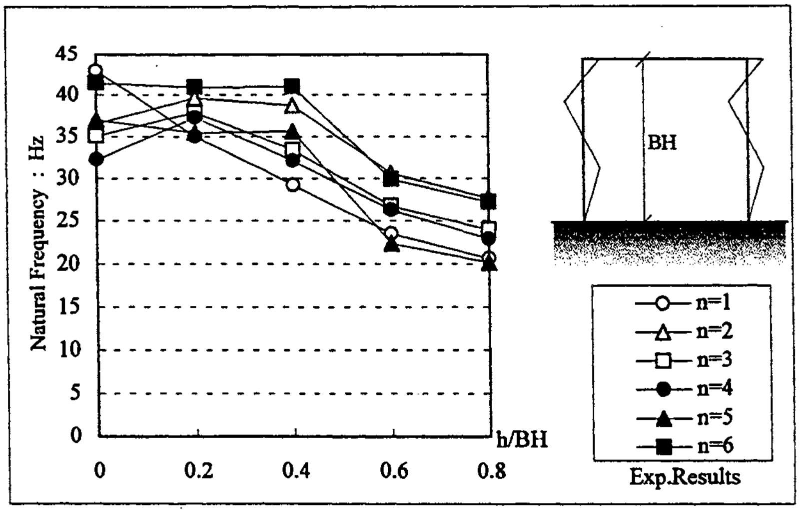


Fig.13 Natural Frequency of Model 1 by Variations of Water-Depth under the Fixed Longitudinal Axial Vibrational Mode Order , m=3

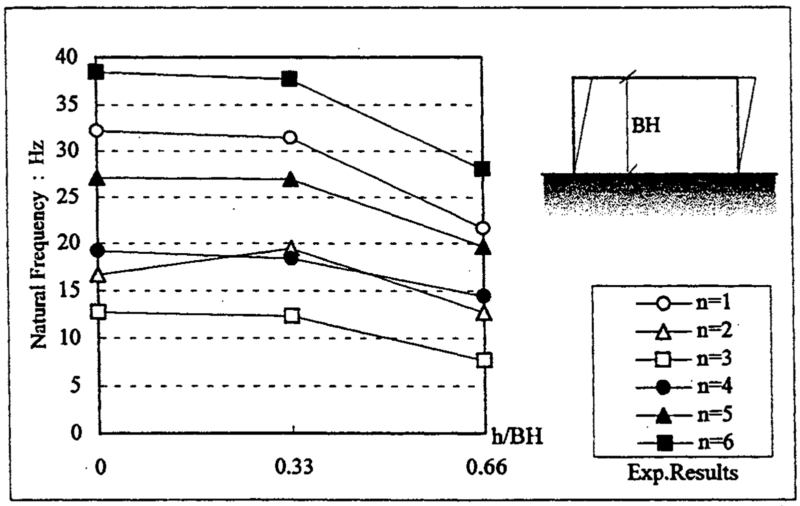


Fig.14 Natural Frequency of Model 2 by Variations of Water-Depth under the Fixed Longitudinal Axial Vibrational Mode Order , m=1

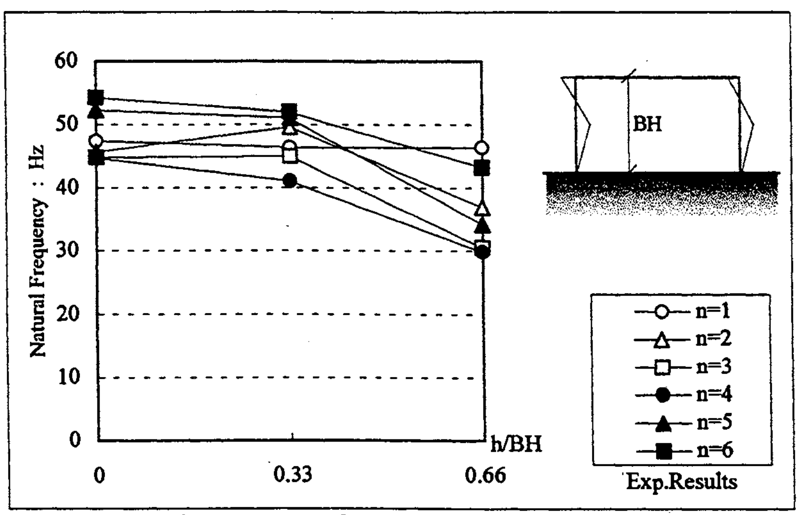


Fig.15 Natural Frequency of Model 2 by Variations of Water-Depth under the Fixed Longitudinal Axial Vibrational Mode Order , m=2

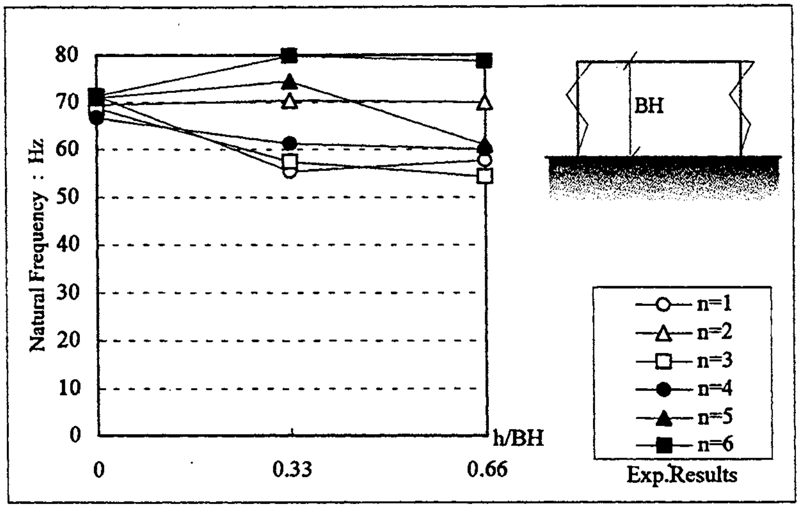


Fig.16 Natural Frequency of Model 2 by Variations of Water-Depth under the Fixed Longitudinal Axial Vibrational Mode Order, m=3

1. Comparisons in the variations of water-depth

The views obtained from the testing of Model 1 are demonstrated in Fig.3 to Fig.7.

Fig.3 shows the comparison of natural frequency in case of in-air. The purpose of this comparison is to check the error of computer program developed by FEM by omitting the extra factors affected from water motion and by making simple condition. The results come to agree with computer results to satisfactory degree except (m,n) =(1,6). Fig.4 to Fig.7 are cases of in-water. Totally, two remarkable views are founded from these figures. First, every computer result shows horseshoe shape distribution. Except m=1, natural frequency at n=1 obtained by experiment denotes lower value than those at n=2, here the horseshoe shape is broken. But this feature exists commonly in Fig.4 to Fig.7. Next feature is, though equations in theoretical development does not include variable of structural damping, experimental results show greater value than computer results. In more detailed study between experimental and calculation results changing the water-depth, the dispersion can be seen widely among the values, it is considered that there might be error in added mass estimation .

The results obtained from the testing of Model 2 are shown in Fig.8 to Fig.10. As the difference of models, the overall length of Model 2 is shorter than Model 1, arround 60%, both diameters of cylindrical shell have same size. In these figures, it is found that all experimental values in air and in water denote greater than computer results. Agreement is admitted only at the lowest frequency at the horseshoe shape; (m,n)=(1,3). Others doesn't come to agree. Fig.8 shows the comparison in case of in-air as well as Fig.3. Good agreement can not be seen here unlike Model 1. In m=1, horseshoe shape keeps and the tendency is roughly similar with computer results. The distribution becomes flat at m=2 and m=3. Fig.9 and Fig.10 show the case of h/BH=0.33 and 0.66. As m becomes greater, errors increase among the values. As mentioned in Fig.8, it is difficult to discuss by the testing results in air. It has been said in general that analysis of short cylindrical shell is more difficult than longer one.

2. Views from the fixed longitudinal axial vibrational mode order

Fig.11 up to Fig.13 show natural frequency of Model 1 in the variation of water depth under fixed vibrational mode order; m. Fig.11 shows natural frequency at m=1. General tendency shows to go down toward the right. As the water-depth is increasing, value of natural frequency is becoming lower by added mass effect. Though expressions of Fig.3 to Fig.10 are different ways as described above, the horseshoe shape can be observed here through this figure, since added mass is combined to structural mass. Fig.12 shows the similar tendency as well as Fig.11. Also the same tendency, which is going down along the water-depth increase, is shown in Fig.13. The distribution at m=3 denotes narrow belt and frequency becomes higher than at m=1 and m=2. It can be presumed that as m becomes greater, the difference relating to n takes smaller value. There are some cases that lines connected with n cross each other irregularly. Judging from Fig.3 to Fig.7, these are understandable cases. Fig.14 up to Fig.16 show results of natural frequency of Model 2. Though data are not reliable, discussion of the cause will be tried. Fig.14 show at m=1 and Fig.15 is at m=2, the tendency is shown here to go down toward the right. As to Fig.16 of m=3, this case describes different feature from Fig.14 and Fig.15. At h/BH=0.0, every value concentrates on 70 Hz. As m becomes higher, it is inferred that natural frequency will converge on the some value. This can be understood from what added mass does not depend on the frequency, and what added mass will converge on one point is well known in high frequency range.

CONCLUSIONS

Natural frequency experiment of elastic cylindrical shell models with the clamped-free condition in water, was carried out by modal analyzer. Theoretical analysis of this cylindrical shell as the research subject of coupled vibration problem by some researchers, has been presented, but experimental approach yet time has passed without any person ever setting his hand except our works. In this paper, It is inferred that the data obtained from theoretical development, if anything, are not more reliable than experimental results, but the experimental results are left with some problems which have to be resolved, too. From this view, the offer of data becomes useful and valuable for other researchers. Data has to be expected to accumulate as a great deal as possible. From the discussion as above, the following conclusions can be addressed. Experimental results of Model 1, especially show good agreement with computer results obtained in air. As to Model 2, the tendency of distribution is only similar to the same case. Experimental values of natural frequency at m=2 and 3 and n=2 break the regular distribution of horseshoe shape obtained from numerical calculation. The cause of this phenomenon can be presumed by hydrodynamic force takes the largest value at n=1. This is studied as follows. As mode shape of n=1 is presented by cos θ of Fourier series such as rigid motion, the hydrodynamic force works on circumferential element totally. Other modes; cos n θ mode, act each other to cancel the force and makes total force smaller. And also added mass depending on vibrational mode can not be explained well by theoretical development. Finally, as the other reason, there is a possibility that it comes out own character of models. Experimental results are obtained greater than computer results in spite of neglecting structural damping in theoretical development. In general, models have same tendency between both data in variation of water depth, but obtained values denote large difference. So far, it is may be concluded that the cause occurs from the estimation of added mass. In the future, accumulating the experimental data, more detailed evaluation of added mass will have to be continued.

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DISPLACEMENT ANALYSIS OF FLOATING OCEANIC ARCHITECTURE BUILDINGS BY FRAMED STRUCTURE SYSTEM

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ABSTRACT

Greater than 50 % of floating oceanic architecture buildings existing in Japan have been constructed by the used ships. In the change of uses of these buildings, and in order to keep larger space in adjustment to the uses, the large scale rebuilding will be done by removal of some main members. Recently, for the preservation of ocean environment, the dismantle and removal of oceanic structures which ended their role is becoming the problem.

The purpose of this paper presents some findings with regard to the displacement analysis of oceanic architecture buildings constructed by three dimensional framed structures. In the future, it will become useful for the elucidation of failure mechanism based on reliability analysis regarding to structural design and fabrication method due to the dismantle & removal and prevention against disaster such as collapsed buildings.

INTRODUCTION

This paper reports some views obtained from displacement analysis of two story floating structures. The floating structural model for our study was assumed by three dimensional framed structure, and the theoretical development was done by FEM using static analysis. Input load deals with dead load, living load, hydrostatic pressure, wind load and wave load, and the numerical calculation was conducted by the combination of these loads. The combination did not introduce load coefficient, and these loads were added simply, and 4 patterns were set up as the combination. The stage of removing member of framed structures was adopted four steps, and the displacement was studied by each step under four combinations of the loads. The obtained displacements at selected interception points are discussed, and concluding remarks through the discussions are addressed.

THEORETICAL ANALYSIS

The theoretical development was adopted static analysis by three dimensional frame structure by FEM.

Nodal point force at an element expressed by local co-ordinate is given by stiffness equation as

$\{ f_e \} = [k_e] \{ \delta_e \}$ (1)

where $[k_e]$=stiffness matrix of element ; $\{ \delta_e \}$ = nodal point displacement vector by local co-ordinate ; and subscript e=element.

$\{ \delta_e \}$ is represented as

$\{ \delta_e \} = [T_e] \{ \bar{\delta}_e \}$ (2)

where $[T_e]$ = transformation matrix ; $\{ \bar{\delta}_e \}$ = nodal point displacement vector by global co-ordinate.

Nodal point force is written as well as the expression of nodal point displacement of Eq. (2).

$\{ f_e \} = [T_e] \{ \bar{f}_e \}$ (3)

where $\{ f_e \}$ = nodal point force vector by local co-ordinate ; and $\{ \bar{f}_e \}$ = nodal point force vector by global co-ordinate.

Substituting Eq. (2) and Eq. (3) into Eq. (1),

$[T_e] \{ \bar{f}_e \} = [k_e][T_e] \{ \bar{\delta}_e \}$ (4)

Multiply both terms in Eq. (4) by inverse matrix of $[T_e]^{-1}$

$\{ \bar{f}_e \} = [T_e]^{-1} [k_e][T_e] \{ \bar{\delta}_e \}$ (5)

In Eq. (5), since there is relation as $[T_e]^{-1} = [T_e]^T$ in this three dimensional transformation matrix, next Eq. (6) is obtained.

$\{ \bar{f}_e \} = [T_e]^T [k_e][T_e] \{ \bar{\delta}_e \}$ (6)

Let three matrices of right side in Eq. (6) express by $[K_e]$ as follows :

$[\bar{k}_e] = [T_e]^T [k_e][T_e]$ (7)

Eq. 6 is rewritten by Eq. (7) as follows :

$\{ \bar{f}_e \} = [\bar{k}_e] \{ \bar{\delta}_e \}$ (8)

Eq. (8) shows the nodal point force and displacement relation by global co-ordinate. As calculated results by Eq. (8) are expressed by global co-ordinate, those values have to be transformed into local co-ordinate by [T_e].

$$\{f_e\} = [T_e]\{\overline{f}_e\} \quad (9)$$

The calculation was performed by replacing quake resisting wall with brace. After this replacing, the geometrical moment of inertia and the area of cross section of column are denoted as follows:

$$I = A \times (\ell/2)^2 \times 2 \quad (10)$$

$$A = A_0 + (t\ell/6) \quad (11)$$

where I=geometrical moment of inertia after the replacing ; ℓ= width of quake resisting wall ; t= thickness of wall ; A_0 = area of cross section of column ; and A= area of cross section of column after the replacing.

CASE STUDIES

1. Calculation Model

The framed structure as calculation model consisted of two stories with 12 x 5 span shown in Fig.1. All of columns, beams and walls were employed same size of members, besides member spacing among columns and among beams, and ceiling heights were adopted uniform distance.

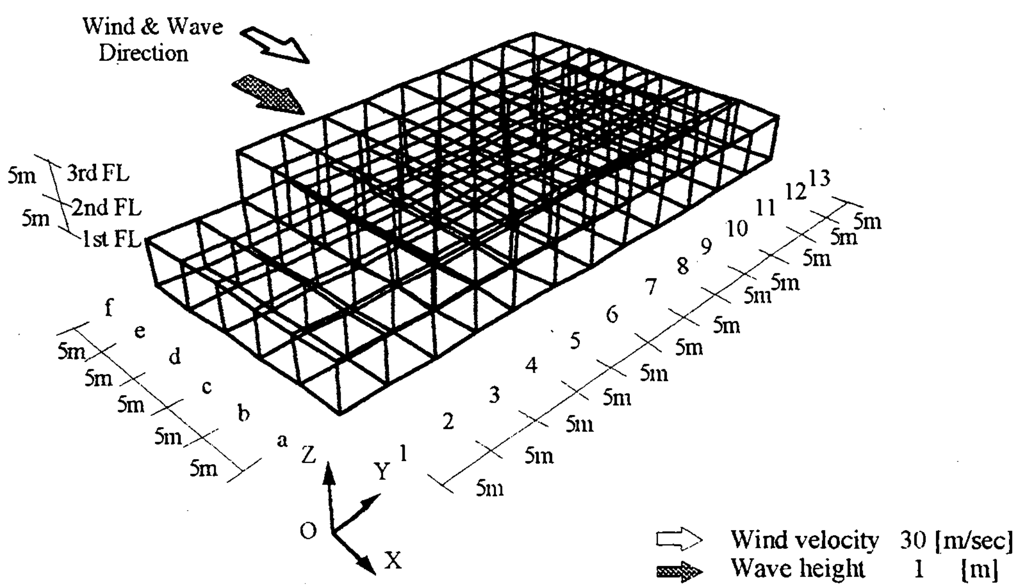

Fig.1 Schematic Sketch of Framed Structure Model

Table 1 Properties of Calculation Model

	Column	Beam
Area of Cross Section	$A=7.50\times10^{-2}$ [m^2]	$A=6.25\times10^{-2}$ [m^2]
Young's Modulus	$E=2.1\times10^{7}$ [t/m^2]	$E=2.1\times10^{7}$ [t/m^2]
Geometrical Moment of Inertia	$Iy=9.375\times10^{-1}$ [m^4]	$Iy=3.255\times10^{-4}$ [m^4]
	$Iz=9.375\times10^{-1}$ [m^4]	$Iz=3.255\times10^{-4}$ [m^4]
Torsional Rigidity	$GJ=6.406\times10^{3}$ [$t\,m^2$]	$GJ=4.449\times10^{3}$ [$t\,m^2$]

2. Displacement analysis

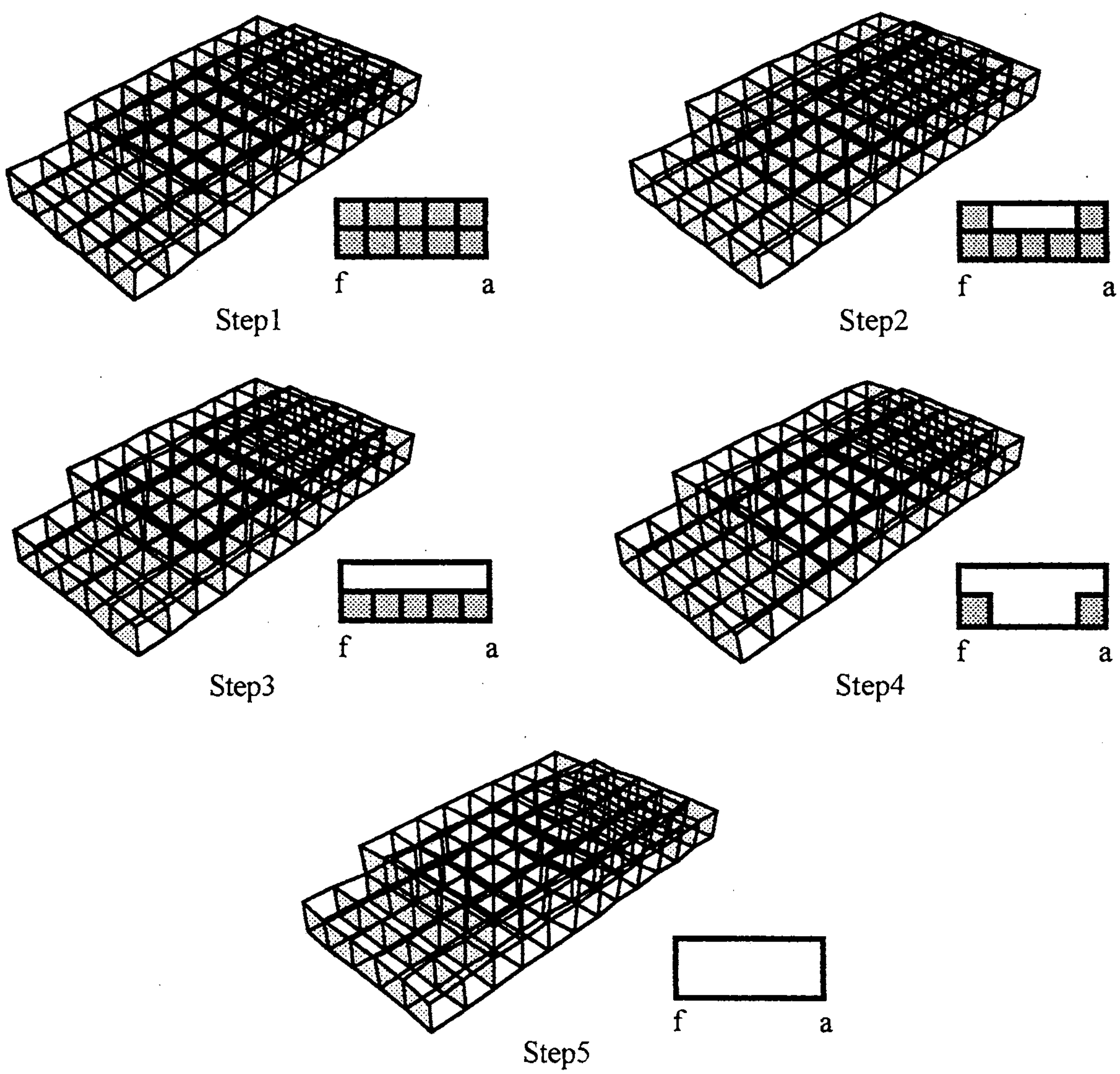

Fig.2 The Removal Step of Framed Structure

In order to keep lager space, it was assumed that columns, beams and walls existing from 4-axis to 10-axis (see Fig.1) were taken away in regular order for this study shown in Fig.2. The part except shade portion shown in each step denotes the space which was kept newly. As to the supporting condition, displacements of z-direction at all intersection points on bottom of structure were fixed, besides displacements of other directions (X , Y) were fixed at 4 points on bottom such as follows: intersection point by a-axis and f-axis with 3-axis , and by a-axis and f-axis with 11-axis.

3. Loads

Regarding to the input forces, five kinds of loads were combined shown in Table 2.

The displacement was calculated by the varying combination. W_{WI} and W_{WA} in Pattern 4 take 1.0, respectively as coefficient of combination. Draft line of structure was considered by each step of removing members of frame work, and which was reflected to load estimation. Fig. 3 shows the change of loads occurred by removing member of frame work. Hydrostatic pressure and wave load become smaller by decreasing loading area due to draft line change, on the contrary wind load increases. Fig. 3 shows the varying load step by removing member of frame work.

Table 2 Load Combinations

Pattern 1	$D_L + L_L + H_S$
Pattern 2	$D_L + L_L + H_S + W_{WI}$
Pattern 3	$D_L + L_L + H_S + W_{WA}$
Pattern 4	$D_L + L_L + H_S + W_{WI} + W_{WA}$

D_L = Dead load , L_L = Living load , H_S = Hydrostatic load, W_{WI} = Wind load , W_{WA} = Wave load .

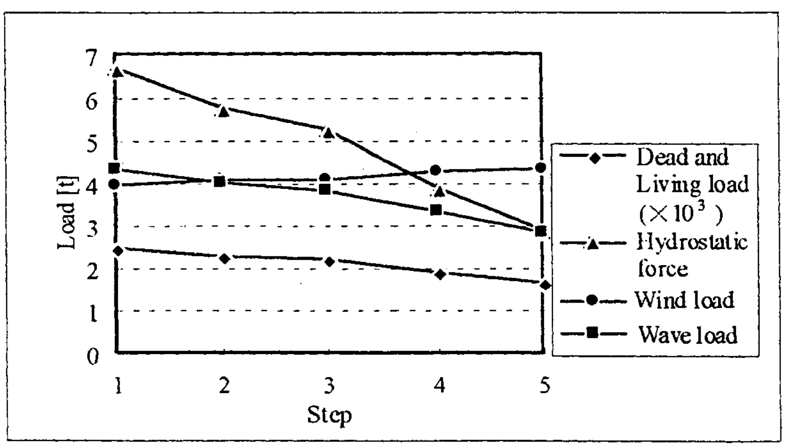

Fig. 3 Varying Load by Removing Member of Frame Work

4. Calculation results

Fig.4-1 to Fig.7-2 show the calculation results of displacement in x-direction and regarding to f-axis of 1st floor and 3rd floor in varying step. Fig.8-1 to Fig.8-2 show the results of displacement of intersection point given by f-axis and 7-axis of 1st (named f-7-1st) and 3rd floor due to removing step and loading pattern. That point was chosen by generating maximum displacement. Fig.9-1 to Fig.9-2 show the calculation results of shearing force of columns on intersection point by f-7-1st and f-7-3rd under the same condition as well as Fig.8-1 and Fig.8-2.

In Fig.4-1, though the hydrostatic pressure acting on the structure by varying step goes down shown in Fig.3, the difference of obtained results could not be observed among steps and intersection points. Both results had been shown by straight and flat distribution and these figures were gotten smaller values of 1/100 order comparing with other cases. Here Fig.4-1 is drawn by magnified scale and Fig.4-2 is drawn by same scale of other Patterns. In this Fig.4-1, there exists the outstanding feature, which phenomenon is that the directions of obtained displacement was inverted by taking away the member. From the displacement orders in these figures, it is admitted that the displacement was not affected clearly by the varying hydrostatic pressure in this calculation model.

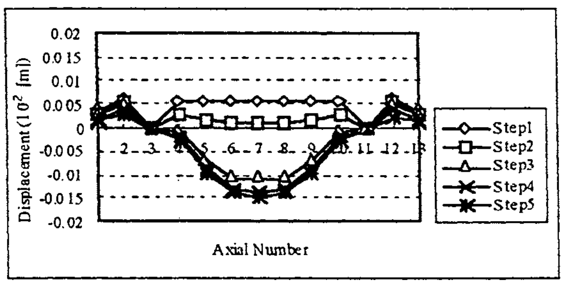

Fig.4-1 Displacement of Pattern 1 of x-direction in f-axis and 1st floor

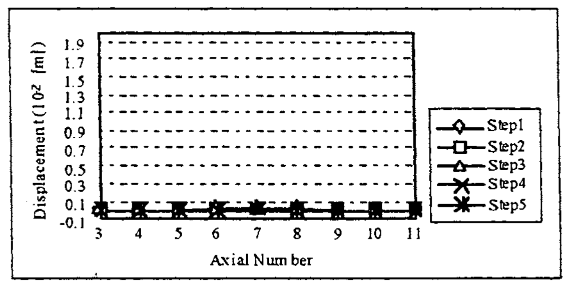

Fig.4-2 Displacement of Pattern 1 of x-direction in f-axis and 3rd floor

Fig.5-1 denotes the displacement of f-axis of 1st floor by adding wind load. As total weight consisted of D_L and L_L becomes light by removing members, the area which charges wind load increases. Consequently the displacement becomes large by varying step. Comparing with calculation results of Pattern 1, the order of obtained displacement denotes very large values. Fig.5-2 shows displacement of 3rd floor, which is obtained greater results than the case of 1st floor. As wind load acts on the structure from one direction, inversion phenomenon shown in Fig.4-1 can not be observed here. This phenomenon might be explained since the distribution of wind load occurred by the acting direction is different from hydrostatic pressure.

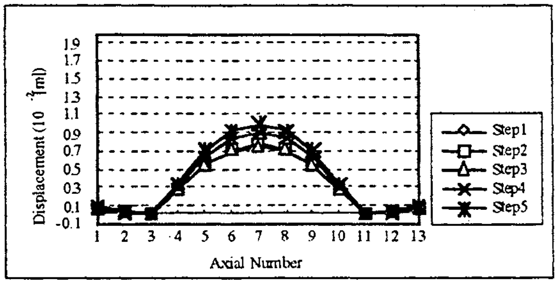

Fig.5-1 Displacement of Pattern 2 of x-direction in f-axis and 1st floor

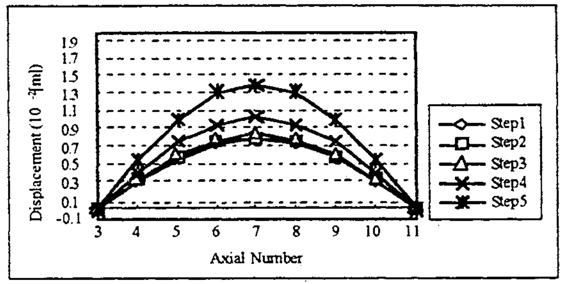

Fig.5-2 Displacement of Pattern 2 of x-direction in f-axis and 3rd floor

Fig.6-1 and Fig.6-2 are relating to Pattern 3. In Fig.6-1, as mentioned above, total wave load decreases because the draft line goes down. From Step 1 up to Step 4, large change of displacement can not be seen, but in Step 5, though wave loads decreases, the displacement increases sharply. This cause is presumed by that the effect of removing members makes themselves than effect of wave loads. In Fig.6-2, the displacement of 3rd floor shows smaller than 1st floor, especially Step 5. Total wave load decreases as mentioned above by the removing member of frame work. By this removing member, the displacement is expected to increase here. But, opposite phenomenon is seen against our prediction.

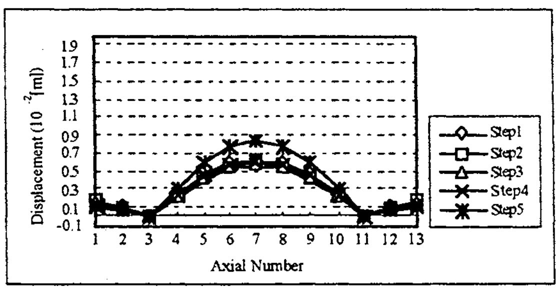

Fig.6-1 Displacement of Pattern 3 of x-direction in f-axis and 1st floor

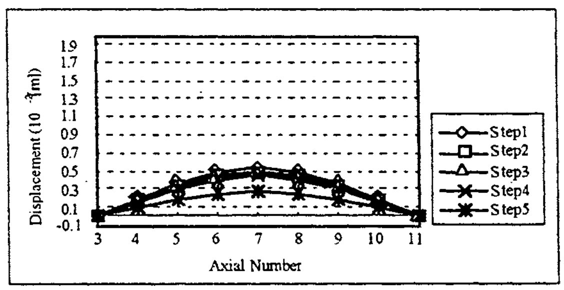

Fig.6-2 Displacement of Pattern 3 of x-direction in f-axis and 3rd floor

Fig.7-1 concerns the displacement obtained by sum of all loads. The displacement of 1st floor is changing regularly depending on varying step. In Fig.7-2, the displacements at the 3rd floor increase as well as Fig.7-1, and also denotes large values comparing with Pattern 1 to Pattern 3 naturally because of sum of loads.

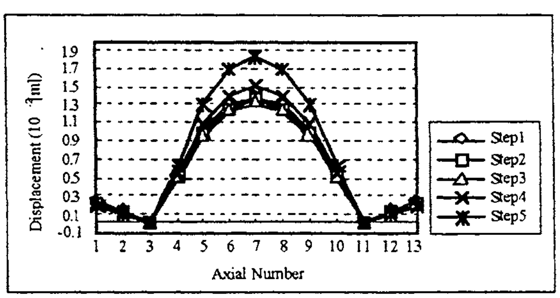

Fig.7-1 Displacement of Pattern 4 of x-direction in f-axis and 1st floor

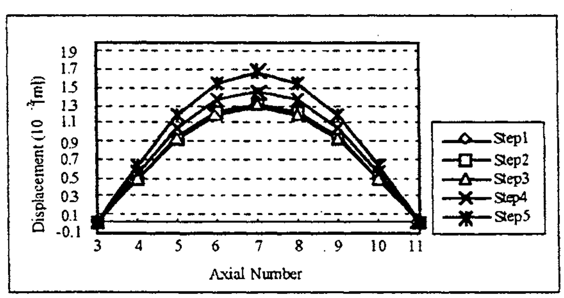

Fig.7-2 Displacement of Pattern 4 of x-direction in f-axis and 3rd floor

Fig.8-1 and Fig.8-2 shows the displacement of a selected point of f-7-1st and f-7-3rd by varying pattern and step. The displacement at the intersection point regarding to Pattern 1 presents flat tendency in both figures. As to Pattern 3, in Fig.8-1 the displacement decreases by varying step. The displacement in Pattern 4 shows loose change until Step 2, but sharp change is presented after Step 3 in Fig.8-1. As to Fig.8-2, the displacement of Pattern 2 goes up by varying step, and different tendency which goes down is observed in Pattern 3.

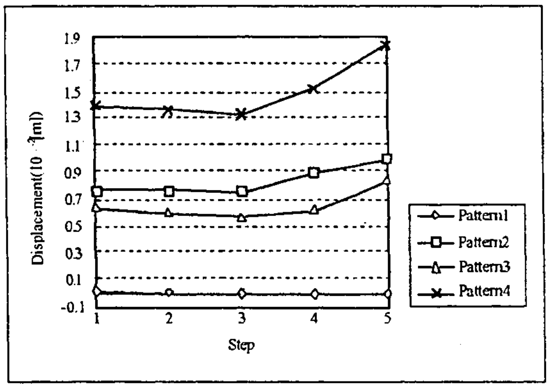

Fig.8-1 Displacement at intersection point by f-axis and 7-axis in x-direction on 1st floor

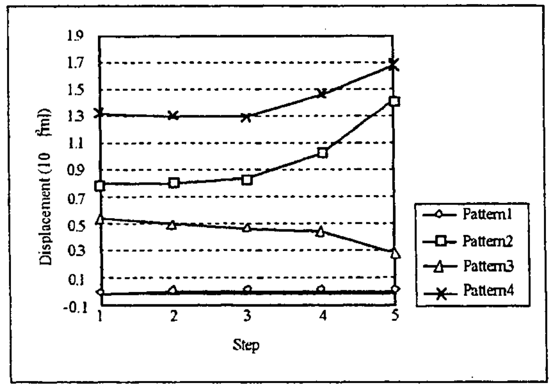

Fig.8-2 Displacement at intersection point by f-axis and 7-axis in x-direction on 3rd floor

Fig.9-1 and Fig.9-2 show the shearing forces of columns on the f-7 point. In Step 2 and Step 3, shearing forces rapidly change. Though the computer program has followed only numerical calculation, it can be said that the member beyond allowable stress goes to damage.

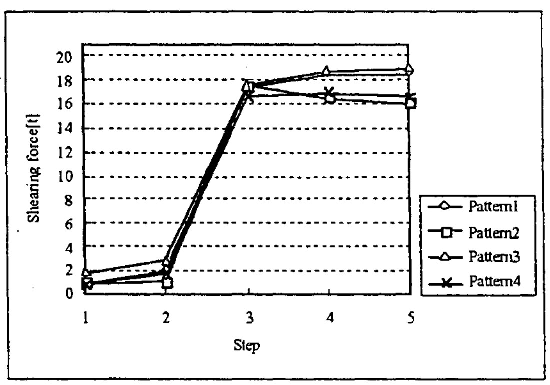

Fig.9-1 Shearing force of column on f-7 intersection point of 1st floor

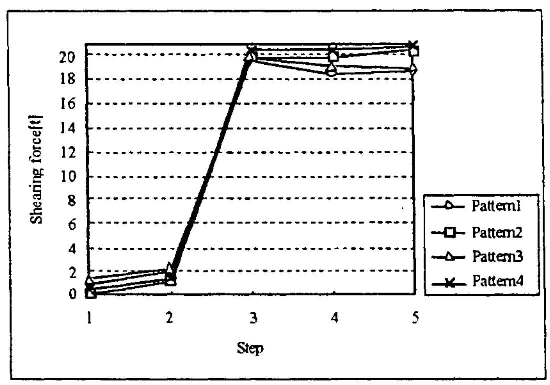

Fig.9-2 Shearing force of column on f-7 intersection point of 3rd floor

The displacement regarding to the plan of 2nd floor is drawn in Fig.10.

The distribution which are symmetrical with respect to central axis between c-axis and d-axis can not be seen naturally by the direction of input loads, but symmetrical to 7-axis.

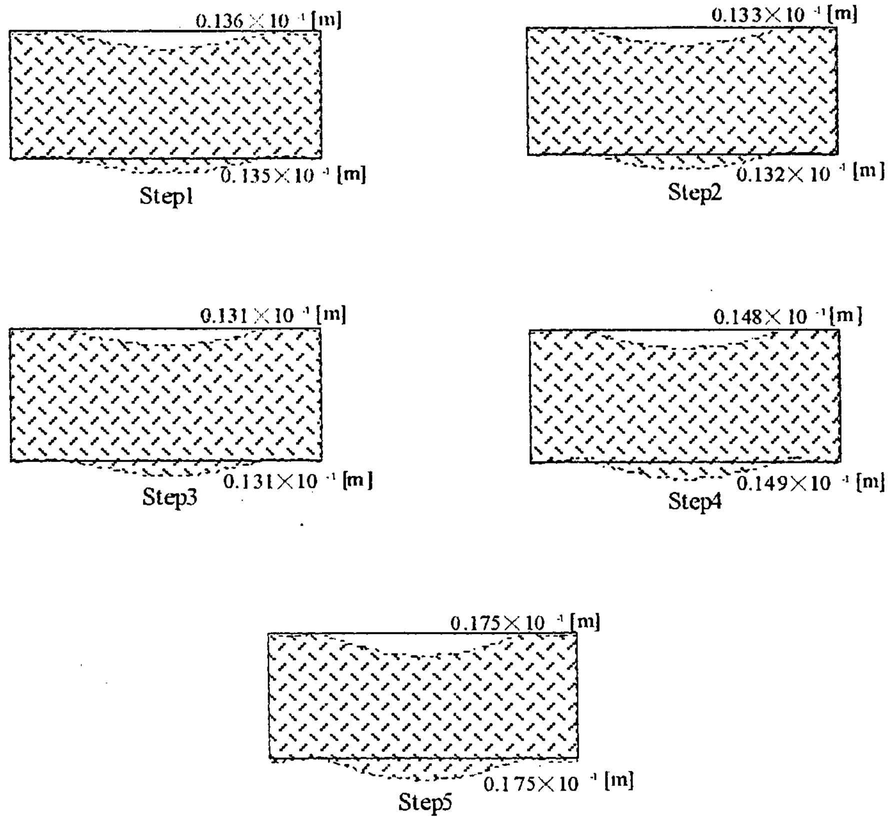

Fig.10 Sketch of 2nd floor Displacement

CONCLUDING REMARKS

The following concluding remarks are stated from the above discussions.

- The displacement was not affected clearly by the varying hydrostatic pressure in this calculation model.
- It is inferred that the effect of removing members makes themselves than effect of wave loads.
- By the removing member, the displacement is expected to increase in Pattern 3 load condition but opposite phenomenon given by step 5 is observed against our prediction.
- The case of Pattern 4 is the sum of all loads, which denotes large values comparing with Pattern 1 to pattern 3 naturally.
- Displacement at intersection point of f-axis and 7-axis of 1st floor regarding to Pattern 1 presents flat tendency, but as to Pattern 2 and Pattern 3, the displacement appears phenomenon to increase slowly by varying step. The displacement in Pattern 4 shows loose change until Step 3, but the change is presented sharply after Step 3.
- The shearing forces of the columns on the f-7 point present rapidly changes in Step 2 and Step 3.
- Though the computer program has given only numerical calculation results, it is better to conclude the damage occurred in framed structure model.

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APPLICATION OF GPS IN MARINE GEODESY

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ABSTRACT

Recent developments in technology and instrumentation have produced a wide range of applications for the use of the Global Positioning System (GPS). For positioning and navigation two different types of positioning services are available, i.e. the precise GPS positioning services (PPS), on the one hand and the standard positioning service (SPS) on the other. A significant change in the field of hydrographic surveys was the introduction of code differential GPS (DGPS) for vessel positioning. In the case of high precision positioning requirements different carrier-phase ambiguity resolution strategies have to be applied. Real-time applications require a data link between reference and rover station and on-the-fly (OTF) ambiguity resolution techniques. Nowadays not only positioning demands can be fulfilled by GPS, but also other marine problems can be solved such as real-time kinematic GPS (RTK-GPS) systems are employed for the measurement of tide and swell, water-borne leveling, determination of vessel orientation or even multi-antenna GPS systems are used for optimal estimation of ship's attitudes.

INTRODUCTION

The marine positioning and navigation market has changed significantly over the past decade. This has been brought about by the rapid acceptance of the use of the Global Positioning System (GPS) as the primary means for navigation and positioning. Within the space of a year the evolution of differential GPS (DGPS) had devastated the traditional market for the conventional radio positioning systems. Operational DGPS services are provided free of charge by many governments to ensure safety of navigation in their territorial waters. In addition commercial DGPS have also been established. Wide Area DGPS Systems (WADGPS) are using also geostationary satellites to broadcast correction and navigation messages. In many areas the offshore community has made use of these.

For precise positioning and navigation real-time kinematic positioning with carrier phases and OTF (on-the-fly) ambiguity resolution strategies have to be applied. Also datum transformations from the satellite coordinate system WGS84 to local grid systems are essential and have to be applied in real-time. High accurate real-time kinematic GPS (RTK-GPS) systems enable the use of GPS for various kind of applications in the field of marine geodesy. Two examples, i.e. the measurement of tide and swell and attitude determination of ships, floating platforms or buoys are described in this paper.

POSITIONING AND NAVIGATION WITH GPS

For positioning and navigation with GPS the Department of Defence (DoD) of the USA provides two different services. The Standard Positioning Service (SPS) can be used by any user and the Precise Positioning Service (PPS) is only available for authorized users. Position determination is performed using C/A-code pseudorange measurements in the SPS and P-code pseudorange measurements in the PPS.

GPS was designed to provide real-time navigational accuracies of less than 20 m to authorized users and accuracies at the 100 m level to the others. With P-code receivers a real-time navigational accuracy of about 10 to 15 m can be obtained. To prevent the access to the P-code for unauthorized users, anti-spoofing (A-S), the encryption of the P-code to the Y-code, was activated with the full operational capability of the GPS constellation in early 1994. However, with C/A-code pseudorange measurements a navigational accuracy of 20 to 40 m in real-time was achieved. Through the implementation of selective availability (SA) in 1990 the position accuracies using C/A-code receivers were degraded to about 100 m (2σ). Maybe in future SA and A-S will not be activated any more. However, the future will not be known until it arrives with the ultimate decision of the White House.

Fundamentals of DGPS

The position accuracy can be increased using differential GPS (DGPS). Depending on the observation type used, three procedures can be distinguished as follows in (Heimberg, Seeber 1994):

- relative positioning with code phases,
- relative positioning with carrier-smoothed code phases and
- relative positioning with carrier phases.

DGPS with code phases can provide relative accuracies in the range of 1 to 10 m and kinematic positioning with carrier phases relative accuracies up to centimeter level. Thereby the relative accuracy of the position is also depending on the distance between the reference and rover station and the moving speed of the rover receiver.

Code DGPS receivers apply usually range corrections which are transmitted from a reference station for the pseudorange measurements to all visible satellites. The standardized RTCM (Radio Technical Commission for Maritime Services) data format is used worldwide for the data transfer. The transmission capacity of the required data link is rather low. In view of selective availability (SA) which causes a strong variation of the range corrections, a rather high update rate for the transmission of the corrections is necessary. To reduce the measurement noise level of the pseudoranges in the rover receiver, carrier phase measurements can be used to perform a combined carrier smoothed pseudorange approach. This algorithm is usually based on the Kalman filter technique.

Most users in marine geodesy are completely satisfied with code DGPS for horizontal positioning. However, for special applications, e.g. in near shore control surveys, hydrography or precise bathymetry, and for vertical positioning, e.g. a ship entering a harbour, accuracies on the decimeter or few centimeter level are required (Heimberg, Seeber 1994; De Loach, Wells, Dodd 1995). Therefore real-time kinematic positioning with carrier phases and OTF (on-the-fly) ambiguity resolution strategies have to be applied. Usually these measurement systems are called real-time kinematic GPS (RTK-GPS) systems.

Real-Time Kinematic GPS

For real-time relative positioning with carrier phases the complete carrier phase data stream has to be transferred from the reference station to the rover station. A higher data communication rate and a higher reliability in the data link is required than as for code DGPS. The RTCM format has also included OTF differential data message structures in the last version of its recommended format standard.

Many techniques have been introduced to resolve the carrier phase ambiguities. Initially these techniques involved post processing and required that both the reference and the rover receiver be stationary for a brief period of time during data collection. Ambiguity resolution techniques while the receiver is in motion offer a more or less similar strategy for resolving ambiguities. Basically, the OTF ambiguity resolution is performed by testing many combinations of ambiguity sets inside a certain predetermined search space. DGPS solutions can be used to create a search space for the estimation of the correct set of integer ambiguities. Further information concerning these technologies can be found e.g. in (Abidin 1994; De Loach, Wells, Dodd 1995).

The speed and reliability of the OTF ambiguity resolution is affected by many parameters. To resolve the ambiguities a minimum number of five common observed satellites on both stations under good station-satellite relative geometry (e.g. GDOP<6) is required. Also the level of observation errors and biases has to be low and a high data rate of 1 Hz or greater is necessary. In principle the OTF ambiguity resolution techniques can be applied either for single or dual frequency GPS measurements. Especially the ionospheric bias degrades the performance of the OTF ambiguity resolution for single frequency data. Nowadays only more expensive dual frequency RTK-GPS systems are available on the market which provide reliable and fast OTF ambiguity resolution.

DGPS and RTK-GPS Services

DGPS provides an accurate and reliable service for positioning in marine geodesy over large areas. All over the world a large number of commercial and governmental services have been established to provide DGPS corrections or RTK-GPS data. These services existed primarily to enable safe navigation in coastal waters, however, they are also used for precise positioning by the offshore industry. Further GPS augmentations are currently under development by various nations (Thomson 1996).

In Hong Kong a permanent GPS reference station was established in 1996. The reference station is equipped with a Trimble 4000 SSE receiver with compact L1/L2 antenna and is located on the island Kau Yi Chau near the harbour in the west of Hong Kong Island (Figure 1). The GPS system is operated by the Hydrographic Office of the Hong Kong Marine Department and provides DGPS corrections in RTCM format free of charge to any user. The installation of a second reference station in the eastern part of the New Territories is planed in future.

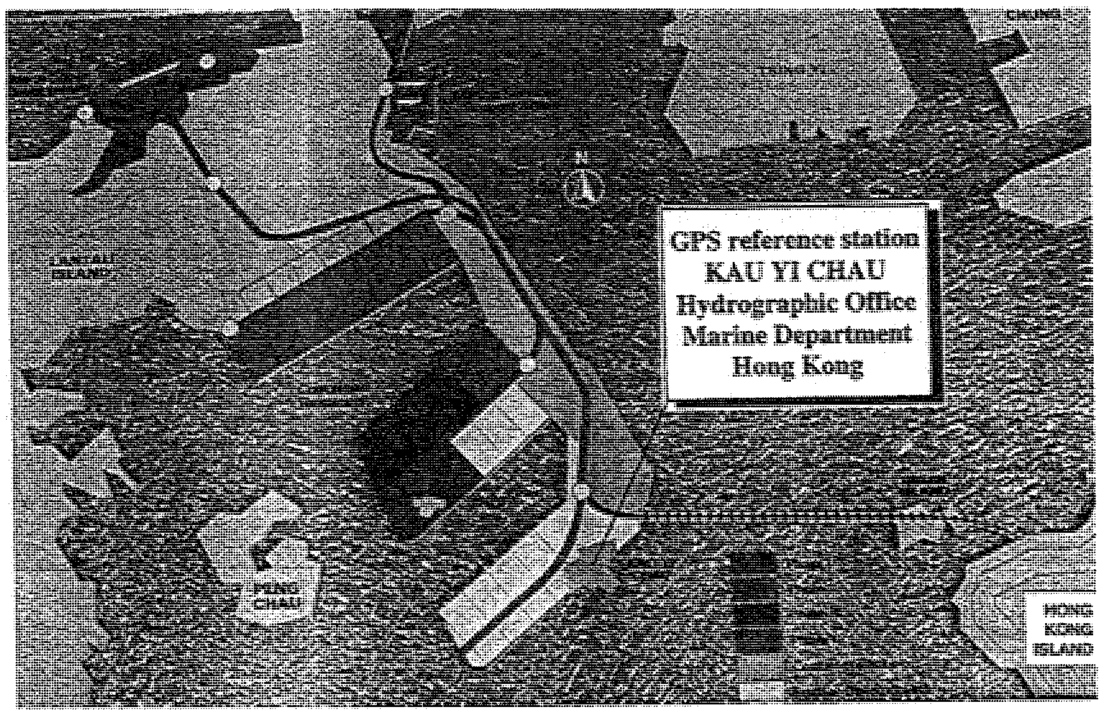

Figure 1. Proposed Development of the Port of Hong Kong
(Marine Department, Hong Kong Government 1997)

The main disadvantage of these conventional Local Area DGPS Systems (LADGPS) is that position accuracy of a user degrades as the reference-to-user separation increases. Therefore Wide Area DGPS Systems (WADGPS) are being developed to overcome the main drawbacks of LADGPS. The spatial decorrelation of the error sources, i.e. the atmospheric propagation and satellite orbit errors, are the main causes for the degradation of position accuracy. The combination of the measurements of several reference station can be used to model these error components separately. Results from test measurements in a WADGPS network in Europe show position accuracies better than 5 m (95 %) in the plane component where the baseline between the user and the reference station range from about 2000 to 3500 km. To achieve these results the satellite orbits were determined with an accuracy of the order of 10 m using pseudorange data from three different reference stations and atmospheric models were estimated. For real-time positioning the orbit and atmospheric models need to be predicted ahead (Ashkenazi, Chao, Chen, Hill, Moore 1997).

The covered area of the LADGPS system is also limited by the perceived range of the used HF/MF radio systems. Satellite based DGPS systems became both commercially and technically feasible with the introduction of broadcasting via communications satellites at the start of the decade (Thomson 1996). However, the main disadvantage are the large costs for satellite delivered DGPS corrections.

For precise navigation and positioning RTK-GPS services have to be established along channels or rivers and near shore waters or harbour areas to avoid navigation hazards and groundings. Using RTK-GPS services the ship navigator knows in real-time the accurate horizontal position and how far the water level is above the chart datum. Therefore deeper draft ships or more fully loaded ships can pass through areas with limited clearance.

Figure 1 shows also the proposed development of new container terminals of the port of Hong Kong. In the south of Lantau Island the deepest water will be used for new terminals. The Lantau Port will also make use of the infrastructure provided for the new airport Chek Lap Kok which is located in the north of Lantau Island. At present detailed design work is taking place for the first two terminals of Lantau Port. The permanent GPS reference station on the island Kau Yi Chau will be located next to the new container terminals and can provide a reliable service for RTK-GPS navigation. The GPS receiver has the full wavelength L1 and L2 carrier phase capability required for OTF and both code and carrier phase data can be broadcasted.

Datum Definitions and Transformations

Normally different local datums are used for horizontal and vertical control. However, the GPS measurements refer to the global WGS84 datum. Therefore 3-D datum transformations have to be applied to get the GPS positions in local datums. For this transformation up to seven parameters have to be determined, i.e. at least three shifts, added with three rotations and a scale factor. For high precision requirements seven transformation parameters have to be determined which are only valid for a local area. The parameters can be calculated from static GPS measurements on at least four control stations. The theory and the computation equations of the datum transformation will not be described in this paper as they can be found in (e.g. Hoffmann-Wellenhof, Lichtenegger, Collins 1994; Seeber 1993). As an example the datum definition of the horizontal and vertical datum for Hong Kong and its link to the WGS84 datum is described.

The Hong Kong HK80 Geodetic Datum was established using International Hayford (1910) as the reference ellipsoid and Patridge Hill as projection origin of the local datum. Transverse Mercator projection is used for the rectangular grid system which is known as the Hong Kong 1980 Grid. Through the survey of fifteen control stations in the whole territory with GPS in 1990, a rigid link between the local HK80 Geodetic Datum and the global WGS84 Datum was achieved. To get plane coordinates the Universal Transverse Mercator (UTM) projection is used. Both geodetic datums are currently in use for horizontal control in Hong Kong (Survey and Mapping Office, Lands Department, Hong Kong Government 1995).

The new charts of the Marine Department of the Hong Kong Government refer also to both systems, i.e. WGS84 and Hong Kong 1980 grid system. The first chart covering the Victoria Harbour of Hong Kong was published on 1st of April 1997.

Also two different vertical datums are currently being in use for vertical control in Hong Kong. All heights and levels on land refer to the Hong Kong Principal Datum (HKPD). The HKPD relates to the mean sea level of the automatic tide gauge situated at North Point, Victoria Harbour which was observed in a period of 19 years (1965-1983). The mean sea level is approximated most closely by the geoid as equipotential surface of the earth's gravity field. For nautical charts the Chart Datum (CD) is used as vertical datum. It should be defined as zero-depth reference below which the water will seldom fall. The Chart Datum of Hong Kong is approximately the level of lowest astronomical tide. The difference between the HKPD and CD is only 0.146 m because the HKPD is approximately 1.230 m below the current mean sea level.

The heights fixed by GPS are the ellipsoid heights which refer to the WGS84 datum. Ellipsoid heights can not be used to define a vertical datum because they have no physical meaning and they are completely artificial. At present the difference between the HKPD and the WGS84 datum, the so called geoidal height or geoid undulation, is only roughly known from a survey by the UK Military in 1991. It is noted that the WGS84 heights are generally higher than the HKPD heights with the magnitude of 2.40 m in the west and 0.40 m in the east of Hong Kong. The accuracy of height conversion is estimated to be better than ±15 cm (Survey and Mapping Office, Lands Department, Hong Kong Government 1995).

For precise height determination with GPS the different datum definitions have to be considered and the geoid undulation has to be estimated with a high level of precision using new methods. In view of the use of Electronic Chart Display and Information Systems (ECDIS) 3-D datum transformations have to be applied in real-time to transform positions from global to local coordinate systems and vice versa.

SPECIFIC APPLICATIONS OF RTK-GPS

In this section two specific applications of GPS in the field of marine geodesy are described briefly. RTK-GPS can be employed to measure tide and swell or to determine of attitude parameters of ships, floating platforms and buoys.

Measurement of Tide and Swell using GPS

For hydrographic surveys code DGPS is used only to determine the horizontal positions of the survey vessel. The raw measured depths from the echosounder have to be corrected for tidal effects to be able to determine depths which refer to the vertical datum, e.g. the chart datum. Therefore tide gauges have to be established close to the local area where the survey operations are carried out. In the case where tidal effects are complex, then more than one tide gauge needs to be established and monitored. The tide corrections are conventionally applied after the survey in post-processing. For real-time applications the corrections can be transmitted from automatic tide gauges over a radio link to the data acquisition package on the vessel. However, the tide level is varying from place to place. Through interpolation methods the value of the tide corrections for the current vessel position has to be estimated. In addition, there is the uncertainty of swell that cannot be monitored by tide gauges. Low frequency swell can be caused by water streaming and high frequency swell can be a result of factors such as wind, wakes from other vessels and wave reflections in confined harbours. To reduce the effect of swell, surveys have to be carried out in calm conditions or a heave compensator has to be used (Walker 1996).

Precise determination of the current level of the water surface and tide corrections in real-time can be obtained using RTK-GPS. The result can be either the reduced level of the water surface above the chart datum or the tide corrected depth. Figure 2 shows the principle of RTK-GPS tide determination.

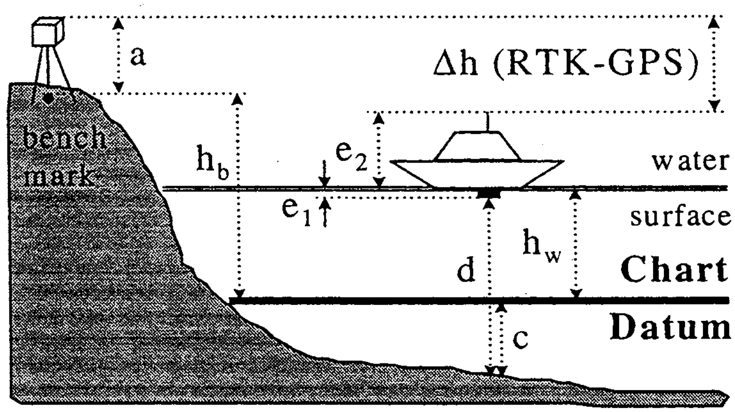

Figure 2. RTK-GPS tide determination

The GPS reference station is situated on a benchmark whose height above the chart datum is known. In most cases, the horizontal coordinates of the vessel should be determined in the local datum. Therefore, also the horizontal coordinates of the benchmark in the local grid system have to be known. For the transformation of the vessel position from WGS84 to the local datum the transformation parameters have to be specified. This values have to be known or determined in a previous static GPS survey and can be entered in the GPS reference receiver. Then the rover receiver can calculate its position and height in the local datum in real-time.

From the fundamental equation which can be deduced from Figure 2

$$a + h_b + c = d + (e_1 + e_2) + \Delta h \qquad (1)$$

where a is the antenna height of the GPS reference station, h_b is the height of the benchmark above the chart datum, c is the charted depth, d is the measured depth, $(e_1 + e_2)$ is the height eccentricity between the GPS antenna phase centre and the echosounder, Δh is the height difference between the reference and rover station measured with RTK-GPS; we get for the charted depth

$$c = d + (e_1 + e_2) + \Delta h - a - h_b. \tag{2}$$

The values a, d and Δh have to be measured, the eccentricity $(e_1 + e_2)$ is a constant factor and h_b has to be known. Then the reduced level of the water surface h_w above the chart datum is

$$h_w = d - c + e_1 = a + h_b - e_2 - \Delta h. \tag{3}$$

Therefore the eccentricity has to be split into its two components e_1 and e_2 as can be seen in Figure 2. Using these method the charted depth and the reduced level of the water surface can be estimated with accuracies on the few centimeter level. There is no need to establish and monitor data from tide gauges and to purchase a heave compensator.

Determination of Vessel Orientation and Attitude

Ship-borne attitude determination systems play an important role in hydrographic and marine navigation. Accurate roll, pitch and heave information of the ship are necessary for several applications, e.g. for surveying of the seafloor with multibeam echosounders to correct the echoed signal. A GPS multi-antenna system with three or more low-cost, high-performance GPS sensors can provide an reliable and accurate attitude information for marine applications.

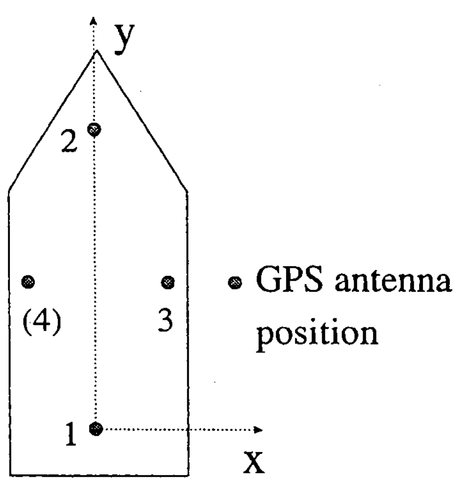

Figure 3. GPS antenna setup

The minimal configuration required to determine the three attitude parameters are three noncollinear GPS antennas situated on the vessel as shown in Figure 3 (antenna position No. 1 to 3). A fourth GPS antenna can be used to provide redundancy (antenna position No. 4 in Figure 3). The antenna positions define a body frame where the y-axis runs from antenna No. 1 to antenna No. 2, the x-axis points to the starboard and the z-axis forms a right-handed system with the x- and y-axes. In order to obtain high-accuracy attitude parameters, the separation between the GPS antennas should be as great as possible (Lu, Cannon 1994).

The attitude of the ship can be obtained by the transformation of the antenna body frame coordinates (x, y, z) to the local coordinate system (X, Y, Z) which is used for the survey. The transformation equation is

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = R(\psi, \theta, \phi) \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \tag{4}$$

with the rotation matrix

$$R(\psi,\theta,\phi) = \begin{pmatrix} \cos\phi\cos\psi - \sin\phi\sin\theta\sin\psi & \cos\phi\sin\psi + \sin\phi\sin\theta\cos\psi & -\sin\phi\cos\theta \\ -\cos\theta\sin\psi & \cos\theta\cos\psi & \sin\theta \\ \sin\phi\cos\psi + \cos\phi\sin\theta\sin\psi & \sin\phi\sin\psi - \cos\phi\sin\theta\cos\psi & \cos\phi\cos\theta \end{pmatrix}$$

where ψ is the heading, θ is the pitch and ϕ is the roll which are the unknown parameters. The rotation angels can be calculated using a direct computation method if three GPS antennas are used. For redundant measurements with four GPS antennas a least-squares adjustment can be employed.

The accuracy of the estimated attitude parameters is depending on the relative antenna positions determined by RTK-GPS measurements. Results from sea trials show that the attitude parameters can be estimated with an accuracy better than 0.06 degrees at a GPS data rate of 10 Hz and the performance under various ship maneuvers was satisfactory (Lu, Cannon 1994). This approach can also be applied to determine the attitude parameters of a floating platform or large buoy.

CONCLUSION

The benefits of GPS have produced a wide range of applications. Most of the positioning and navigation demands in marine geodesy are completely fulfilled with code DGPS. Governmental and commercial DGPS services have been established to provide safe navigation all over the world. Communication satellites are also used to broadcast correction and navigation messages from WADGPS networks.

For high precision requirements real-time kinematic positioning with carrier phases and OTF ambiguity resolution have to be applied. In the near future, RTK-GPS services have to be established along channels or rivers and near shore waters or harbour areas to provide precise and safe navigation. Determination of the current level of the water surface is essential in areas with limited clearance. For hydrographic surveys tide corrections can be obtained in real-time using RTK-GPS. With multi-antenna GPS systems the attitude parameters of a ship, a floating platform or large buoy can be determined with a high level of precision.

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ASSESSING THE STABILITY OF THE NEW MARINE DGPS STATION OF HONG KONG AND ITS CONNECTION TO THE WGS84 DATUM

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ABSTRACT

The permanent DGPS station of Marine Department, located on Kau Yi Chau Island in Hong Kong, has begun its operation in 1996. One of the factors which affects the quality of the differential corrections generated by the station is the accuracy of its reference coordinates in the WGS84 datum. Although the station is positioned over one of the existing trigonometric stations of Hong Kong datum whose position is also known in the WGS84 datum, the accuracy of the known coordinates needs to be verified independently. We have used two months data to calculate repeated baselines from this station to five IGS core stations located in China, namely, Wuhan, Shanghai, Xian, Lhasa, and Taiwan using the GAMIT software. Sub-centimeter rms baseline error has been demonstrated during this period. These results indicate stability of GPS measurements over a long period of time well beyond expectations. We have used the estimated baseline vectors to connect Kau Yi Chau station to the ITRF94 and subsequently to the WGS84 datum. Preliminary results indicate centimeter and decimeter level agreement in latitude and longitude between the known reference coordinates and the ones derived from ITRF-94 connection. We have observed, however, over three meters of discrepancy in height.

INTRODUCTION

The Marine Department of Hong Kong Government has established a permanent DGPS station on Kau Yi Chau Island, Hong Kong in 1996 (abbreviated as HKPO). The station is equipped with a Trimble 4000SSE GPS receiver with compact L1/L2 and G/P antenna.

One of the factors which affects the quality of the differential corrections generated by the station is the accuracy of its reference coordinates in the WGS84 datum. Although the station is positioned over one of the existing trigonometric stations of Hong Kong datum whose position is also known in the WGS84 datum, the accuracy of the known coordinates needs to be verified independently.

Continuos observations collected during November and December 1996 were processed together with the data of other five IGS (International GPS Service for Geodynamics) core stations located in China to calculate the station's precise coordinates in WGS84. The ancillary stations used in this process are located in Lhasa,Tibet (LHAS), Shanghai (SHAO), Taiwan (TAIW), Wuhan (WUHN), and Xian (XIAN). The distribution of these stations is shown in Figure 1. Among these stations, the longest baseline is 3018km from LHAS to TAIW while the shortest is 643km from

WUHN to XIAN.

In this study we first discuss the data and the computational procedures used in calculating baselines among different stations. The results show that the baseline length repeatability is about 1cm for observation periods of approximately two months. Th coordinates of HKPO in ITRF94 is then calculated using a network adjustment by fixing the coordinates of TAIW station in ITRF94 and checking the coordinates of SHAO station in ITRF94. Finally, the coordinates of HKPO in ITRF93 are transformed to the WGS84 datum.

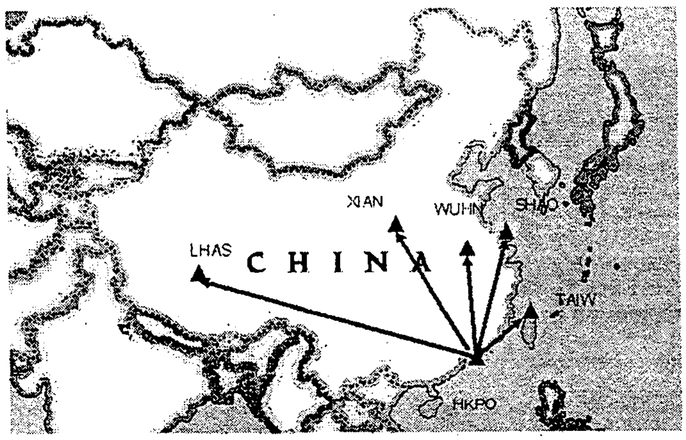

Figure 1. Distribution of ancillary stations and HKPO

DATA HOLDINGS

The data holdings of HKPO, LHAS, SHAO, TAIW, WUHN, and XIAN stations are presented in Figure 2. All the stations are equipped with ROGUE receivers except HKPO. TAIW and SHAO stations began their routine operations after IGS'92 global GPS campaign. WUHN, LHAS, and XIAN stations are also IGS permanent stations.

As compared to the others, HKPO station has only begun its operation late last year. It was established for marine navigation. We processed only the data observed in November and December of 1996. Consequently, despite the availability of large amount of data, only two months of overlapping GPS observations have been used in this study.

Station	X	Y	Z
TAIW	4928936.8970	2681234.5060	3024781.8700
SHAO	4675666.0970	3275369.5840	2831733.1580

Table 1. Coordinates of TAIW and SHAO at epoch December 1, 1996.

The precise ephemeredes used in the computations refer to ITRF94 (IERS - International Earth Rotation Service - Terrestrial Reference Frame). The ITRF94 station coordinates for these stations (at epoch 93.0) were obtained from a combination of VLBI , GPS, SLR and DORIS solutions submitted to the IERS's Central Bureau in 1995.

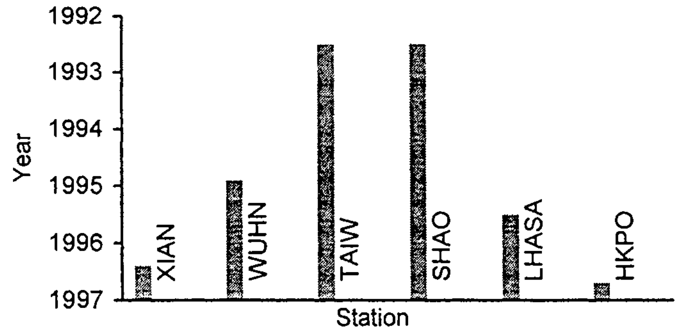

Figure 2. Data holdings of HKPO, LHAS, SHAO, TAIW, WUHN, and XIAN stations.

The adopted epoch for the HKPO observation data is December 1, 1996 corresponding to the middle of observation span. Among these stations, only TAIW and SHAO are class C stations in ITRF94 and other stations are not part of the reference frame. The ITRF94 coordinates of TAIW and SHAO at epoch December 1, 1996 are given in Table 1. They were calculated from positions and velocities provided by IERS referring to ITRF94 whose epoch is 1993.0. Note that TAIW coordinates and the velocities are calculated (adjusted) in the realization of the ITRF94 reference frame. However, although the position of the SHAO station is adjusted, its velocity is derived from NNR-NUVEL1 plate motion model. Since the orientation of the network is provided by the precise ephemeris of IGS, the only constraint needed for the solution is to fix one station. Therefore, during data processing TAIW station was first fixed to the its known values whereas SHAO station position was assumed to be unknown to compare the calculated results against the known position as a check.

GPS DATA PROCESSING MODEL

The GPS analysis software GAMIT developed at MIT and Scripps Institute of Oceanography has been adapted for processing the observations and for performing the network adjustment (King and Bock 1995). The software makes use of the following ionosphere-free combination of phase

$$\phi_{LC} = \frac{1}{1-g^2}\phi_{L1} - \frac{g}{1-g^2}\phi_{L2}$$

where ϕ_{L1} and ϕ_{L2} are observed phases on L1 and L2, and g is the ratio of the frequencies of L2 and L1. Another combination used is given by,

$$\phi_{LG} = \phi_{L2} - g\phi_{L1}$$

which is called "LG". In LG observable, all geometrical (due the station and satellite configuration) and other non-dispersive delays (e.g., the troposphere) are canceled, so that we have a direct measure of the ionospheric variations. One-cycle slips in L1 and L2 are of course difficult to detect in the LG phase in the presence of high ionospheric noise since they are equivalent to only 0.221 LG cycles. Using LC and LG observables, GAMIT calculates double difference observations and forms the normal equations for the solution.

To determine the integer ambiguities for the data at hand, pseudo-range P1 and P2, available on the two GPS bands, are used. In other words, "wide-lane" (WL) combination of L1, L2, P1, and P2 can be formed. This combination is free of both ionospheric and geometric effects and is simply the difference in the integer ambiguities for L1 and L2,

$$WL = n_2 - n_1 = \phi_{L2} - \phi_{L1} + (P_1 + P_2)\frac{f_1 - f_2}{f_1 + f_2}$$

This WL observable is used to fix cycle slips in one-way data, but should be combined with LG and doubly differenced LC to rule out slips of an equal number of cycles at L1 and L2. To resolve the wide-lane ambiguities (ambiguities difference between L2 and L1) both the pseudoranges and the "phase wide-lane" with ionospheric constraints were used (ibid).

Although GAMIT can also solve for the state vector, we made use of satellite ephemeris from the IGS service referring to ITRF94. The software incorporates a weighted least squares algorithm to estimate the relative positions of a set of stations by fitting to doubly differenced phase observations (LC).

A zenith delay parameter for each site is estimated to account for the tropospheric model errors. The cycle slips are detected and repaired automatically and manually.

The adopted statistical model consists of station coordinates, tropospheric delay corrections, and ambiguities as parameters. The influences of ionospheric delay are almost eliminated by adopting the combination observable LC. The satellite clock differences come from broadcast ephemeredes. The receiver clock differences were calculated from observed pseudo-range and approximate station position.

DATA PROCESSING RESULTS

We have obtained network solutions to sessions with 24 hours data span using the GAMIT software for two months data. All session normal equations were subsequently combined to obtain a total solution for two months data.

Figure 3 shows the repeatability of baseline vectors and lengths. The root mean square, rms, error of each session for both plane components (East-West and North-South components), is less than 1cm. The height component reaches up to 3 cm. When compared to the other baselines height errors, the HKPO heights exhibit more variability but overall all baseline vertical components are markedly different than the other baseline components. Together with the rms error of the baseline length, which is about 7mm, these results show that, overall the baseline accuracies are comparable to the other station data even though the HKPO station is not designed for this purpose.

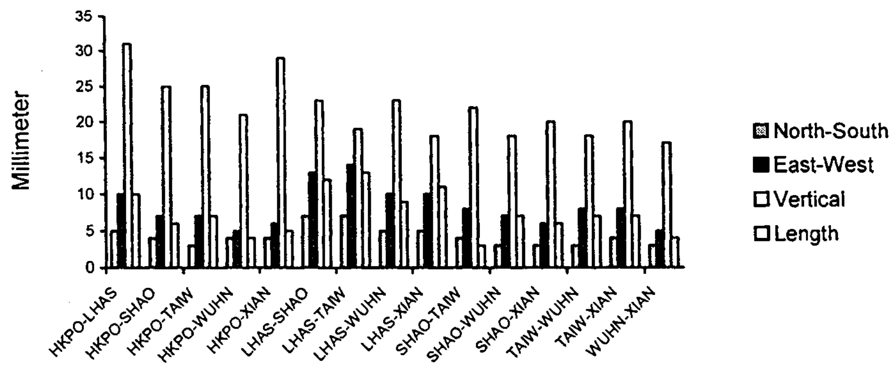

Figure 3. Baseline length and component rms error among different stations.

Figure 4, 5, 6 depict the standard deviations of HKPO station position components. Although the errors of each session solution (standard deviations are indicated by error bars in the figures) for all components are almost the same magnitude from session to session, they exhibit periodic variations that may be due to the effect of various modeling errors systematic in nature. The sources of this variability will not be discussed in this study. In most cases, the variations remain within 1 to 3 cm range.

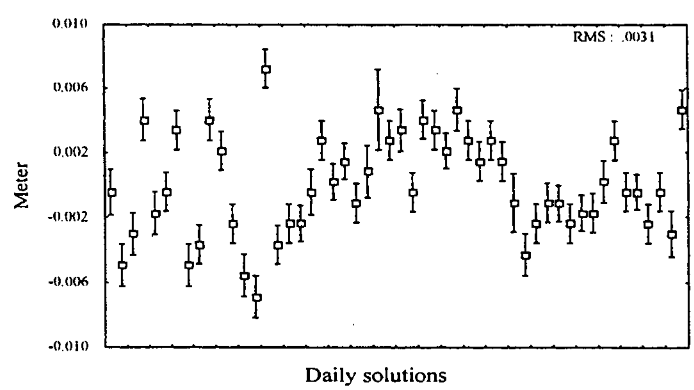

Figure 5. Standard Deviation of Latitude of HKPO

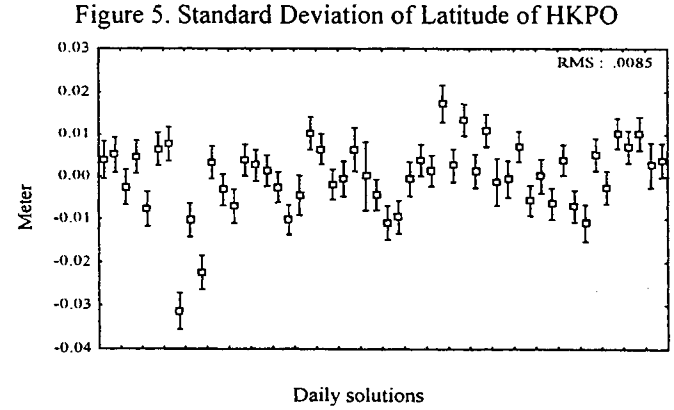

Figure 6. Standard Deviation of Longitude of HKPO

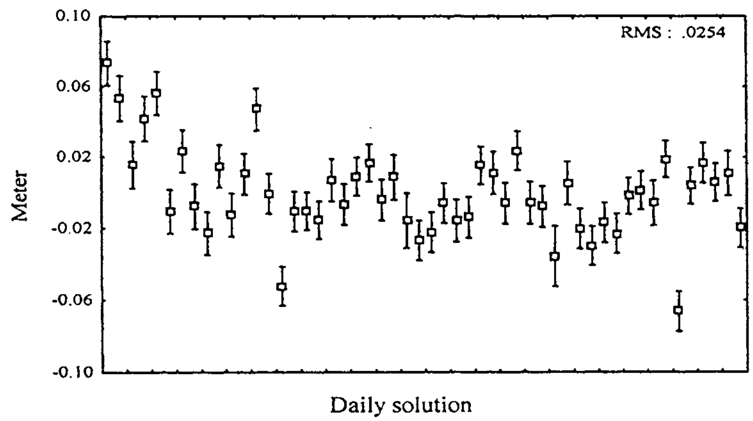

Figure 7. Standard Deviation of Height of HKPO

COMBINED SOLUTION

The daily session solutions are informative for analyzing time dependent history of baseline variations. Nevertheless, their average values over time are not formally representative of the accuracy of the overall solution. We have obtained a total solution by combining the normal equation of each daily solution using

$$N_i \delta x = C_i$$

where N_i, C_i, are the normal equation related matrix and vector for each session i, and δx is the correction vector for the parameters to be estimated common to all solutions. It can be shown that the combined solution can be obtained using the following relationships[1],

$$\left(\sum_i N_i\right)\delta x = \left(\sum_i C_i\right)$$

In the solution, the fixed TAIW station coordinates were updated to the middle of the data span (i.e. December 1, 1996 to account for the effect of the plate motion on this station and also the precise ephemeris for the satellite positions which refer to the middle epoch of each session).

The adjusted coordinates of each station referring to ITRF94 and their standard deviations are given in Table 2. They exhibit better statistics as compared to the average results of each indi-

[1] Since the data span is about two months, too short for the effect of the plate motions, each session normal matrices need not to be to be shifted to a common approximate set of coordinates. But still, since the approximate coordinates of each session are different, the normal equations were modified to have common approximate values.

vidual solution since the correlations among the parameters are also taken into consideration.

Station	X	σ	Y	σ	Z	σ
HKPO	-2408854.4211	.0004	5391041.8647	.0007	2403590.5383	.0003
LHAS	- 106937.5228	.0004	5549269.7211	.0007	139215.8218	.0004
SHAO	-2831733.1611	.0004	4675666.1346	.0006	3275369.5917	.0003
TAIW	-3024781.8700	--	4928936.8970	--	2681234.5060	--
WUHN	-2267749.0391	.0004	5009154.4141	.0006	3221290.8226	.0004
XIAN	−1735212.2155	.0004	4976839.7456	.0007	3580538.1011	.0004

Table 2. Coordinates of each station in ITRF94 at epoch Dec. 1, 1996 and their standard deviations from the combined solution. Results are in meters.

To provide an independent check for the total solution, we have compared the estimated coordinates of the SHAO station against the values independently calculated by IERS using not only GPS data but also SLR and VLBI data. Since the IERS solution refer to the ITRF94 frame during the same year, to account for the effect of plate motion from 1994 to 1996, the SHAO station coordinates were corrected using the NNR-NUVEL1A global plate motion model. Differences between the two sets of solutions, shown in Table 3, are about few millimeters on X and Z components and 4 centimeters for the Y components indicating that the current solution is reliable.

ΔX	ΔY	ΔZ
-0.0031	-0.0376	0.0077

Table 3. Coordinate differences of the calculated values of the SHAO station in this study from the ITRF94 published values. Differences are in meters.

TRANSFORMATION TO THE WGS84 COORDINATES

Having determined the adjusted position of stations in the ITRF94 system, the corresponding coordinates in the WGS84 datum can now be calculated. Although, the transformation parameters are not readily available, it can be achieved by applying the existing seven-parameter similarity transformations from ITRF94 to ITRF92, then, ITRF92 to WGS84 (NOAA, 1993).

Station	X	Y	Z
HKPO	−2408854.509	5391041.014	2403590.763
LHAS	- 106937.640	5549268.878	3139216.058
SHAO	−2831733.222	4675665.197	3275369.743
TAIW	−3024781.937	4928936.005	2681234.686
WUHN	−2267749.117	5009153.497	3221291.004
XIAN	−1735212.298	4976838.814	3580538.279

Table 4. Cartesian coordinates of each station in WGS84 datum. Results are in meters.

Table 4 shows the coordinates of the stations referring to WGS84 datum results of these transformations. The corresponding geodetic coordinates are given in Table 5.

Station	Latitude (d m s)	Longitude (d m s)	Height (m)
HKPO	22 17 2.607245	114 4 34.712044	114.0818
LHAS	29 39 26.442164	91 6 14.350910	3624.1839
SHAO	31 5 58.735135	121 12 1.604954	21.5446
TAIW	25 1 16.810693	121 32 11.560972	43.4138
WUHN	30 31 53.972397	114 21 26.145340	25.2831
XIAN	34 22 7.241095	109 13 17.376734	462.8793

Table 5. Geodetic Coordinates of Each Station.

When compared to the existing WGS84 coordinates for the HKPO station, the above results show discrepancies of 3.87 meters in height (referring to the top of the station), 0.0191 arcsecond in latitude (0.59m) and –0.0015 arcsecond in longitude (-0.05m). Most of these differences can be attributed solely to the inaccuracies of the WGS84 coordinates of the Hong Kong GPS network which are derived from a single fixed Doppler station.

CONCLUSION

We have demonstrated that the whole network is providing continuous baseline monitoring with standard deviation better than 1 cm over two months data. In particular, the coordinate standard deviations of the permanent DGPS station of the Marine Department of Hong Kong are better than 1cm for the horizontal component and 2 to 3cm for the height component. The results show that the data quality for the dual-band Trimble 4000SSE equipped station HKPO is performing well beyond the requirements of the Hong Kong Marine DGPS activities.

Since the WGS84 coordinates of the station have been obtained through the most accurately realized reference frame ITRF94 together with high precision baseline observations, they are capable of connecting the Hong Kong Datum to other datums in the region.

A pleasant by-product of this investigation is that the data will enable us to monitor Eurasian plate stability with accuracy comparable to the other existing GPS stations in the region.

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NEAR-FIELD MIXING OF WASTEWATER EFFLUENT FROM THE PALI MARINE OUTFALL, NORTHERN TAIWAN

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ABSTRACT

The Pali marine outfall, an important element of the Tansui River water pollution control project in Northern Taiwan, was designed to discharge wastewater at a rate of 37 cubic meters per second, or about 840 million gallons per day, into Taiwan Strait. To minimize the potential adverse impact of this discharge on the marine environment requires a thorough understanding of effluent mixing in receiving water. Generally, the negative environmental impact would be small if the waste materials in an effluent plume could be significantly diluted. The magnitude of near-field mixing depends on both waste effluent characteristics and ambient ocean conditions. Relevant ocean conditions include ocean current, density stratification, and ocean waves. The effect of ambient ocean waves on near-field mixing has been ignored by almost all existing mathematical models. In this study, the popular near-field mixing model UM was modified to include wave effect. The modified model was then used to predict effluent mixing in the Pali outfall area. Simulation results show that the minimum required initial dilution ratio of 100 to 1 can be achieved when the ambient current velocity is 2 meters per second or higher. Further, the simulation results indicate that ambient waves play an important role in near-field mixing. When the amplitude of ambient ocean waves is 2 meters or higher, the Pali outfall effluent can achieve the required dilution, even in the absence of ocean currents.

INTRODUCTION

Tansui River flows through the center of the city of Taipei, a metropolis of over five million people in Northern Taiwan. It is heavily polluted because municipal and industrial wastewaters with little or no treatment are discharged into the river and its tributaries. Seepage flow from solid waste dumping sites and storm runoff add to the pollution problem. Two large reservoirs built in the upper reaches of the Tansui River are the principal sources of water supply for Taipei. Therefore, pollution in this river is a major concern in terms of environmental quality and public health. A huge water pollution control project was formulated and has been under construction since the early 1980s (Liu and Kuo, 1988). This project includes an extensive sewer system by which domestic and industrial wastewaters are intercepted before they reach the Tansui River. The intercepted wastewaters, along with some storm water, are then transported to the Pali wastewater treatment plant near the mouth of Tansui River. After primary treatment, the effluent is discharged into Taiwan Strait (Figure 1). The Pali outfall was designed to operate with two 3,699-m-long steel pipes having an inner diameter of 3.6 m. The last section of the outfall pipes, where diffusers are located, is 1,500 m long and lie 30 to 40 m below the ocean surface (Figure 2). One of the pipes has been in operation since summer 1997; the other is not under construction yet.

After a large quantity of wastewater is released through the ocean outfall, the combined action of buoyancy and momentum produces entrainment by which the effluent plume incorporates ambient flow to dilute the pollutant concentration. Rapid near-field mixing can usually be accomplished with a properly designed diffuser structure. The initial dilution is the amount of near-field mixing achieved when an effluent has exhausted its initial momentum and buoyancy and reached a neutral position. The initial dilution of effluent discharged by a large outfall diffuser depends on a number of parameters, including the flow and velocity of the effluent, the length of the diffuser, the depth of the diffuser, ocean currents, ambient density stratification, and ocean waves. The last three are environmental parameters, which are beyond the control of designers; whereas the first three are discharge parameters, the values of which can be controlled by system design.

In this study, investigation focused on wave effects on initial dilution, a subject which has not been thoroughly dealt with in previous studies. A mathematical formulation of these effects is added to the U.S. Environmental Protection Agency's UM model (Baumgartner et al., 1994), a popular initial dilution model. The modified model is then used to investigate the near-field mixing of wastewater effluent plumes from Pali marine outfall.

LITERATURE REVIEW

In a simple approach, initial dilution can be estimated in terms of asymptotic relations with relevant discharge and environmental parameters. Usually, experimental data are used to determine empirical coefficients included in these asymptotic relations. A simple approach provides useful "order-of magnitude" estimates. Examples of mathematical models developed using a simple approach are the ULINE model of the U.S. Environmental Protection Agency and its updated version, the RSB model (Baumgartner et al., 1994). The RSB model was recently used to model the behavior of wastewater effluent discharged through the Sand Island and Barbers Point ocean outfalls in Mamala Bay, southern Oahu, Hawaii (Roberts, 1995).

Ocean outfall effluent usually takes the form of buoyant jet. Detailed studies on near-field mixing of buoyant jets have been conducted by many investigators. Generally, these studies involve formulation and solutions of governing equations of mass, momentum, and energy conservation. Rouse et al. (1952) studied a buoyant plume with a continuous heat source in a nonstratified, stagnant environment. They used an integral method to solve the equations of mass, momentum, and energy conservation. In their integral model, a spreading ratio was introduced to overcome the complicated turbulent mixing phenomena at the boundary of the plume and ambient ocean water. Rouse et al. (1952) also assumed that the lateral distributions of velocity and temperature across a plume can be expressed in terms of Gaussian distributions. Priestley and Ball (1955) followed the same approach to study the dilution of thermal plumes issuing into a stratified, uniform environment. Morton et al. (1956) studied buoyant plume convection by introducing an entrainment hypothesis in the integral model instead of a spreading ratio. The entrainment hypothesis relates the rate of inflow of diluting water into a plume to the plume's mean local velocity. The entrainment hypothesis was adopted in many later studies on the mixing of buoyant jets and plumes (Fox, 1970; Hirt 1971; List, 1982). Fan (1967) investigated the problem of buoyant plumes in a flowing, uniform-density ambient fluid and derived a theoretical solution. Wright (1984) derived a solution of buoyant plume dilution and trajectories in a cross flow with both uniform and stratified ambient fluid. Based on the mathematical formulation proposed by Frick (1984), a Lagrangian jet model (JETLAG) was presented by Lee and Cheung (1990) to study the movement of a round buoyant jet in an ambient current, with a three-dimensional trajectory.

Recently, initial dilution models were developed by simulating the turbulent flow directly and avoiding the use of the entrainment hypothesis. Li and Chen (1985) used a $\kappa - \varepsilon$ turbulence model, which calculates the actual turbulent flow field, to study buoyant jets in stagnant stratified environments. A three-dimensional numerical model based on the $\kappa - \varepsilon$ turbulence model was developed by Hwang and Chiang (1995).

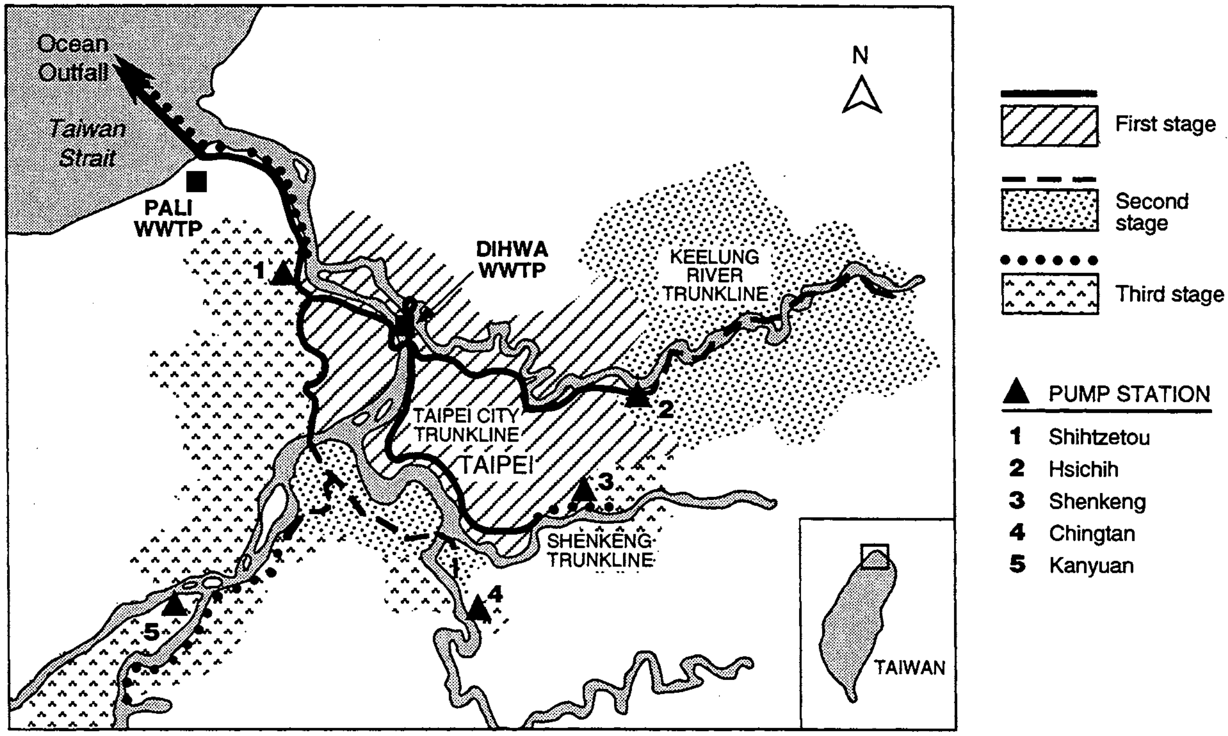

Figure 1. Tansui River water pollution control project

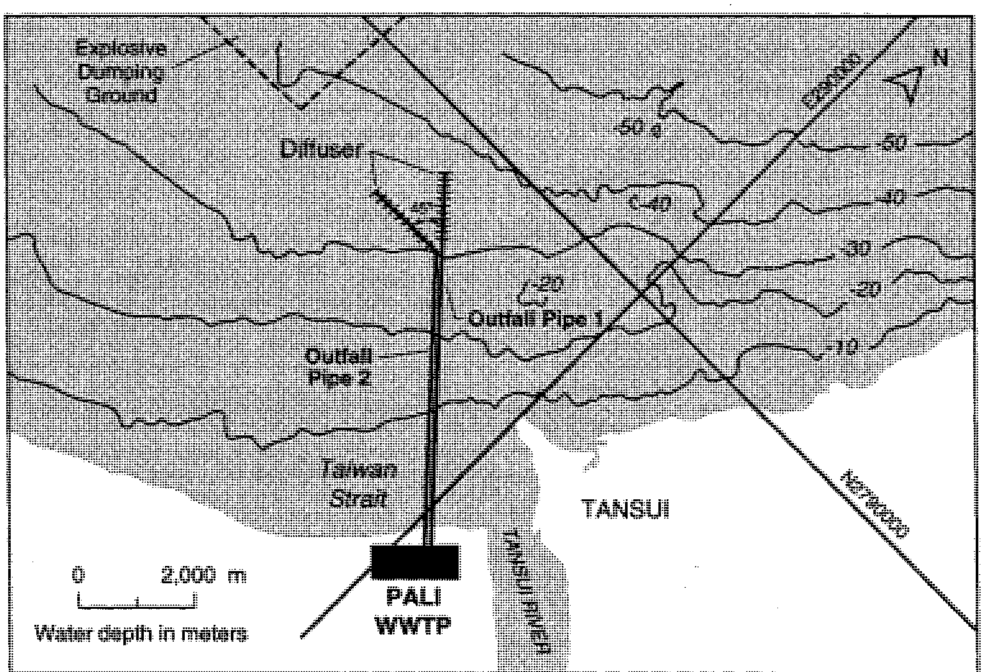

Figure 2. Pali ocean outfall, Taipei, Taiwan

U.S. EPA UM MODEL

The U.S. Environmental Protection Agency's UM model is a steady-state two-dimensional model capable of simulating near-field mixing of positively and negatively buoyant plumes and tracing contaminants in an effluent through the plume trajectory (Baumgartner et al., 1994). The density stratification, non-uniform current velocity, temperature, and salinity profiles are calculated numerically by the UM model with simple linear interpolation. The UM model allows multiple-port discharge and is capable of predicting dilution with the merging effect of adjacent plumes.

The amount of effluent plume mixing with ambient ocean water is calculated by the UM model as the summation of the Taylor entrainment and the forced entrainment, or

$$\frac{dm_E}{dt} = \frac{d}{dt}(m_T + m_f) \tag{1}$$

where m_T is the Taylor entrainment mass and m_f is the forced entrainment mass.

Inside an effluent plume is a region of high velocity and low pressure. The pressure gradient established between the plume and the ambient ocean water produces an inflow into the plume. This inflow is called the Taylor entrainment. Therefore, Taylor entrainment would occur even in the absence of ocean currents (Baumgartner et al., 1994). The rate of Taylor entrainment is calculated by multiplying the Taylor entrainment velocity and the plume's peripheral area. The Taylor entrainment velocity is proportional to the local velocity of the plume; the constant of proportionality, or entrainment coefficient, is related to the plume characteristics (Morton et al., 1956).

Forced entrainment takes place only in the presence of ocean currents. It is equal to the sum of mass carried by currents normally flowing through the plume's projected area (Frick, 1984).

The UM model follows the Lagrangian approach in solving mathematical equations of mass, momentum, and energy conservation. The Lagrangian approach implies that a steady-state effluent plume is formed by a series of elements which follow the same trajectory. Thus the integration of conservation equations can be performed with individual plume elements. A simple Lagrangian model provides an estimation of the trajectory of the plume element by calculating only the path of its center-of-mass; other variables characterizing the distribution of mass are inferred or assumed (Baumgartner et al., 1994). In the UM model, the plume element is defined as a section of bent cones. This definition allows a more realistic representation of the element's projected area and therefore a more accurate determination of forced entrainment.

The equation for momentum conservation along the z-direction can be expressed by the UM model as

$$V_{jz}(z_i) \bullet M_j(z_i) - V_{jz}(z_i - \Delta z) \bullet M_j(z_i - \Delta z) = \frac{\rho_a(z_i) - \rho_j(z_i)}{\rho_j(z_i)} g \bullet \Delta t(z_i) \tag{2}$$

where z_i is the vertical location of the plume element at the i-th iteration; Δz is the increment along the vertical direction; M is the mass of a plume element; ρ_a and ρ_j are density of ambient ocean and effluent plume, respectively; and g is the gravitational acceleration.

With only horizontal ambient flow, the total mass inflow carried by ocean currents is

$$U_a(z_i)\left[2R_j(z_i)\Delta h(z_i) \bullet \sin\theta(z_i) + \pi R_j(z_i) \left.\frac{\partial R_j}{\partial s}\right|_{z_i} \Delta h(z_i) \bullet \cos\theta(z_i) - \frac{\pi}{2} R_j^2(z_i) \left.\frac{\partial \theta}{\partial s}\right|_{z_i} \sin\theta(z_i)\right] \tag{3}$$

where $R_j(z_i)$ is the average diameter of the plume element at depth z_i, $\theta(z_i)$ is the directional angle of the plume element to the horizontal axis, and s is the pathline of the plume element.

MODEL MODIFICATION

Surface waves can be classified as shallow, intermediate, or deep waves, based on the ratio of water depth (H_0) to wave length (L_w). The H_0/L_w ratio is less than 0.005 for a shallow wave, between 0.005 and 0.5 for an intermediate wave, and greater than 0.5 for a deep wave.

As a surface wave passes by, the water particles below take orbital motion. A velocity field is produced. For an intermediate wave, the velocity field produced can be described by the following equations (Kinsman, 1984):

$$u_w(x, z, t) = A_w \sigma \frac{\cosh n(z + H_0)}{\sinh nH_0} \cos(nx - \sigma t) \tag{4}$$

$$v_w(x, z, t) = A_w \sigma \frac{\sinh n(z + H_0)}{\sinh nH_0} \sin(nx - \sigma t) \tag{5}$$

where $u_w(x, z, t)$ and $v_w(x, z, t)$ are velocity components of the wave along horizontal and vertical directions, respectively; A_w is wave amplitude; σ is wave frequency; and n is wave number.

Modification of the UM model is based on the assumption that the two velocity fields—one generated by ocean currents and the other generated by ocean waves—can be combined. Considering this combined velocity field, the momentum equation along the vertical direction becomes

$$V_{jz}(z_i) \bullet M_j(z_i) - V_{jz}(z_i - \Delta z) \bullet M_j(z_i - \Delta z) = \frac{\rho_a(z_i) - \rho_j(z_i)}{\rho_j(z_i)} g \bullet \Delta t(z_i) + V_{az}(z_i) \bullet \Delta m_E(z_i) \tag{6}$$

Forced entrainment can then be determined as a product of ambient current velocity multiplied by the plume's projected area, or

$$-V_{ax}(z_i)\left[2R_j(z_i)\Delta h(z_i) \bullet \sin\theta(z_i) + \pi R_j(z_i) \left.\frac{\partial R_j}{\partial s}\right|_{z_i} \Delta h(z_i) \bullet \cos\theta(z_i) - \frac{\pi}{2} R_j^2(z_i) \left.\frac{\partial \theta}{\partial s}\right|_{z_i} \sin\theta(z_i)\right]$$

$$-V_{az}(z_i)\left[2R_j(z_i)\Delta h(z_i) \bullet \cos\theta(z_i) - \pi R_j(z_i) \left.\frac{\partial R_j}{\partial s}\right|_{z_i} \Delta h(z_i) \bullet \sin\theta(z) - \frac{\pi}{2} R_j^2(z_i) \left.\frac{\partial \theta}{\partial s}\right|_{z_i} \cos\theta(z_i)\right] \tag{7}$$

The wave effect can therefore be included in the modified UM model by replacing Equation (3) with Equation (7).

NEAR-FIELD MIXING OF THE PALI MARINE OUTFALL EFFLUENT

The modified UM model was used to calculate the average initial dilution of the Pali outfall effluent plume without the presence of ocean waves. The results were compared with those calculated in a previous study by Dodson & Young Consulting Engineers (Taiwan Housing and Urban Development Bureau, 1986). The initial dilution model DKHPLM, one of the previous models developed by the U.S. Environmental Protection Agency (Muellenhoff et al., 1985), was used by Dodson & Young Consulting Engineers in their calculation. Figure 3 shows that the modified UM model and the DKHPLM model give similar predictions for average initial dilution of the Pali outfall effluent plume, when the wave effect is not considered. It also shows that the minimum required initial dilution ratio of 100 to 1 can be achieved with the presence of ocean currents. However, problems may arise when the ambient ocean current is very weak.

The waves generated by seasonal winds in the Pali outfall area have average measured amplitudes of 1.5 m in winter and 0.5 m in summer (Taiwan Housing and Urban Development Bureau, 1986). Wave periods are between 7 and 9 s, with an average period of 8 s. An oceanographic study conducted from December 1981 to July 1984 indicated that a significant wave height of 2.5 to 3.0 m occurs 2.3% of the time in winter months. Note that during severe weather conditions, such as those caused by a typhoon, the significant wave height in the Pali outfall area can be as high as 7.5 m and the wave period can be 12 s. Since the outfall diffuser is located at a

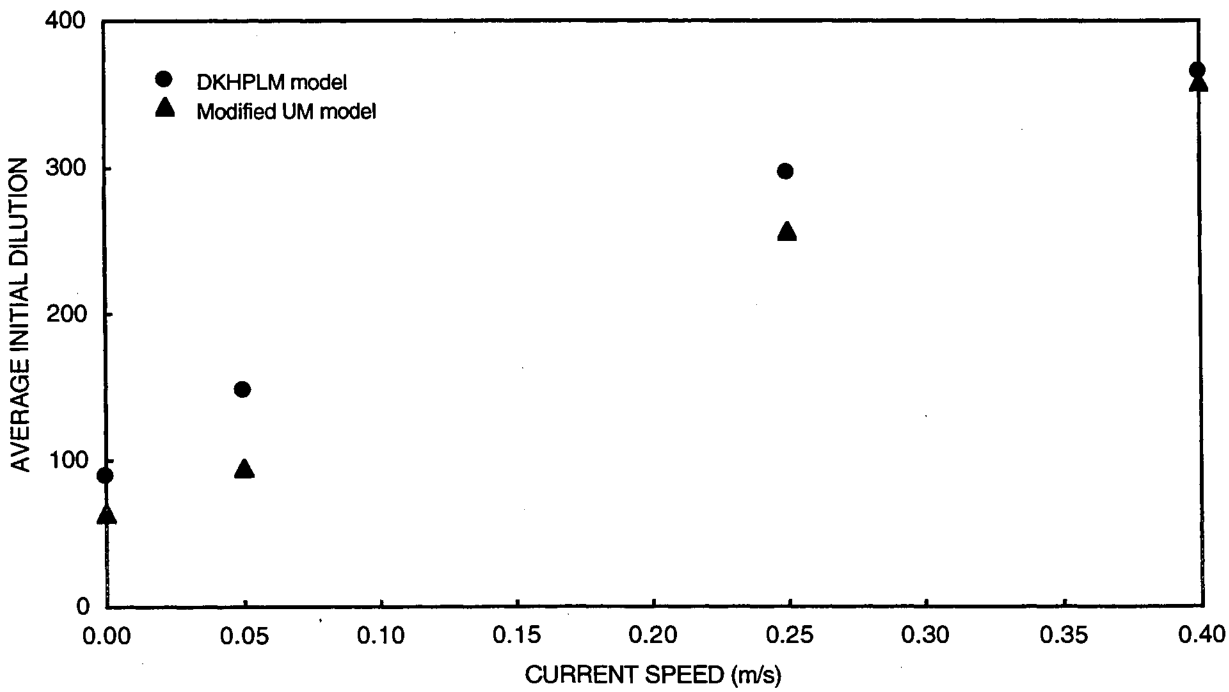

Figure 3. Average initial dilution predictions for Pali outfall effluent plume, with the presence of ocean currents but absence of ocean waves, using DKHPLM model by Dodson and Young Consulting Engineers (Taiwan Housing and Urban Development Bureau, 1986) and modified UM model

water depth of 30 to 40 m (Figure 2), waves in the area are intermediate waves. Velocity fields produced by these waves can be calculated using Equations (4) and (5).

Simulation results (Figures 4, 5, and 6) indicate that the level of initial dilution of the effluent plume from the Pali outfall depends on both ocean currents and waves. The initial effluent dilution ratio would be much larger than 100 to 1 if the ocean current is larger than 0.5 m/s. Since ambient ocean current is normally larger than 0.5 m/s, the Pali wastewater discharge would produce no significant negative impact on marine water quality. Even without significant ocean currents, the marine water quality still can be maintained if the amplitude of the prevailing waves is larger than 2 m. An irregular pattern of initial effluent plume dilution occurs when waves of large period and amplitude are encountered.

DISCUSSION AND CONCLUDING REMARKS

Wave effect on near-field mixing of an ocean outfall effluent plume was investigated using a modified version of the U.S. Environmental Protection Agency's UM model. In the UM model, near-field mixing is calculated as the summation of Taylor entrainment and forced entrainment. Taylor entrainment is produced by the shear force acting along the plume boundary with ambient ocean water. Forced entrainment, on the other hand, is produced by the advective transport of ambient current velocity. In the modified UM model, wave-generated velocity is combined with ocean current velocity to calculate forced entrainment. Model results indicate that ocean wave is an important mixing mechanism, especially when ambient ocean currents are weak. With wave action, the Pali ocean outfall effluent plume can achieve its required 100 to 1 initial dilution ratio even when the ocean current velocity is minimal.

The initial phase angle, or the phase angle of a simple wave when it passes the exit point of a diffuser, brings about a specific wave velocity field around the diffuser. This would dynamically

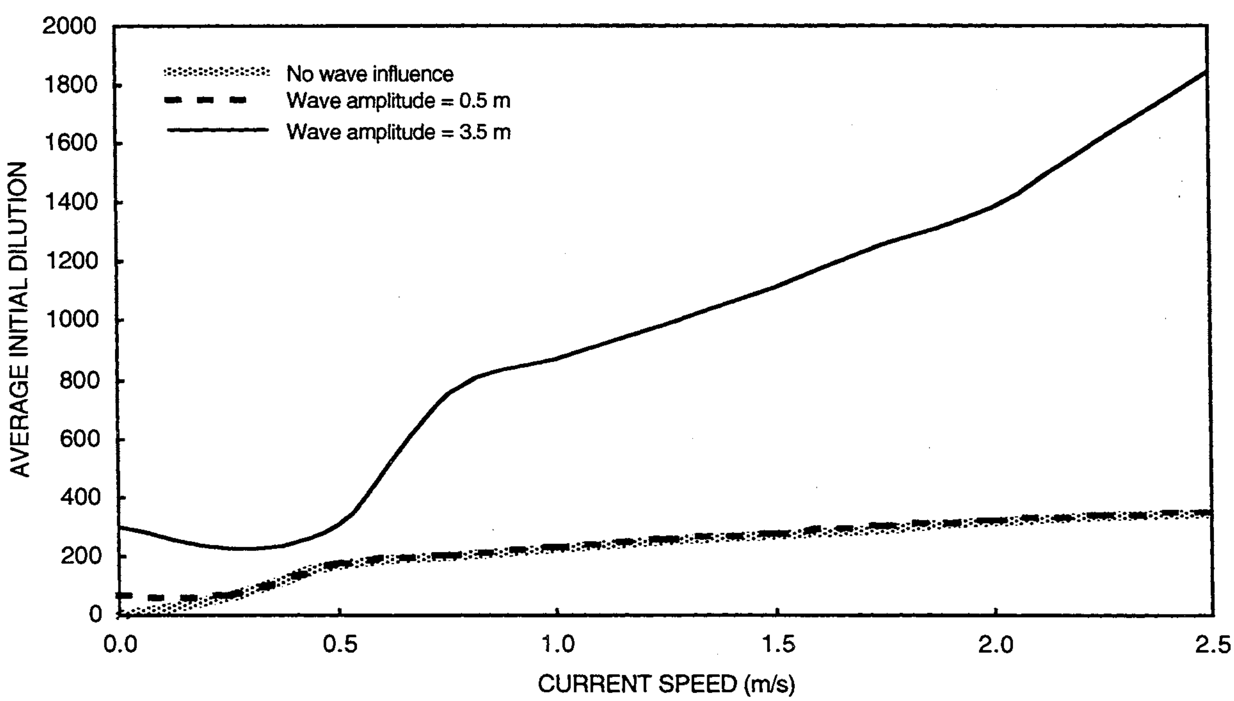

Figure 4. Average initial dilution of Pali effluent with varying current velocity

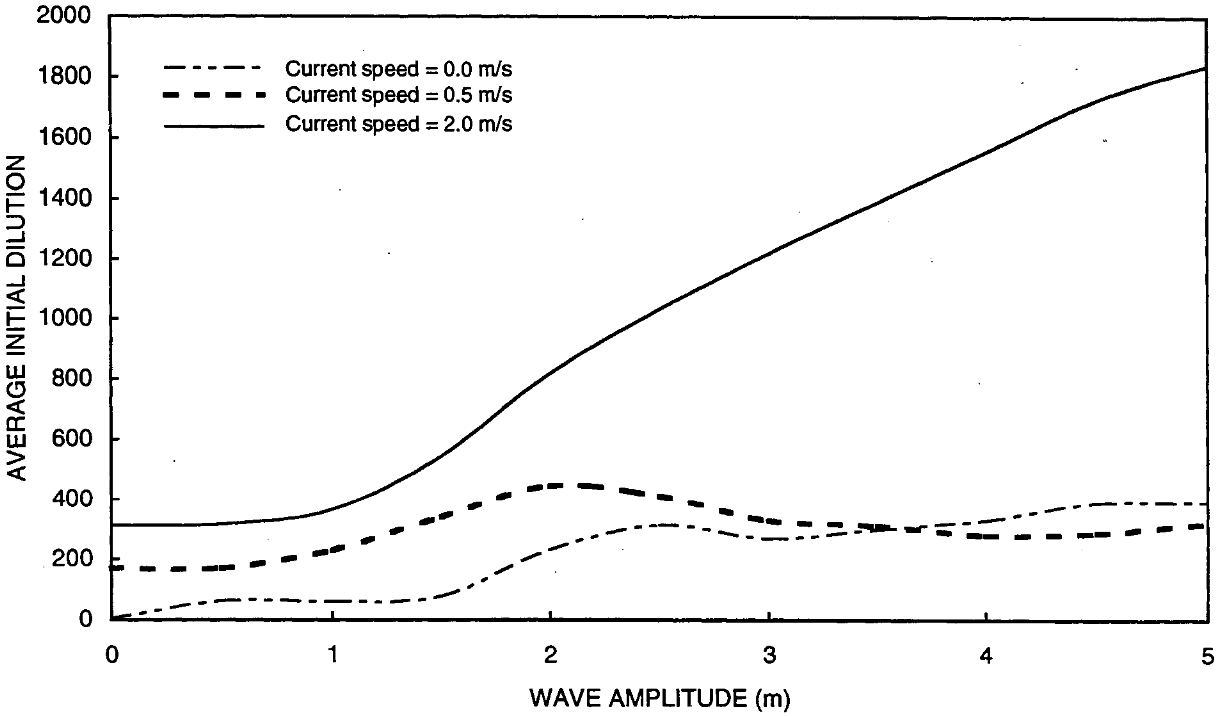

Figure 5. Average initial dilution of Pali effluent with varying wave amplitudes

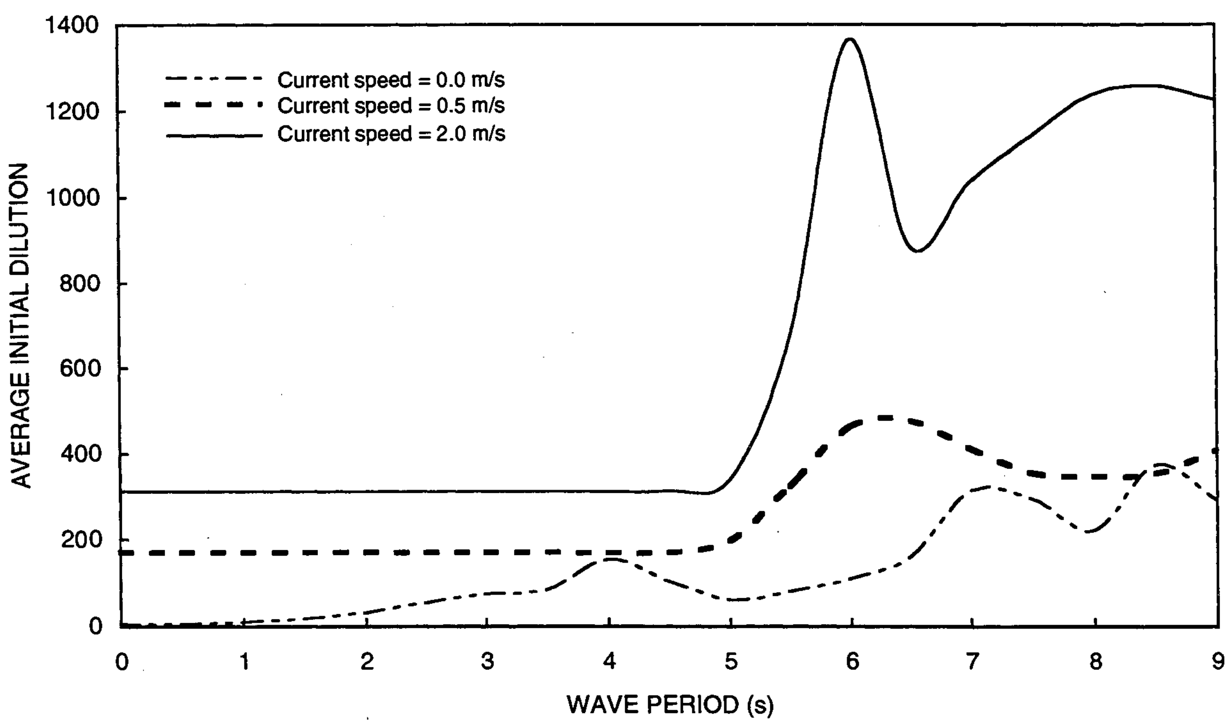

Figure 6. Average initial dilution of Pali effluent with varying wave periods

determine the trajectory of an effluent plume. Different phase angles produce different velocity fields in which a plume element emerges; that is to say, a plume element will follow totally different trajectories, depending on the initial phase angle. This problem occurs because the UM model is a steady-state model, whereas wave action is a time-varying phenomena.

In hydraulic experiments of near-field mixing, a simple sinusoidal wave is used; thus, the initial phase angle must be considered in the mathematical modeling analysis based on hydraulic experimental data. In this study, a wave-period averaging method was developed and applied. A simple wave was divided into many increments of specific phase angles. Initial dilution was then determined as an arithmetic average of the calculated initial dilution corresponding to each of these elements.

Re-entrainment occurs when a plume is bent or overlapping during its development; besides fresh ambient water, part of the water entrained into the plume consists of effluent water. Bending and overlapping may occur very frequently for a plume in an ambient ocean with strong surface waves (Frick et al., 1994). The problem of re-entrainment is not considered by the UM model (Baumgartner et al., 1994) or the modified UM model. Overestimation of plume dilution by the modified UM model may become very considerable due to re-entrainment. Further studies are needed to address this re-entrainment problem.

ACKNOWLEDGMENTS

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Satellite Remote Bathymetry and Shallow Water Terrain Mapping in Coral Reefs

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Abstract

The coral reef and islands in the tropical oceans are a unique ecosystem, whereas atolls (coral reef rings) are mainly distributed in the Pacific Ocean and the Indian Ocean near the equator. Due to the importance in the geographic locations, international navigation, natural resources and environments, many marine scientists and industrialists have increasingly paid attentions to the tropical special water areas. However, it is difficult to survey the areas utilizing the traditional methods due to the complexity of the topography and geomorphology of coral reefs and islands. This paper discusses the methods and develops a strategy for mapping and visualizing the bathymetry, topography, and geomorphology of coral reefs with remote sensing, digital terrain modelling.

Introduction

Coral reefs and islands is a special ecosystem in the tropic ocean area on the earth. Its geological structure, landform geomorphology, environmental condition , development process , biological community are all special landscape. Whereas it is the communications center of ocean and air with abundance oil, gas, fishery, tourism resources ,it has great prospect in both ocean development and ocean industry.

Coral reefs and islands belongs to biologic landform which is of various kinds and with differential water depth. It is very difficult to survey using traditional method. Since 1970s , satellite remote sensing provides efficient means for the water depth and terrain survey of coral reefs and islands. Fubian C. Polcyn has ever given an overall assessment on satellite bathymetry remote sensing technique (1978), after the lunching of Landsat, Hu Jiamin(1990), Serwan M.J.Baban (1993) and W.Ahmad and D.T.Neil (1994) have conducted mapping and classification of North Male'Atoll of Maldives , lakes of England and Big Barrier Reef of Australia using TM data. Recently, many scholars discuss the model mechanism of satellite bathymetry remote sensing , the application and specification of radiation model in water depth calculation, the attenuation characteristics of remote sensing in coral reefs water column (Wei Ji, Daniel L. Civco and William C. Kennard 1992, John G. Lyon and Wendy S. Hutchinson 1995, S. Maritorena 1996). This paper try to discuss the application prospect of Landsat TM and SPOT in the mapping of coral reefs bathymetry and topology , using the theory of bathymetry remote sensing and technique of GIS. Finally, some cases are studied.

Foundation of Theories and Methods

The water depth computed from satellite remote sensing data lies on the penetrability into water and the reflection energy of diverse spectrum bands which influence parameter are band property 、 solar height angle 、 azimuth 、 height of platform 、 character of air scattering, absorbing, and reflection 、 transparency of water column 、 attenuation rate of light in water 、 reflection characteristics of sea bottom 、 scattering characteristics of suspended material in the water.

In the visible light bands, the shorter the wave length is, the smaller the attenuation coefficients in the water column is. So satellite bathymetry remote sensing often uses MSS-4(0.5~0.6 um), Landsat TM1(0.45~0.52 um) and SPOT B1(0.5~0.9 um) . According to the experience of theory and practice, the maximum penetrate depth of blue and green light is 40 m, available depth is 22~28 m.

Due to the difference of the penetration ability in water of the visible lights' diverse bands ,we can conduct the classification of water depth and terrain by multiple spectrum image. With computer processing 、 linear filter and transform 、 bands ratio and composition, satellite remote sensing digital image can show the topogrphy and its details efficiently.

Because the terrain of coral reefs and islands undulate rapidly, reef plat, reef slope and sea bottom drape is obvious, the result of the bathymetry and topography compounded by DTM and DEM technique and remote sensing image can mirror the greomorphology landscape of coral reefs and islands thoroughly .

Case Study

1. The water-depth、terrain、landforms structure analysis of coral reefs and islands

According to the difference of coral reefs within geological structure、development process and dynamics conditions, they can be divided into Fringing Reefs、Bank Reefs、Ridge Reefs、Barrier Reefs、Atolls. Different terrain structures as Island、Islet、Cay、Reef flat、Lagoon、Outer Slope and different landforms morphology as reef edge、Spurs and Grooves、Shingle Ridge、Radial Lineations、Patch Reefs are presented. It is difficult to describe and distinguish by traditional water depth mapping. Two examples areas in the South China Sea are selected and the depth, topography of coral reefs and islands by Landsat and TM images are conducted.

Area 1: The first example is North Balabac Strain which is located in the south of Balawa island, Philippine. At first, TM4 is used to distinguish the boundary of the ocean and the land to get the land image of the reefs and islands, then color density slicing is introduced to show the different layers and levels of shallow water depth thoroughly using TM1. Reefs, islands, reef flats, reef slope, marine bottom topography can be distinguished by TM1/TM3 or TM1/TM2 ratio images. The details of vivid topography of reef flats are presented after processing of TM1/TM4 ratio image by Kirsch non-linear edge enhancement and Laplacian Transform . Finally, the perfect remote sensing images of coral reefs and islands are conducted by pesudocolor composition of TM1/TM2, TM2 and TM1/TM3.

Area 2: Some atolls of Zhenghe Reefs in Nansha Islands are selected as example. At first, the distribution of submerged reef and 泻湖 is created through extension processing of TM1 images; then, the bathymetric data of the different parts of the reefs and islands are showed by density slicing of each atolls; finally, the up water areas of the reefs and the islands and reef ridges are distinguished by TM4.

2. Digital terrain modeling of coral reefs

Digital terrain modeling is effective to visualize and analyze bathymetry and topography of coral reefs and lagoons. The North Danger Reefs of the South China Sea is selected as the study area, which is located at approximately 114(E/11(N (close to the Tizard Bank and Reefs). The coral reef atoll is about 15 km long and 8 km wide. It consists of four major reefs, named as North Reef, North East Cay, South West Cay, and South Reef.

The original water depths of the North Danger Reefs were surveyed by Japan in 1936. The bathymetric data map, obtained from U.S. Defence Mapping Agency, Hydrographic/Topographic Center, was scanned and water depths were digitized using Intergraph hardware and software. The data processing and digital terrain modeling were conducted using MGE Terrain Analyst (MTA) with Bentley's Microstation 95 on the Microsoft Windows NT based Intergraph TD-40 personal workstation housed in the Coastal GIS Research Laboratory of Coastal Studies Institute, Louisiana State University.

The digitized water depths and contours were converted to TIN and GRID model from which the digital terrain model (DTM) was created. Digital bathymetric data, contour lines, slopes and aspects, profiles, and shaded relief maps were derived from the DTM. Figure 1 is a top-view bathymetry of the coral reef atoll with the locations of three profiles A-A', B-B', and C-C'(Figure 2). A-A' is a NW to SE cross-section profile of the North East Cay, which starts with a very steep slope representing the outer slope of the reef. The top of the reef is flat and submerged from water. B-B' and C-C' are cross-section profiles of long and short axis for the reef atoll, showing very steep slopes of outer reefs and smooth and flat sea floor in the lagoon surrounding by the reefs. A slope map was produced for the area to show the characteristics of the reef atoll topography . It is noted that the coral reef atoll has an approximately 25-40(outer slope; some places are 60-70(, at the water depth between 20 and 200 m. A relatively steep slope also occurs at the inner reefs at water depth of 20 to 35 meters. The lagoon has a smooth and flat sea floor with water depths of 35 to 43 meters.

Figure 3 is a 3D grid surface map created from DTM with a standard iso-view and 75 meter grid size to show the general topographic characteristics of the coral reefs. The depths, slopes, and sea floor can be visualized with the shaded relief maps; even small protrudings in the lagoon can be identified .

In addition, the landsat TM data in the area obtained on May 13, 1992 were also used to analyze the bathymetry and topography of the reef atoll. However, the TM data have a 30 meter spatial resolution and a limitation of penetrating water columns, merely using TM data is difficult to analyze bathymetric and topographic characteristics of the reef atoll. Therefore, the TM data were hereby combined with the digital terrain model. In order to do so, a TM image for the study area was extracted from the scene 120/52 and geographically registered to the Mercator projection in which the DTM was. Then the image was

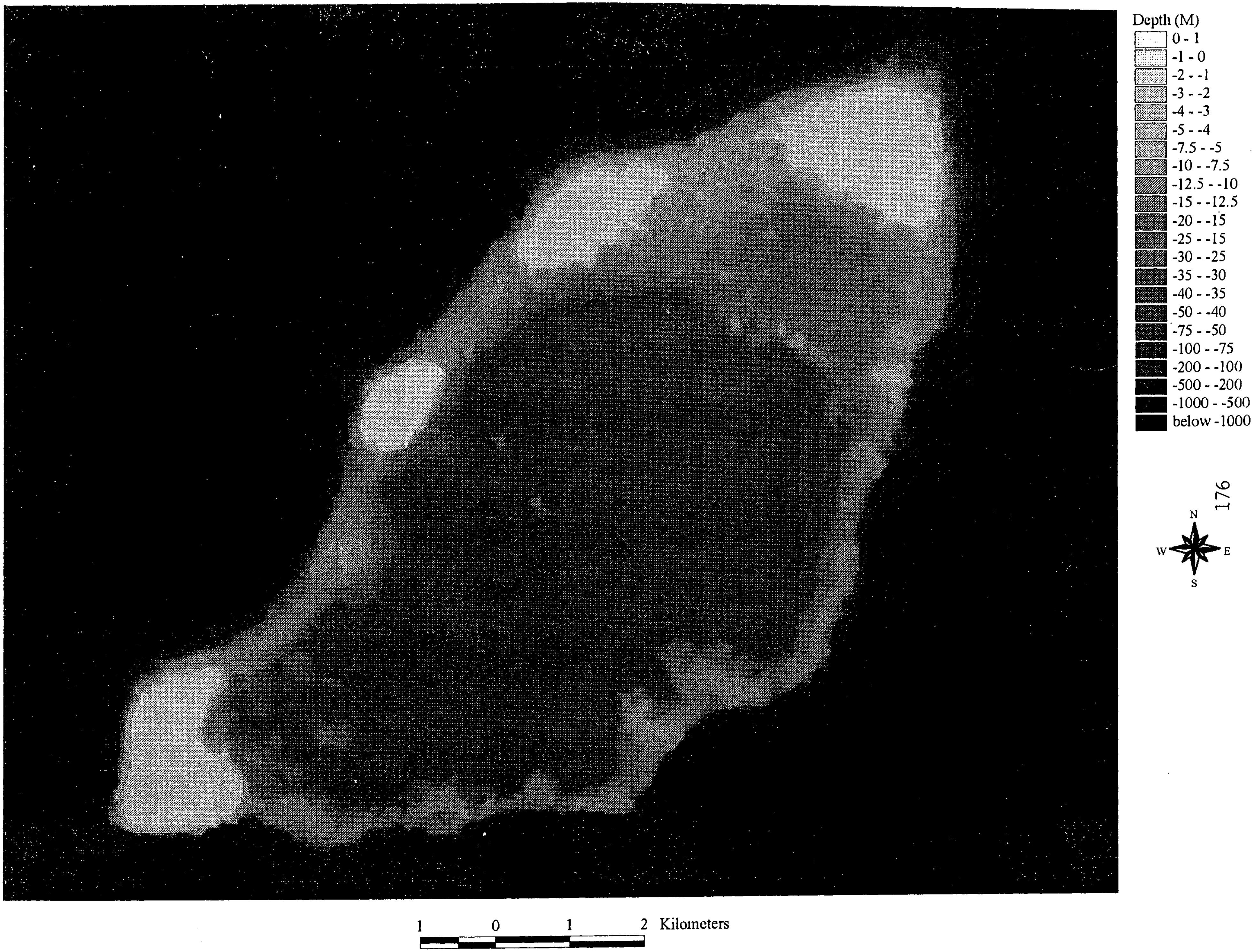

Fig 1 A top-view bathymetry of the coral reef atoll of South China Sea

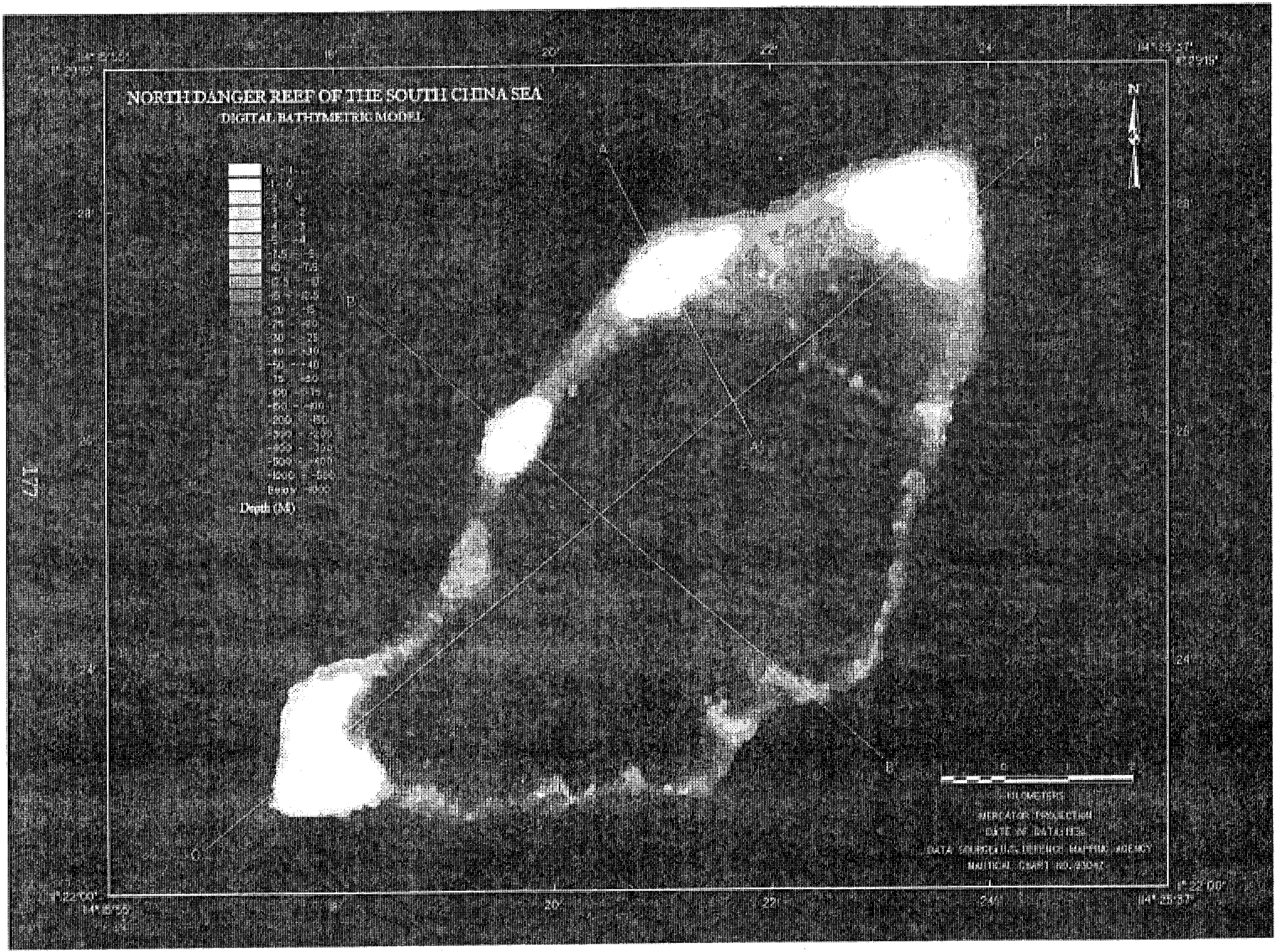

Fig 2-1 The locations of three profiles A-A', B-B' and C-C' in North Danger Reef

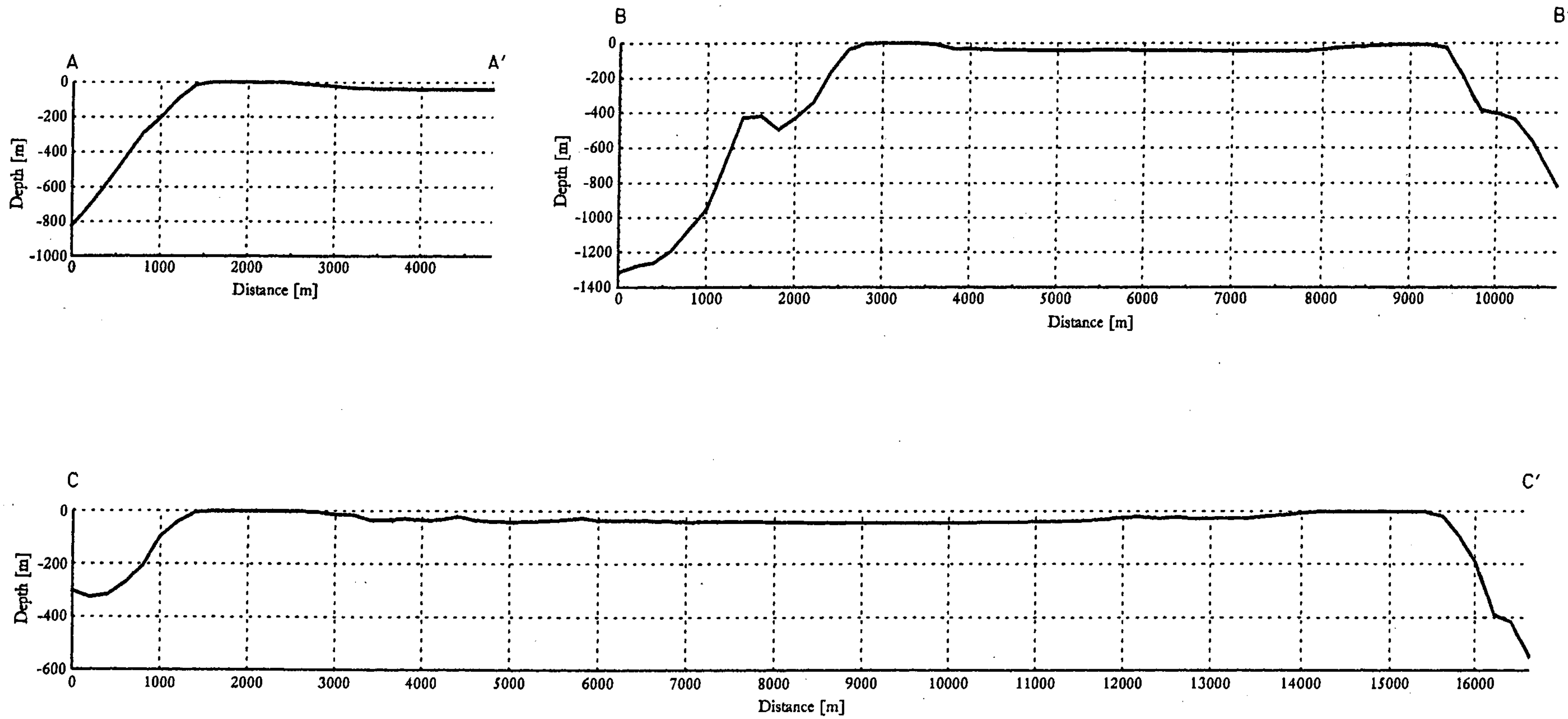

Fig 2-2 The profiles of North Danger Reef

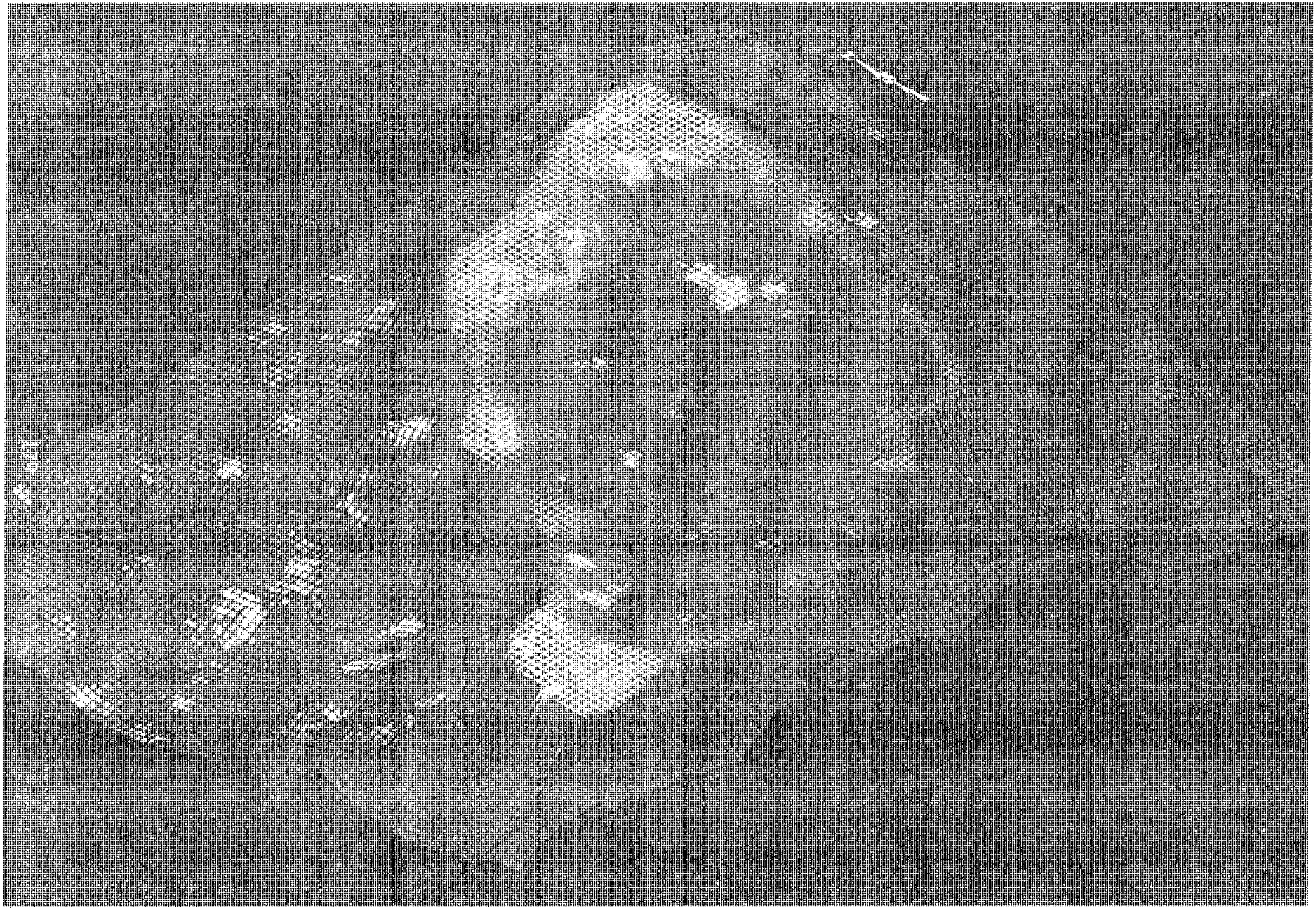

Fig 3 3D grid surface map created from DTM

resampled to 25 meter spatial resolution and draped on the grid model with the 25 meter grid size. Figure 4 is the resultant draped image with grids on the top showing the topographic characteristics of the reefs with different tones. The two elongate-shaped areas are the North East Cay and South West Cay above the water surface. The DTM data can also be used to verify the bathymetry results produced from digital satellite images.

3. The Composition of Fringing reefs RS image and DTM

Diamond Head , a dead crater located at the south-east corner of Oahu island, Hawaii, is selected as the case study area in this example. The coral fringing reefs are all distributed in shallow water area in the range of breaker zone . Because of the small area and disperse distribution of the reefs, SPOT satellite RS image with the spatial resolution of 10 m and 20 m is selected as the main information source.

Step 1. After the image enhancement and pesudocolor composition of the SPOT satellite Panchromatic mode(0.51~0.73 um, resolution is 10 m) and Multispectral mode(B1: 0.50~0.59 um, B2: 0.61~0.68 um, B3: 0.79~0.89 um) using ERMAPPER version 5.2, the coral reef information is extracted and displayed .

Step 2. The digitized terrain and bathymetry data by GIV software are converted to grid data from which three dimension DTM data with actual coordinate and projection is created.

Step 3. At first three dimension grid data are loaded into ERMAPPER. Then the grid data is composed with SPOT satellite RS image and the view angle is adjusted to a appropriate position after the transform and rotation of the coordinate and projection(rotation equals 0). The final result is done.

Further Studying Subject

1. The penetration depth through water column of visible light rest with solar altitude angle, azimuth, roughness of the sea level , the size and density of the suspended grain in water.
2. The alga , the composition and the color of sea bottom material may lead the greater error of bathymetry calculation.
3. The evaluation of capacity using SAR detecting the shallow water topography.

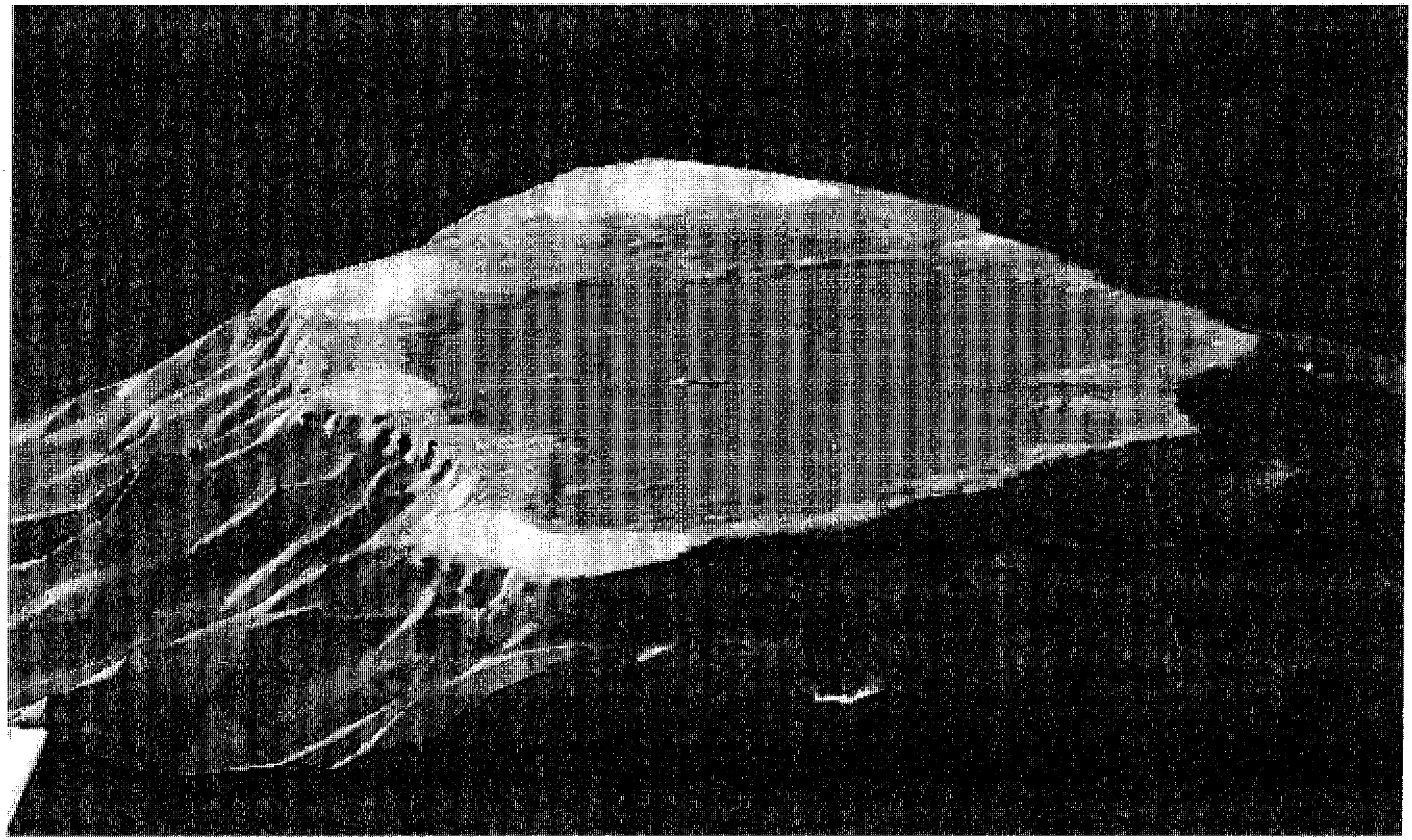

Fig 4   Composition map of image and DTM

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LASER BATHYMETRY IN AUSTRALIA

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ABSTRACT

The Laser Airborne Depth Sounder (LADS) commenced operational service with the Royal Australian Navy (RAN) in February 1993. Since then the RAN LADS has successfully surveyed over 10000 square nautical miles of the Australian continental shelf.

As a result of this success a new generation system, LADS MkII, has been developed. The system is fitted in a deHavilland DHC (Dash 8) aircraft, and will commence operations in 1998.

This paper will discuss the operations of the RAN LADS, and outline the capabilities of the LADS MkII.

SYSTEM OVERVIEW

The LADS system as operated by the Royal Australian Navy (RAN) comprises the following systems:

Airborne System

- Specially modified Fokker F27 aircraft
- On board Airborne Data Acquisition System (ADAS)

Ground Processing System

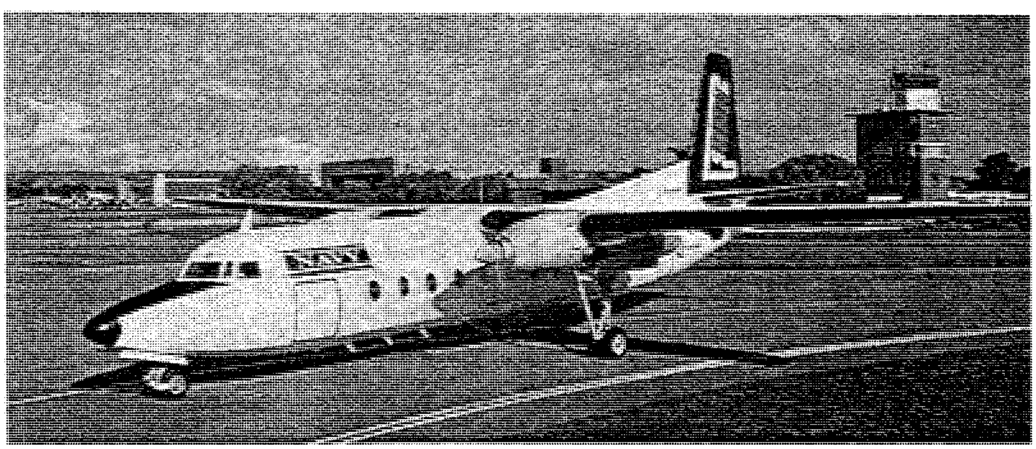

Figure 1: The LADS Aircraft

Airborne System

Survey data is collected by the Airborne Data Acquisition Subsystem (ADAS). During survey operations the F27 is flown at an altitude of 500 metres and a speed of 145 knots. It has a transit speed of 220 knots, and its maximum sortie duration is 7.5 hours. Position control is provided by P code GPS.

The laser is fitted to a stabilised platform and fires at 168 hertz; an infra-red beam is produced to reflect from the sea surface to measure aircraft height and provide system timing, and a narrow green beam is used to profile both the sea surface and sea bed. At the sea surface beam diameters are 25 metres for the infra red pulse and 3 metres for the green pulse. The green pulses are nominally spaced 10 metres apart in a rectilinear scan pattern 240 metres wide. Half & third scan capabilities have also been developed for shoal examinations; in these modes green laser pulses are spaced 5 & 3 metres apart respectively across each scan. Data is logged in real time onto magneto-optical disks, and then passed to the ground processing system.

Ground Processing Systems

Survey planning and data processing are conducted at the aircraft operating site. The original processing system is called the Ground Analysis Sub System (GASS), and consists of two MIPS 3330 processors and two Sun work stations installed in a ISO container which is mounted on a semi-trailer. Advancements in computer hardware have enabled the survey planning and data processing tasks to be conducted on a smaller and fully portable processing system, the Porta-GASS. This platform is routinely deployed in the aircraft to any new site, and is usually set up in a hotel room. The GASS and Porta-GASS currently have hard disk capacities of 18 Gb and 12 Gb respectively. An A0 ink jet plotter is provided in the GASS van to produce hard copy products, and an A1 plotter is routinely deployed with the Porta-GASS.

MAINTENANCE AND SUPPORT

The philosophy used for the support of the RAN LADS system is to contract out maintenance and logistics support. This is considered to be the most cost effective solution, as it avoids the requirement to sustain these capabilities within the RAN, and enables the uniformed personnel to focus on survey tasks. An initial 3 year maintenance contract was established, and due to the success of the arrangement it has recently been extended for a further period of 5 years. This contract has been established with LADS Corporation.

The maintenance philosophy has 3 levels. At the first level trained technicians in the field (known as field maintainers) are responsible for correct system set up, daily pre-flight checks, routine preventative maintenance and first line defect maintenance. A comprehensive holding of Field Replaceable Units (FRUs) and test equipment are held in the field, which enables the field maintainer to conduct defect analysis and repair by replacement unit. The second level of maintenance is conducted by engineers in the contractor's depot to repair and calibrate FRUs. The third level of maintenance is specialist advice and support from the senior engineers at the depot.

There is daily contact between the contractors field maintainers, contract field manager and the RAN Officer-In-Charge (OIC) at the operating site. This is supplemented by monthly contractor progress reports and three Operational Support Contract meetings per year, where all activities are reviewed. Systems Development and Technical Strategy Meetings are also held at the same time. The LADS system is supported by a full set of technical documentation including manuals, drawings and written procedures.

The overall maintenance and support for LADS approach has been found to minimise failures and has enabled 4 sorties per week to be maintained at different operating sites.

A complete set of operating manuals have also been developed, and a fully documented operator training course of 5 weeks duration is run annually. Uniformed hydrographic surveying personnel generally serve between 18 months and 30 months in the unit. Personnel changes are staged to ensure there is a slow but continual rotation of personnel.

SURVEY OPERATIONS

General Operations

Since 1994 the LADS system has operated from the General Aviation section of Cairns international airport in Far North Queensland, Australia. Approximately 150 sorties are flown annually which provides in excess of 1000 hours of operation. This is broken up into 3 or 4 Missions of between 8 and 16 weeks duration. Each year the LADS Unit generally deploys to another operating site for one mission of up to 3 months duration. Additional short forward deployments of only 1 or 2 weeks duration are also conducted for tasks of a more urgent nature.

The survey team consists of 6 RAN hydrographic specialists; 3 officers, 2 senior sailors and 1 junior sailor. Support personnel consist of 3 pilots, 2 Licensed Aircraft Maintenance Engineers (LAMEs), 2 systems technicians and a field manager in the field, as well as management, design and maintenance personnel at the contractor's depot in Adelaide, South Australia.

Generally a number of surveys are conducted concurrently which enables the mobility of the aircraft to be used to best advantage. In this way each area can be surveyed when the environmental conditions in that area are optimum, which results in the capture of the highest quality data at all times. It also enables areas of low cloud or high turbidity to be avoided, which minimises the effects of these constraints to the extent that they seldom curtail operations. Large survey areas are broken up into smaller blocks of approximately 1000 square nautical miles, which assists data management in the field unit and in the RAN Hydrographic Office, by enabling surveys to be rendered progressively.

On each survey sortie a primary objective is nominated, but an alternative survey plan is always carried to enable survey operations to be moved in real time if required. Sorties are generally timed to arrive in the survey area 2 hours prior to sunset; operations throughout the day are possible, but in deep water high sun elevations increase noise levels, which consequently increases operator data review and validation times.

Each sortie generally consists of a transit, navigation calibration, benchmark (depth quality assessment) and a number of survey lines. On a typical sortie of 7.5 hours duration, between 3 and 6 hours is available on task depending on the length of transit. Four survey sorties are flown each week, which gives an average of over 30 hours flying time per week. Importantly, the number of sorties each week is restricted only by pilot and survey staff availability, not the LADS system.

All data processing is conducted in the field. Following each sortie the data is automatically processed by the system that night. Data processing takes approximately the same time as data collection. This processed data is then validated by a survey operator (one sortie requires approximately one day's work), checked by a survey coordinator (one sortie requires approximately 0.5 day's work) and approved by the OIC (one sortie takes approximately 2 hour's work). Data is collected in a similar manner to surface units; blocks of work (sub-areas) are completed, gaps are filled (reflies), shoals are examined at reduced laser spot spacing and cross-lines are sounded.

The time required by operators to validate, check and approve each sortie depends on the amount of data collected and the complexity of the bathymetry in the survey area. Simple areas may only require half the times stated above, however when operations have been conducted in the complex reef areas close to the operating base in Cairns, up to twice these times have been required. The field unit's data processing capacity, storage and operator access then becomes yet another issue that needs to be managed through the use of alternative survey areas, to maintain an even rate of data capture.

LADS products include hard copy plots or fair sheets, and on completion of a survey data is also exported digitally in a defined ASCII format (Final Survey Data). Three dimensional imagery can also be produced off-line using third party products. Additional LADS data processing systems also exist at the RAN Hydrographic Office for quality control, at the Australian Government's Defence Science and Technology Organisation (DSTO) for ongoing research, and at the contractor's depot for software development. The Porta-GASS located in the field, is also routinely used for data processing.

Each survey is also supported by a detailed Report Of Survey (ROS) which is compiled using a similar methodology to surface units. This report includes a list of significant bathymetric features (Shoal Summary) which lists all the significant features in the survey area that have been newly found, relocated or disproved / not found. An assessment is made for each shoal of whether the least depth has been found is made by examining the raw laser waveform. Charting action can then be recommended.

The completed survey is then forwarded to the RAN Hydrographic Office where a quality control process is conducted prior to undertaking charting action.

SURVEYS CONDUCTED

Most surveys have been conducted in the Great Barrier Reef area on the north eastern coast of the Australian continent. This part of Australia's coastal zone is characterised by complex, unsurveyed reef areas to which access is denied for most surface navigation. The area of Torres Strait, between Cape York and Papua New Guinea, is remote, shallow and extremely hazardous. Access is denied to surface survey vessels.

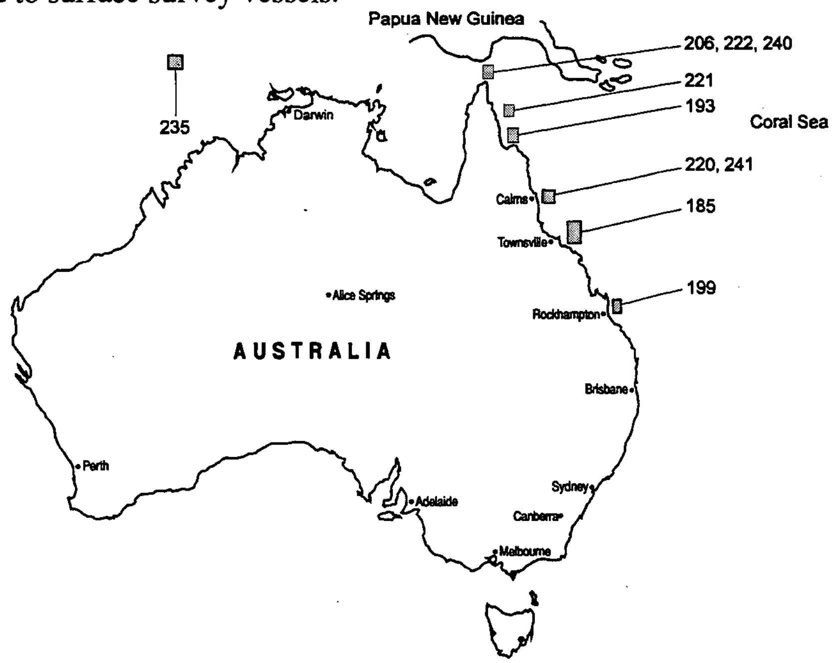

Figure 2: Survey Areas around Australia

Surveys in 1993

Survey instructions are issued to the LADS Unit, as they are to all survey surface vessels. These survey instructions, known as Hydrographic Instructions (HI) contain the following:

- previous survey data
- objective of survey
- charting action that will occur
- datums to be used
- any other special instructions

HI (Hydrographic Instruction) 185 - Flinders Passage

This survey was LADS first and was conducted between 10 March and 12 December 1993. The unit was deployed to Townsville to minimise transit times, and an area of 2260 square nautical miles was surveyed. The survey was also conducted with support from two Survey Motor Launches (SML), and confirmed the existence of two passages for deep draught shipping from the Two Way Route off Abbot Point to the Coral Sea. During the period a number of system enhancements were also implemented, and the system was formally accepted into naval service on 8 October 1993. The survey data is shown on 31 fairsheets at a scale of 1:25000. Importantly, the data finally depicted on the fairsheets represent about 0.5% of the total actual data collected by LADS during the survey. The survey reported 138 new and relocated shoals, and disproved 12 charted shoals. This survey has been incorporated in the release of a new edition of chart AUS 826.

Surveys in 1994

HI 199 - Capricorn Group
The Capricorn Group is located on the Tropic of Capricorn in the Great Barrier Reef off the coast of Queensland.

This survey was conducted from 24 January to 31 March 1994, with the aim of providing modern charting in an environmentally sensitive area in the Great Barrier Reef Marine Park. The survey area is located near Rockhampton therefore the unit deployed to Rockhampton, to minimise transit times. An area of 688 square nautical miles was surveyed. The survey data is shown on 19 fairsheets at a scale of 1:25000. The survey reported 84 new shoals, relocated 38 charted shoals and disproved 6 charted shoals.

The following two surveys, HIs 193 and 206, were conducted concurrently. Survey operations were conducted where environmental conditions were most suitable.

HI 193 - Fairway Channel
Fairway Channel is located off the coast of Far North Queensland about 300 miles north of Cairns. The aim of the survey was to delineate a safe north/south route between the inner and outer reefs along the North East Coast of Queensland.

This survey was conducted from 9 November to 6 December 1993 and 13 May to 2 December 1994. The unit operated from Cairns which is the closest reasonably serviced airfield, nevertheless a daily 300 mile transit was involved. An area of 1212 square nautical miles was surveyed by the aircraft, to complete a total enclosed area of 850 square nautical miles. A new 96 mile long potential shipping route was surveyed with a width of between 4.5 and 11 nautical miles. In addition numerous outer reef entrances were also surveyed to determine their suitability for navigation. The survey data is shown on 15 fairsheets at a scale of 1:25000 over the full survey area plus 14, 1:10000 fairsheets of various areas within the survey area. A total of 397 shoals were reported; 225 new shoals were found, 160 charted shoals were relocated and 12 charted shoals were disproved.

HI 206 - Torres Strait
Torres Strait is situated between the northern most point in Australia, Cape York at the top of Queensland, and Papua New Guinea. The survey area is about 500 miles north of the base at Cairns. It is an extremely hazardous area and there is a lack of any survey data and access is denied to survey vessels.

This survey was conducted between 2 May and 2 December 1994 with the aim of improving charting to support surveillance and patrol operations, as well as providing data for use in the fields of science and the environment. This part of Torres Strait proved to be a difficult area to survey due to its remoteness, the common occurrence of very low cloud, high water turbidity and lack of archived tidal data.

The aircraft operated from Cairns, but was also forward deployed for up to three days at a time to Weipa on Cape York, and Port Moresby in Papua New Guinea, to improve productivity. Some 553 square nautical miles were surveyed by the aircraft, to complete an enclosed survey area of 404 square nautical miles. The survey data is shown on 7 fairsheets to a scale of 1:25000 and 1 fairsheet to a scale of 1:10000. A total of 118 shoals were reported; 54 new shoals were found, 49 charted shoals were relocated and 15 charted shoals were disproved.

Surveys in 1995

The surveys under HIs 220, 221 and 222 were conducted concurrently. Survey operations were conducted where environmental conditions were most suitable.

HI 220 - Cooks Passage to Trinity Opening
This area is located just off the coast from Cairns in the Great Barrier Reef. This survey was conducted between 3 May and 11 December 1995, to provide modern charting in an unsurveyed area widely used by vessels in the tourist industry and to provide data for reef management. This survey was conducted in two separate databases; the southern database was completed as HI 220, and the northern database was completed in 1996 under HI 241. The survey data is shown on 10 fairsheets at a scale of 1:25000 and an additional 7 fairsheets at 1:10000. The aircraft surveyed an area of 1136 square nautical miles and 580 shoals were reported. On one sortie a record 88 square nautical miles was surveyed. In addition a block correction to chart AUS 830 was produced by the Hydrographic Office part way through the survey, to allow immediate access to an unsurveyed reef area for tourist operations.

HI 221 - Cape Weymouth to Blackwood Channel
This survey area is located 350 miles north of Cairns in the Great Barrier Reef off the Queensland coast. The survey was conducted from 15 May to 8 December 1995 as an extension to the HI 193 Fairway Channel survey, to provide a potential alternative North/South shipping route on the northern Great Barrier Reef. A total enclosed area of 354 square nautical miles was surveyed. The survey output comprised 5 fairsheets to a scale of 1:25000 over the full survey area and 2, 1:10000 fairsheets of areas within the survey area. Some 273 shoals were reported; 143 new shoals were found, 125 charted shoals were relocated and 5 charted shoals were disproved. In addition the HI 193 Fairway Channel survey was also extended West to the Two Way Route off Cape Direction, and three potential passages were found. An additional 170 square nautical miles was surveyed, and another 80 shoals were reported; 31 new shoals were found, 40 charted shoals were relocated and 9 charted shoals were disproved. A number of other miscellaneous tasks (refer to Miscellaneous Tasks) were also conducted during this survey, and a total of 655 square nautical miles were surveyed by the aircraft.

Figure 3: 3D Image of Agincourt Reefs

HI 222 - Torres Strait

This survey was an extension of HI 206 described above and was conducted from 22 June to 28 November 1995. Some 554 square nautical miles were surveyed to enclose a total surveyed area of 394 square nautical miles. The survey data was shown on 5 fairsheets to a scale of 1:25000. Some 231 shoals were reported; 138 new shoals were found, 75 charted shoals were relocated and 18 charted shoals were disproved.

Surveys in 1996

HI 241 - Hope Island to Lark Pass

This survey area is located near Cooktown in Northern Queensland. This survey was conducted concurrently with HI 220 in 1995 and continued until 3 April 1996, to extend the survey north to Lark Pass. The survey data is represented on 6 fairsheets at a scale of 1:25000 and reported in excess of 250 shoals.

HI 235 - Sahul Banks
The aircraft deployed to Darwin for a twelve week period from 13 May to 5 August 1996, to conduct a survey over the Sahul Banks off the northwest coast of Australia. This survey is discussed as a case study later in the paper.

HI 240 - Torres Strait
This survey was conducted from the 9 September until 13 December 1996. The Torres Strait surveys under HIs 206 and 222 were extended farther North towards the Papua New Guinea coastline.

HI 245 - Coral Sea
This survey was conducted concurrently with HI 240, as an alternative in the event of poor environmental conditions in Torres Strait.

Hydrographic Instruction	No. of Sorties	Flying Time (hours)	Time on Task (hours)	Area Covered (sq nm)	Coverage per Sortie (sq nm)	Coverage per Hour on Task (sq nm/hr)
185	69	417.00	301.00	2260.00	32.75	7.51
199	30	157.80	130.00	688.00	22.93	5.29
193	46	277.75	153.60	1212.27	26.35	7.89
206	29	184.15	75.65	553.41	19.08	7.32
220/241	39	217.69	138.82	1135.71	29.12	8.18
221	29	188.72	76.72	654.95	22.58	8.54
222	25	179.58	59.62	554.44	22.18	9.30
235	44	337.57	176.05	1497.32	34.03	8.51
240	26	187.16	57.75	513.17	19.74	8.89
245	34	231.22	111.90	774.58	22.78	6.92
Totals	**371**	**2378.64**	**1281.11**	**9843.85**	**26.53**	**7.68**

Table 1: Summary of Major LADS Surveys

Miscellaneous Tasks

Various miscellaneous small surveys were also conducted from 1994 to 1996 for various reasons:

a) Indonesia - Enganno Island - LADS demonstration survey. This was an overseas deployment to demonstrate LADS to the Government of Indonesia. It involved 5 sorties over a 2 week deployment.

b) Wreck site of HMS Pandora for Queensland Museum. Involved two half sorties of the wreck site 400 miles north of Cairns. The results enabled the placement of a mooring for boats with scuba divers.

c) The Bar - Lakes Entrance. This was a 10 sq nm survey of the entrance to a commercial fishing port. LADS was deployed 1400 miles from Cairns to conduct this survey.

d) Ashmore and Scott Reefs. Significant territorial sea baseline terminal points were surveyed at Ashmore Reef, some 500 miles west of Darwin. This was conducted to coincide with high water spring tides in 1996. Nine survey lines were flown tangential to the reef edges to determine the significant points. In addition the position of the high water and drying lines were surveyed at Cartier Island.

e) Booby Island. This island is located on the Western approach to the Torres Strait shipping route. A merchant vessel had reportedly touched bottom and LADS was used to determine if an uncharted shoal existed.

f) Barthalumba Bay and Milner Bay. This was conducted in support of a major Australian Defence Force exercise. Specifically the data was used for an amphibious operation. This survey was conducted at short notice as part of testing 'Crisis Response' capability.

CASE STUDY - SAHUL BANKS SURVEY (HI 235)

The Sahul Banks are a long chain of hazardous poorly charted shoals in a remote area off the Northwest coast of Australia. The area has both commercial (oil & gas) and defence importance. Because the Sahul Banks are remote, survey ships and LADS are the only means by which they can be surveyed. The poor status of charting made survey by ship too hazardous, so the RAN engaged LADS to survey the outer edges of the banks to allow subsequent survey by ship of other parts of the Banks.

A reconnaissance of the Sahul Banks was conducted to select suitable benchmark and navigation calibration sites and to determine the general nature of the area. On Monday 28 August 1995 the LADS aircraft proceeded from Cairns to Darwin, a distance of 900 miles. A two hour investigation of a reported shoal off Port Essington in Arnhem Land was conducted enroute. On Tuesday 29 a seven hour reconnaissance sortie was conducted over the potential survey area; suitable navigation calibration and benchmark sites were identified.

A miscellaneous survey task was also conducted during the visit to Darwin; the survey team members observed a geodetic GPS network across the Darwin area to coordinate the site of a DGPS monitor station for future use by surface survey units. The LADS team then returned to Cairns in the aircraft on Friday 1 September.

Following this reconnaissance a survey plan was proposed which was subsequently endorsed by the RAN Hydrographic Office. HMAS MORESBY was tasked to conduct a survey of the proposed benchmark site on Echo Shoal, and the coordinates of the proposed navigation calibration site, Cape Fourcroy Light, were obtained from archives. A Hydrographic Instruction was then issued to the LADS Unit.

On Monday 13 May 1996 the LADS aircraft was deployed to Darwin. The field site was set up in two days, and on Thursday 16 a calibration flight was conducted to confirm correct system operation, verify the set up of the survey databases and sub-areas and check the tidal model over the benchmark site. These objectives were successfully achieved, and survey operations were commenced.

Over the following eleven weeks 43 survey flights were conducted. Operations were conducted on a number of discrete survey areas over large groups of shoals which extended from 175 miles NNW to 450 miles W of Darwin. Despite an average transit distance of 700 miles (350 nautical miles each way) an average of 34 square nautical miles was surveyed per sortie. One sortie was affected by weather; a heavy rain squall prevailed in the centre of planned sub-area, and the cloud base was below survey altitude. After 15 minutes on task operations were moved 200 miles to the east to the planned alternative objective at Evans Shoal.

For the duration of the deployment, four sorties were flown each week from Monday to Thursday. On two occasions sorties were deferred until the Saturday whilst awaiting the air freight of essential spare equipment from the contractor's depot. In both cases no survey time was lost. Routine aircraft maintenance was conducted every second Friday, and daily checks were also conducted each forenoon; an engine compressor wash was also conducted following each flight. Average flight duration exceeded 7.5 hours per sortie, and flights were scheduled between 1430 and 2200.

Sortie processing commenced at 2230 each evening on return of the aircraft. A backup copy of the Magneto-Optical disk containing the raw data was made prior to processing the navigation calibration and benchmark objectives. Automatic processing was then commenced, and personnel would generally be clear of the site by 2300.

The processed data was able to be inspected the next morning. To balance the operators' work loads the same survey team would generally fly four consecutive sorties, and so the validation and checking of that data occurred the following week. The OIC then approved all outstanding survey data on an as-required basis. Towards the end of the deployment the validation, checking and approving processes were conducted on the day immediately following each sortie, and plots were produced almost daily. This facilitated real-time survey management and ensured all survey work in each sub-area was fully completed including requirements for reflies, shoal examinations and disproving searches.

During the survey both the data collection and data processing systems were optimised to collect the highest fidelity survey data. Survey operations commenced approximately two hours prior to sunset, which reduced background noise levels. Due to the strong seabed returns from depths beyond 50 metres the ADAS maximum gain levels were also able to be reduced. The processing system was also optimised to ignore deep water noise, but retain the sensitivity required to detect small boulders of 1 only metre in diameter on top of the shoals. This was achieved through manipulation of the signal processing parameters, with the result that few manual edits of the automatically processed data were required.

LADS collects data at a nominal 10 metre of primary sounding interval; hydrographically approved secondary soundings were produced at 30 metre spacing. Hard copy colour banded fair sheets were produced at scales of 1:25000 and 1: 10000. In addition the digital data was exported in ASCII format.

During the course of the twelve week deployment to Darwin, two previous major LADS surveys were also fully reported. These tasks were conducted on the Porta-GASS to minimise disruption to the processing of the current survey. This enabled the full details of all shoals to be extracted, fair sheets to be produced, the survey data to be exported into the defined Final Survey Data format and the Report of Survey to be completed.

COMPARISON OF LADS DATA WITH SHIP WORK

As a result of the HI 193 Fairway Channel survey with the LADS system, a potential alternative to a constrained part of the inshore Two Way Route through the Great Barrier Reef was identified. Some parts of the proposed new route cross an area of seabed with numerous features between 12 and 15 metres depth. To verify the LADS results two 37 metre SMLs were tasked to examine a number of these shoals.

Some 200 shoals were surveyed by the two surface units in an area of less than 46 square nautical miles. Very close agreement was achieved between the two data sets, and the least depth over most shoals agreed to within 0.3 metres. The difference over a small number of shoals exceeded this, but in these cases the differences in the surveyed depths were less than the sum of the precisions of the two survey systems. Three significant differences were identified. Two LADS shoals of doubtful quality were disproved, and the surface units found a discrepancy of 3 metres on a 9 metre LADS shoal which had been given the attribute of *'less water may exist'*. These three discrepancies had been anticipated, and the surface survey confirmed the doubt that existed. In summary there was remarkable agreement between the two surveys, which gave great confidence in the high quality of the LADS data.

In the west of the survey area the LADS work had been extended under HI 221 further inshore into the turbid water off Lockhart River where many reefs had been reported. Three potential routes were identified from the LADS data. The surface units were also tasked to confirm these passages through these turbid areas. This activity demonstrated the importance of LADS data in turbid water where the seabed had not been detected, as it enabled the surface survey units to be employed safely and efficiently.

It is interesting to note that during survey HI 193, LADS surveyed in excess of 1000 square nautical miles at an average of 26 square nautical miles per sortie. With the benefit of the LADS data the surface survey vessels surveyed 46 square nautical miles at an average of 0.5 square nautical miles per ship day in the survey area. The shoal examinations conducted by the ships confirmed the high quality of the LADS data. This comparison also demonstrates the huge productivity gains offered by a LADS system in complex hazardous areas.

Since the HI 193 survey, the LADS system has been enhanced with a mode that reduces the scan width to 120 or 80 metres, which provides the laser spot spacing at 5 or 3 metres intervals on the sea surface across each scan. This mode is now used routinely to examine anomalous features where the least depth may not have been found, and has significantly lessened the dependence of the LADS system on surface units to resolve anomalies.

LADS data is used to select proposed routes within the Great Barrier Reef. In areas where complete seabed illumination has been achieved, and least depths have been found, no further work is considered necessary. With respect to feature detection, the LADS data is of such high quality that these routes are not routinely swept with side scan sonar. In areas where least depths have not been found, or full seabed illumination not achieved, additional soundings by a surface vessel may be required.

In summary, in relatively clear coastal waters of less than 50 metres depth LADS is a highly effective stand alone survey capability. It offers such enhanced productivity and complete area coverage that surface units are no longer routinely tasked in these areas. In regions of higher turbidity LADS is a complementary capability to surface survey units. LADS is able to survey the hazardous features and identify the potential deep passages prior to survey by surface units.

LADS MKII PERFORMANCE CHARACTERISTICS

As a result of the success of the RAN LADS System, LADS MkII has been developed by LADS Corporation Ltd for commercial survey operations worldwide.

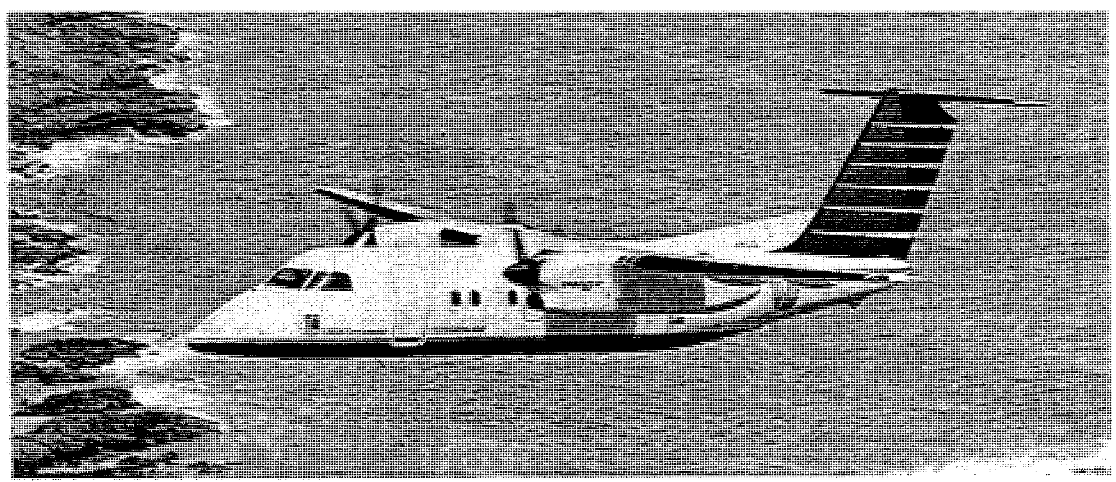

Figure 4: Dash 8-200 Aircraft

A summary of LADS MkII characteristics is as follows.

a) **A self contained survey unit for remote hydrographic survey**
- DHC-8-200 aircraft with auxiliary power unit (APU) and cooling for ground and tropics operations
- transportable ground processing computing facility, capable of being ferried in the aircraft
- short and unsealed runway capability
- high temperature operations capability.

b) The airborne platform mounted in a fixed wing aircraft with long range capability and endurance

- DHC-8-200 aircraft with long range tanks
- ferry range in excess of 2000 nautical miles (3700km)
- in excess of 4.5 hours survey at a range of 300 nautical miles (550km)
- 1.5 hours survey at a range of 800 nautical miles (1500km)
- airborne equipment and laser platform mounted internally to aircraft fuselage with optical port in bottom fuselage
- airborne equipment mounted via seat rails
- total LADS MkII equipment <700kg and <6kW
- total aircraft modifications and special mission equipment approx. 200kg
- aircraft transit speed 248 knots at up to 25000 feet.

c) Survey Configuration

- survey speed, nominal 175 knots (90 metres per second)
- survey height 500 or 366 metres (1640ft or 1200ft)
- survey track keeping, manual or via autopilot coupling
- total aircrew four (two pilots plus two survey operators)
- sea state up to 3
- wind to 30 knots.

d) Depth Sounding

- spatial density 5m x 5m normal with 3m x 3m capability
- swath width, nominal 240 metres
- survey rate 65 square km per hour (19 square nautical miles per hour)
- depth range 0 to 70 metres
- depth accuracy IHO S44 Dec 95, Order 2
- position accuracy <5m, CEP 95%.

e) Ground Processing

- a commercial transportable computing system
- mission and sortie planning
- raw data processing (< 1:1)
- operator validation
- final survey data preparation
- computing equipment operated in normal office accommodation.

f) Logistics

- operational spares and first line maintenance in the field
- basic level maintenance support
- convenient relocation without support vans and ground transport items.

CONCLUSION

LADS operations have been conducted in Australia with the RAN system for almost 5 years, and will continue into the future. The LADS MkII system will shortly commence survey trials, and will then provide a world wide commercial survey service. Australia's continued commitment and leadership of laser bathymetry will continue for the foreseeable future.

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PROGRESS OF OCEAN ENERGY TECHNOLOGY IN CHINA

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ABSTRACT

China is a large sea country, 18,000km sea board-coastline, 6500 sea islands and 3,000,000km^2 sea area, holds abundant ocean energy sources included tide, wave, current, thermal and salinity gradient energy. It is the earliest to use tidal energy in the world, and the wave energy conversion technology has been put into practice in China. Because ocean energy is a clean and renewable natural energy, it is of benefit to the sustained development in the world, the ocean energy technology will be utilized in large scale in the 21st century.

Since the ocean energy is lower in its density, unsteady in adverse sea environment, some special techniques must be researched and developed. China has been provided advanced technology to build a large scale tidal power station included a large scale water turbine-generator, for example, the Jangxia tidal power plant was built with the bulb turbine in 1980s, it is similar to the La Rance tidal power station in France. Several tidal power sites in 10MW scale have been planed in China. The wave-activated generators for navigation have been developed and used along Chinese coast, a 20kW on-shore wave power experimental plant was built, next 100kW wave power station is being built in China. Ocean thermal and salinity gradient power model were also tested in laboratories.

INTRODUCTION

There are 8 tidal power plants in China, 6025 kW of the total capacity. The Sashan is the earliest built at a small island in 1961. The Jiangxia is the largest with 3200 kW of its capacity at a bay in Zhejiang province. Most were built during in the 1970's, with small scale of the capacity, several tialal power sits of 10 MW scale have been planed. It is focualized two provinces, Zhejiang and Fujian, 4-5m of the tidal mean lever. The wave-activated generators for navigation has been used along Chinese seacoast, more than 500 units have been manufactured in China. A small on-shore wave plant has been built on sea trail since the 1980's. Other ocean power models of tidal current, ocean thermal and salinity gradient were also tested in sea or laboratories.

This paper will present some examples on ocean energy conversion technologies and plans in China.

1. Tidal Power Plant

Thirty years ago, the first tidal power plant, Sashan was built in 1961. The rotor of its water turbine was made of wood, 40 kW of its capacity. It was very useful to develop the local economics for processing farm produces and improving the rural life. Several year later the wood rotor was replaced with a iron rotor and has been operated until now. The largest tidal power plant, the Jiangxia plant was completed in 1986, 3200 kW of its total capacity with 5 waters turbine generators. The unit is a bulb turbine generator system (Fig.1), its is similar to the La Rance Tidal Power Station in France.

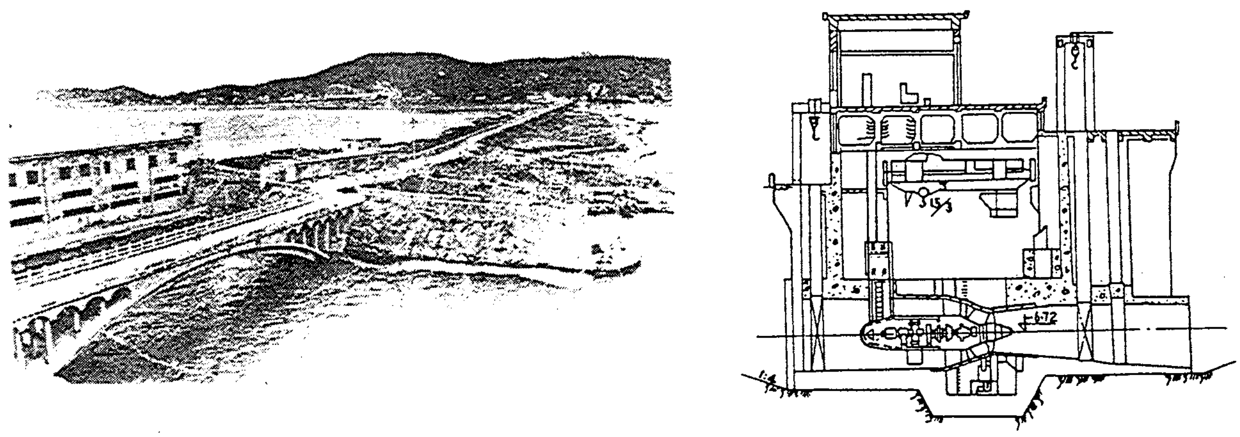

Fig.1 The Jiangxia Power House & The Vertical Section

Jiangxia plant is a experiment tidal power plant for building the large scale plant in the future in China. Ten years of its operating experience, it has proved that the technologies of the Jiangxia Tidal Power Plant is successful and advanced, China has ability to build a large-scale tidal power station. Our tidal power specialists were invited to Southkorea to survey and design their large-scale tidal power station. Five years ago, the No.3 unit of its water turbine-generator was improved, its new rotor had a high specifications including three operating cases: normal rotation, reverse rotation and reversible release sea water (tide fluctuation).

Most of these small tidal power plans use of axial water turbine, because of lower head of the tidal level, their capital invested are very high, that it limits the growth of new and large-scale tidal power station in China. Five years ago, the straflow water turbine generator was began to developed. A lower head (H=2.8m) water power plant used of the straflow water turbine was completed in Guangdong province, with 420 kW of its total capacity with 3 units. Because of its simple construction and saving steel, it could cut done on the capital outlay about 15-20% in the lower head water power plant. It is planed to introduce to the No.6 unit site of the Jiangxia tidal power plant, a empty tunnel for the future.

2. Wave-activated Generator

(1) Wave-activated Generator for Navigation

Research on wave energy conversion technology in the Guangzhou Institute of Energy Conversion (GIEC) began in 1979, it was focused on pneumatic wave power system, specially in the symmetrical aerfoil turbine (Wells turbine). Until now, more then 500 units of the BD Type Wave-activated Generator for Navigation Buoys have been produced and working along Chinese sea coast, including normal light buoys and lager scale light ships. There are two kinds of these units, the symmetrical aerfoil turbine without valve, and the impeller turbine with valves. (Fig.2)

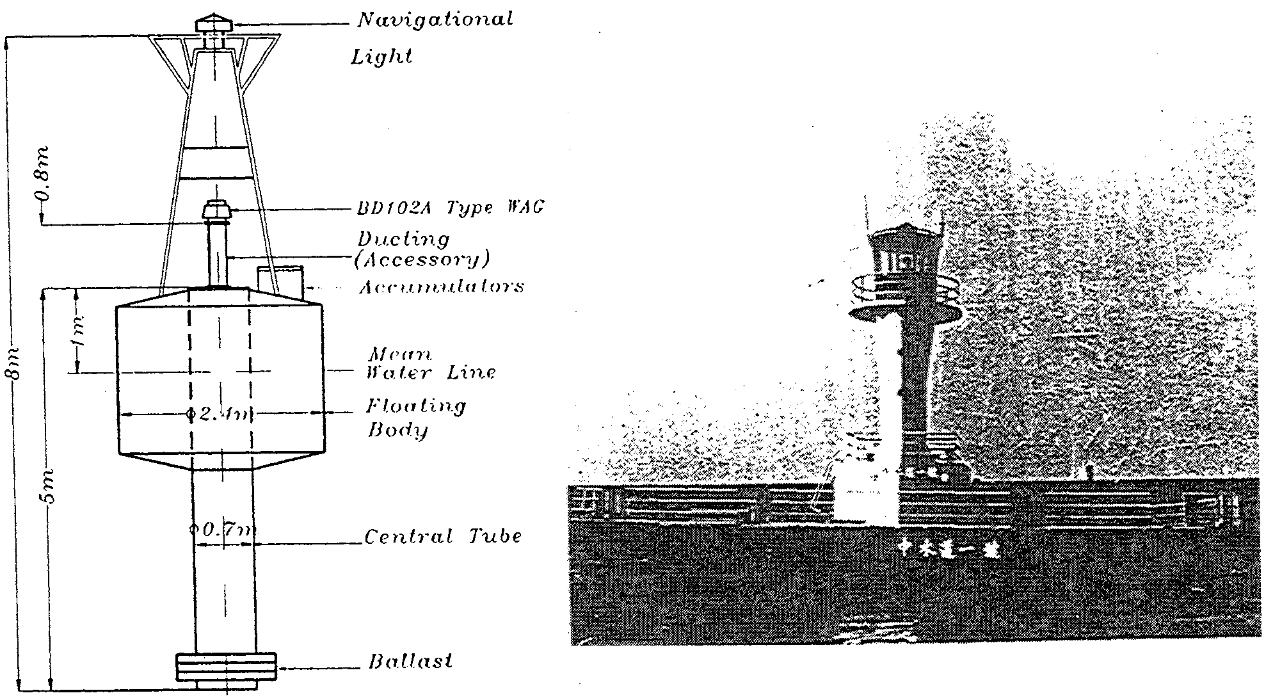

Fig.2 The Wave-activated Generator for Navigation Buoy & Light Ship

(2) The Oscillating Water Coulumn (OWC) Wave Energy Conversion

The pneumatic wave energy conversion system is that, the oscillating water column is excited by incident wave, the water column, in an air chamber, an airflow is drawn out or in to drive an air-turbine to rotate an electrical generator. The air-chamber could be made of a float structure or a bottom-standing structure on seashore.

An OWC Wave Power Plant was began to be built from 1987, at the Dawanshan Island in the Pearl River Estuary, and successful in sea trial. It had a symmetrical aerfoil turbine connected with a 3 kW DC generator. In the same site, a 20 kW OWC wave power plant with the same kind of a symmetrical airfoil turbine was trailed 2 year ago (Fig.3) . The generator was a special generator called a varying speed constant frequency set, it suited for varying rotating rotor to generator constant frequency electrical current to user. Next 100 kW OWC wave power plant has been designed and will be built at another island, Nan Ao Island in the east of Guangdong province, near Taiwan strait. It will generate AC electrical current to supply the main in the island. In this island, there is a larger wind field, more than 10M kW of its total capacity.

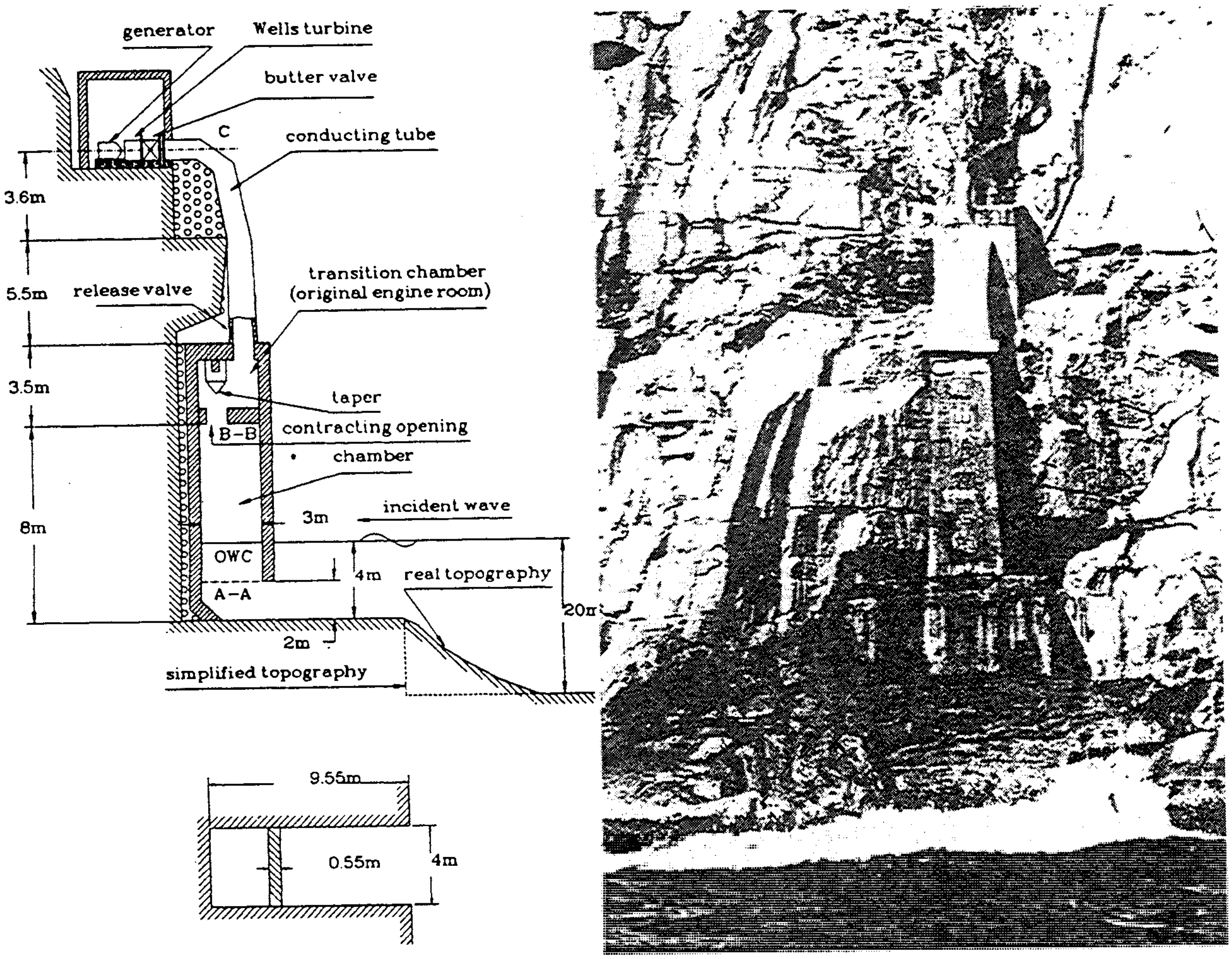

Fig.3 The Dawanshan OWC Wave Power Pant

The Dawanshan Wave Power Plant consists of a reinforced concrete air chamber, which stands on the shore rock, its opening below water faces toward the South China Sea, the opening is 4m width, 2m high up the sea bed. In January of 1996, under the wave (conditions: wave height H=1.5m, wave period T=4-5 sec, its generated 4-5 kW of its average electrical output, the maximum was about 14.5 kW. It was 18-40% of its total efficiency from the incidence power to the electrical power output. The Dawanshan plant is the first wave power plant in China.

3. Tidal Current Power Device

In 1970's, a 8 kW tidal current power experiment device was trailed at a channel of the

Zhoushan Islands in East China Sea. The system consisted of a floating boat, two propellers and a AC generator. The power transferring system was a hydraulic consisted of a oil pump and oil motor. Another 10-20 kW tidal power plant has been designed, it will be a floating vessel fixed by multipoint anchors, its water turbine will be a special vertical blade rotor.

4. Ocean Thermal Energy Conversion (OTEC) and Salinity Gradient Energy Conversion

Two models of the OTEC and salinity gradient energy conversion were experimented separatly in two laboratories, in Guangzhou and Xian, and made either light bulb to light. The OTEC model is a open cycle system, drawing cool water in the depths of 700-1000m below the sea surface. The thermal energy of the temperature gradient between the sea surface and the depth, will be changed to generate electrical power and supply fresh water (by-produce). It is sure that the OTCE technology could be able to co-operate with the mining technology in the depth sea bed in the 2000's.

5. The 21's in Prospect

To sum up the ocean energy will be utilized comprehensively, specially in China, because of the serious problems of increasing population and increasing economics, as well as the energy consumption and environmental pollution in China, it is a important policy to government to utilize the new and renewable energy including ocean energy. 10 MW-scale tidal power stations will built, such as Jian Tiao Gang site: 4.18m in mean tide lever, 15 MW in the total capacity with 5 units of 3000 kW capacity. It will be benefit to enclosing virgin soil, sea breed, ocean chemical industry and tourist trade and etc.

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UTILIZATION AND CASE STUDIES ON WAVE POWER EXTRACTING CAISSON BREAKWATER

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ABSTRACT

Since 1982, the Japanese Ministry of Transport has been developing a special caisson breakwater designed to convert wave energy into electrical power. This converter can be used as a caisson for composite-type breakwaters and seawalls, functioning simultaneously as a breakwater and power generating device. Three stages of field verification/demonstration experiments have been carried out in Sakata Port. First-term experiments verified as rational the structural design of wave-resistant breakwaters and the design of power generation systems, and also confirmed the effectiveness of the wave power extracting system. Second-term experiments verified the power utilization system using "large-volume pumping tests" and "system linking tests," while third-term experiments will verify the durability of the completed demonstration wave extracting power generation system. Studies and experiments carried out thus far indicate that cost-saving wave power extracting breakwaters can be realized under prescribed conditions.

This paper mainly describes the second-term verification experiment and the results of case studies in which wave generated power is utilized in systems for isolated island power generation, sea water desalinization, and below-ground sand filtration. Respective system operation, harbor selection, and cost estimation are discussed.

INTRODUCTION

Utilization of renewable energy has attracted world-wide interest as an effective means of protecting the global environment and maintaining abundant supplies of natural resources. The development of renewable energy sources such that we no longer rely on the use petroleum for power generation has received considerable attention, especially following the 1970 oil embargo. Solar, geothermal, and wind power, all of which provide "clean" energy, are the most popular sources. Exploitation of wave energy, however, provides another clean, abundant source of renewable energy, being of particular interest in Japan and other nations with long coastlines hit by rough seas.

Since 1982, the Japanese Ministry of Transport (MOT) has been developing a special caisson breakwater designed to convert wave energy into electrical power. This unique energy conversion device can be used as a caisson for composite-type breakwaters and seawalls, while functioning simultaneously as a breakwater and power generator. Three stages of field verification/demonstration experiments have been carried out in Sakata Port. First-term experiments ran from 1989 until 1991, where the structural design of breakwaters resistant to wave action and the design of power generation systems were verified to be rational, while also confirming the effectiveness of the wave power extracting system. Second-term experiments ran from 1992 until 1995, where the power utilization system was verified using "large-volume pumping tests" and "system linking tests." From 1996 to 2003, third-term experiments will verify the durability of the completed demonstration wave extracting power generation system. Studies and experiments carried out thus far indicate that cost-saving wave power extracting breakwaters can be realized under certain conditions.

This paper mainly describes the second-term verification experiment and the results of case studies in which wave generated power is utilized in systems for isolated island power generation, sea water desalinization, and below-ground sand filtration. Respective system operation, harbor selection, and cost estimation are discussed.

Figure 1 shows the potential wave energy in ocean areas surrounding Japan, with the total amount being estimated as 36×10^6 kW on the average. In other words, waves with an energy corresponding to 33% of all electricity generated in Japan are breaking along the shores. The potential power of shore-breaking waves at Port Sakata, for example, is 9 kW/m; and when considering that the average Japanese household consumes 3 kW of power, the potential benefits become quite apparent.

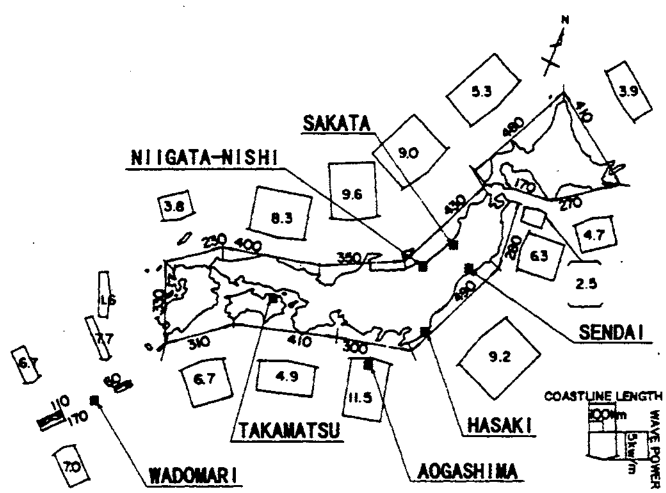

Fig. 1. Potential Wave Power around Japan and Locations where Case Studies were performed.

Wave Power Extracting Caisson

The developed wave power extracting caisson consists of a steel-walled, box-shaped air chamber situated in front a standard caisson, i.e., rear caisson, which serves as a structural support for the air chamber. The front wall of the air chamber has a curtain-like perforated wall with numerous slit-type openings, under which there exists a wide opening allowing the entrance of waves. Figure 2 shows the main components and electrical generation operating principle employed in the wave power extracting caisson breakwater. Basically, the force provided by wave actions drives the water level in the air chamber such that it vertically oscillates, compressing and expanding overlying air that is forced though a nozzle installed at the top of the chamber. The nozzle generates reciprocating, high-velocity air flow used to drive a constant-direction Wells turbine which rotates an electrical power generator. Figure 3 shows a conceptual diagram of the converter machine room.

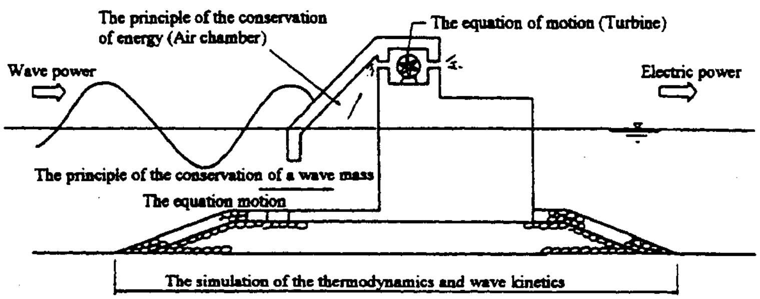

Figure 2. Conversion of the wave energy

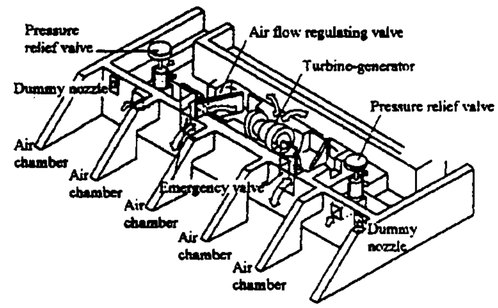

Figure 3. The conception of the machine room

FIELD VERIFICATION EXPERIMENT [1)~4)]

Overview of 1st-term Verification Experiment

The positive findings determined by the Overall Research Committee led to the commencement of a 1st-term verification experiment directed by the MOT; a first-step 5-yr (1987–91) experimental field study which considered a practically applied wave energy absorption type breakwater located at Port Sakata, Yamagata Prefecture. Verification of design method suitability was conducted by comparing experimental power generation data to corresponding design values based on the thermodynamics and wave kinematics method. Major results include:

1) Turbine operation was designed to commence when significant wave height reached 0.7 m, with power output being about 20 and 50 kW at significant wave heights of 2 and 4 m, respectively. In cases where the wave direction was not normal relative to the caisson face, however, power output was slightly lower. At significant wave heights from 1 to 5 m, it was close to the design values.
2) The measured air output efficiency of the air chambers, i.e., conversion efficiency from wave power to pneumatic energy, ranged from 0.4 to 0.9, being slightly higher than the design values based on the thermodynamics and wave kinematics method. In addition, the measured turbine efficiency of the Wells turbine ranged from 0.3 to 0.4, while that of the generator was close to 0.9.
3) The measured power generation efficiency, i.e., efficiency of converting wave power to electric power, was higher than expected, ranging from 0.15 to 0.3 as a result of the higher than expected air chamber conversion efficiency.

Overview of 2nd-term Verification Experiment [5),6)]

In response to the results of the 1st-term verification experiment, which provided valuable operational data on practical use of breakwaters for wave-activated power generation, the MOT modified the initial caisson design to better study how to improve power generation efficiency, optimize the design method, and enhance practical utilization. With these modifications in hand, a 3-yr 2nd-term verification experiment (1992–1994) was launched.

Results of System-linking Tests

System linking tests were carried out to verify the suitability of connecting the wave power generation system to a commercial power system, e.g., one supplying residential power on remote islands. Due to inherent fluctuations in frequency and reverse power effects, generated power must first be transformed to dc voltage and then inverted back to ac voltage before connection to a commercial power grid. One important issue concerns the effect of reverse power once connected; thus, to investigate its effects on commercial power voltage/frequency, a constant-voltage constant-frequency (CVCF) type transducer was installed in the demonstration shelter of the on-shore observation station. Test results were considered to satisfy guidelines prescribed by the Agency of Natural Resources and Energy, Ministry of International Trade and Industry (MITI). That is, power system linking must not adversely effect the reliability or characteristics of the commercial power supply, or the safety of the general public or power company/facility employees.

Results of Large-volume Pumping Tests

Large-volume pumping tests were carried to verify the suitability of applying wave-extracted power to supply large-volume induction pumps used in (*i*) a seawater exchange system designed to filter harbor seawater to improve water quality and (*ii*) a below-ground sand filter system designed to lower the level of ground water to prevent erosion of sand beaches. The tests involved supplying wave-extracted power to a 60-kW generator operating a 55-kW induction pump. Two methods of pump operation were tested: constant speed operation using an inverter or generator-pump direct coupling.

In the constant speed operation test, normal pump operation at a specified speed was obtained by gradually increasing inverter output frequencies. Satisfactory operation was also demonstrated in performance tests which monitored pump speed and power consumption at various inverter output frequencies. Regarding the results of the direct coupling test, while the feasibility of this method of operation was confirmed, further study was deemed necessary with respect to starting conditions.

3rd-term Verification Experiment[7)]

The 1st- and 2nd-term verification experiments provided much information advancing practical development of wave power extracting breakwaters, they were not, however, intended to provide information on long-term operation or data for enhancing practical development. Therefore, in 1996, MOT commenced a 7-yr age deterioration test at the wave power extracting breakwater at Port Sakata, a study expected to elucidate the effects of age on the caisson, power generation unit, and control system, as well as on other facilities, while also allowing evaluation of maintenance requirements/activities and operational costs. This series of tests is referred to as the 3rd-term verification experiment.

CASE STUDIES ON WAVE ENERGY UTILIZATION

Based on the results of past research, cases studies were carried out to determine the most suitable methods for utilization of wave-generated power. Considered forms of energy utilization include the "power supply type," including sea water conversion and below-ground sand filter systems; and "electric power supply type," including isolated island power generation, sea water desalinization, and breakwater lighthouse operation. In other words, systems which do not require constant energy, as well as auxiliary energy systems and systems for converting energy to other forms for storage. The case studies were conducted at the harbors indicated in Table 1, i.e., those sites where the use of this technology is considered realistic in terms of factors such as the annual wave energy available, effectiveness, and scheduled breakwater construction projects. Discussed here, are the case studies related to isolated island power generation, sea water desalinization, and the below-ground sand filter systems.

Table 1. Case Study Item Table

Purpose		Harbor Used	Economic Effects
Electric Power Supply	Electric power generation on isolated islands	Tokyo: Aogashima Harbor Kagoshima Prefecture: Wadomari Harbor	Electric power generation cost reduction
	Sea water desalinization	Tokyo: Aogashima Harbor Kagawa Prefecture: Takamatsu Harbor	Drought prevention, emergency water source, public access breakwaters
	Breakwater lights	Miyagi Prefecture: Sendai Harbor	Transportation cost reductions
Power Supply	Sea water exchange	Niigata Prefecture: Niigata-Nishi Harbor Ibaraki Prefecture: Hasaki Fishing Harbor	Water quality improvement, multi-dimensional use, amenity space, environmental creation
	Sub sand filter	Niigata Prefecture: Niigata-Nishi Harbor	Control of beach erosion, preservation of scenery

Isolated Island Power Generation System

Gas turbine or internal combustion diesel engine generators are typically used to produce power on isolated islands. Such power generation, however, requires that petroleum fuels be transported there, which can substantially increase electric power costs relative to those on the mainland. Because of this, and because there is abundance of surrounding wave energy, isolated islands are ideal for utilization of wave-generated electric power produced for residential use. Thus, a case study was commissioned to investigate economic aspects of this electrical generation system.

Harbor Selection

The following factors were used as a basis for selecting the harbors considered by the case study.

1) Island electric power is currently provided by internal combustion type generators at a

high cost of power production.

2) There is an abundance of wave energy that can be easily utilized.

3) Breakwater construction is already planned for the harbor (port or fishing); thus, only the power generation equipment of the breakwater is an additive cost.

4) Facility costs other than generation equipment costs, e.g., transmission lines, are low.

Selected islands meeting criteria 1)–4) were Aogashima Harbor, situated within the Izu Islands which are part of Tokyo Prefecture, and Wadomari Harbor, situated on Okinoerabu Island in Kagoshima Prefecture (Fig. 1). Two locations were selected to allow a comparative study of electric power generation cost fluctuations caused by differences in available wave power.

Power Generation Capability

Table 2 shows the power generation situation to date. On Aogashima Island, the goal is use wave power as the principal source of electricity, i.e., generation of a maximum output of 800 kW using a breakwater length of 80 m (200 kW × 4 caissons); while on Okinoerabu Island at Wadomari Harbor, the goal is to use wave power to supplement the existing internal combustion engine source, i.e., generation of a maximum output of 1,600 kW using a breakwater length of 160 m (200 kW × 8 caissons).

Table 2. Power Production on Islands

Island	Land Area (km^2)	Power Production Facility (kW)	Population (1985) (people)	Maximum Past Electric Power (kW)	Annual Electric Power Production (1984) (MWh)
Aogashima	5.20	240	211	(199)	(1,134)
Okinoerabu	93.60	14,200	15,965	11,550	51,272

Note: ( ) is data in 1993.

Energy Utilization System

The system-linking tests performed in the 2nd-term verification experiment demonstrated the viability of utilizing wave-generated power within a commercial power system. A remote island power generation system was considered that was similar to that studied in verification testing. In this case, power is directly supplied for residential use as shown in Fig. 4. The wave power extracting caissons were assumed to be installed within the existing offshore breakwater as part of harbor improvement work, with generated electric power being fed through an undersea cable to an land-based electric power converter connected to the normal power supply grid.

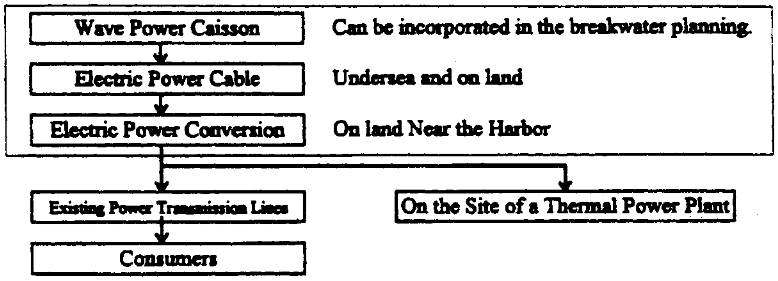

Figure 4. Waver Power Utilization System Flow Chart

Cost Estimation

As mentioned, the cost estimation was premised on the breakwater being constructed with harbor project funds. That is, the power generation cost was estimated considering construction and facility costs, e.g., power generation system, transmission equipment, and system linking equipment, and management and operating costs; while the total operating cost was calculated including interest costs. Table 3 summarizes results, where it can be seen that in both cases utilization of wave power lowers the production cost relative to current costs. In addition, power generation costs are lower for Aogashima due to a larger supply of available wave power, i.e., a greater frequency of larger waves; thereby indicating higher practicality for the case of an isolated island with already scheduled (funded) breakwater construction projects.

Table 3. Cost of Generating Electric Power from Waves and Wave Power

Harbor	Wave Power (Wave Data)	Scale of Power Production		Electric Power Production Cost (Yen/kWh)
		Max. Output	Annual Average Electric Power	
Aogashima	10.8 kW/m (Habuminato Harbor)	200 kW x 4 units	43.3 kW/unit	19.5 (31.3)
Wadomari Harbor	6.4 kW/m (Nakashiro Harbor)	200 kW x 8 units	23.9 kW/unit	28.3 (48.5)

Note: The electric power generation cost calculation assumes that all the power generated can be utilized, and while the top figure ignores the interest, the bottom figure accounts for interest of 6%. The wave data used is data from wave observation points close to the locations in question. Present electric power generation costs are estimated to be 100 yen/kWh at Aogashima and 50 yen/kWh at Wadomari.

Sea Water Desalinization System

On isolated islands where topographical conditions make the construction of dams and reservoirs difficult, freshwater (tap water) is obtained by separately collecting and filtering rain and ground water. In many cases, however, ground water must first be desalinized, which not only adversely affects daily life, but industrial activities as well. Thus, a case study was performed to evaluate using wave power to operate a sea water desalinization system designed to supply freshwater. This system can be considered a method for storing transformed wave energy.

Harbor Selection

Aogashima Harbor was again selected for study due the local's difficulty in obtaining a stable supply of freshwater.

Energy Utilization System

The reverse osmosis method was selected as the basis of the considered sea water desalinization system; a method whose low energy consumption has attracted much interest in recent years. The electricity generated by the wave extracting power system is used to drive the motors of several of types of pumps. The target capacity was set at 500 m^3/day of freshwater, being based on available wave power estimated using the isolated island power production case study. Figure 5 shows a block diagram representing the conceptualized desalinization system.

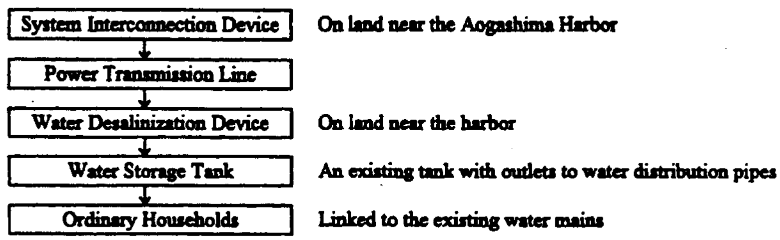

Figure 5. Outline of the Water Desalinization System

Cost Estimation

Table 4 presents estimated costs for operating a water desalinization system. Utilizing wave-generated energy in this manner is advantageous because desalinated water can be stored in reservoirs or tanks when wave energy is available, thus making the system independent of wave fluctuations, unlike powering remote islands.

Table 4. Desalinization System Operating Cost

Harbor	Quantity Desalinated	Electric Power Required	Actual Unit Price of Water
Aogashima Harbor	500 m^3/day	162kW	137 yen/m^3
(Trial Calculation Conditions) Because wave power systems and water desalinization systems are constructed as public facilities, it only accounted for the filter replacement charge and sterilization.			

Below-ground Sand Filter System

A below-ground sand filter system is one designed to pump seawater, using a high-capacity storage pump, from an infiltration well buried along the direction of the shoreline in order to lower the level of groundwater such that it cannot infiltrate into the unsaturated stratum lying below the sand region of a beach. This allows absorption of seawater and sand in the non-saturated stratum. Establishing a zone where the water level is reduced (unsaturated region) not only prevents the flow of groundwater offshore via absorption, but also promotes sand accumulation of sand such that the beach maintains a stable gradient mitigating wave-caused erosion.

Utilization of wave-generated power in this manner is advantageous because greater pumping power is required with increasing wave size; and naturally more power is proportionally generated as wave size increases. Thus, there is no major disadvantage when wave power is not available.

Harbor Selection

The coast of Japan is about 34,000 km in length, and over the past 100 years, ≈7,000 hectares of coastline have been eroded. In this case study, the selection of a location was governed by the need for a coastline where (i) erosion is particularly severe, (ii) sufficient wave energy can be obtained, and (iii) harbor construction projects are scheduled. The west coastline of Nishi-Niigata met these criteria.

Utilization System

Although below-ground sand filter systems have been introduced in several countries, no established design exits in Japan. Therefore, based on implemented systems, the quantity of pumped water required per meter Q was set as $0.025 m^3/min/m$, while the pumped water quantity per pump Q_p was set at $12.5\ m^3/min$ assuming an underground water absorption line 500 m in length. Figure 6 shows the conceptualized layout of the system, where drained water permeating into the underground absorption line from the sand is directed into a drainage. The water level in the pit is then raised by the high-capacity storage pump.

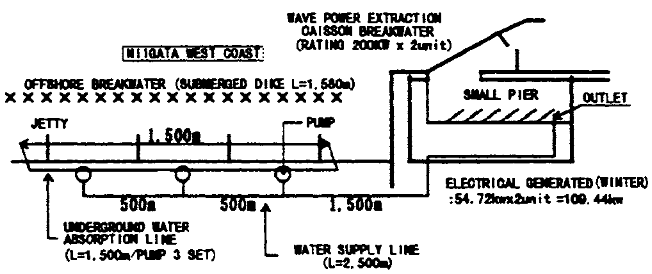

Figure 6. Layout of utilizing system and power generation system

Cost Comparison Analysis

Along the Nishi-Niigata coastline, erosion has been prevented by offshore breakwaters, jetties, or about 5 m high seawalls constructed behind the shoreline. One factor to be considered is that offshore breakwaters have in recent years been replaced by submerged breakwaters as part of coastline improvement projects which emphasize the appearance of coastlines. Table 5 presents the results of a comparison analysis of construction costs related to erosion control measures implemented in this region using various coastal structures for protection. Below-ground sand filter systems are well-suited with respect to minimizing the impact on coastal beauty, as because most components are buried underground.

Table 5. Construction Cost (L=1,500m)

Item	Estimated Construction Cost by Ordinal Method	Construction Cost using Sub Sand Filter Method
Offshore breakwater of Submerged Dike	1,500mx2,750 thousand yen = 4.1 Billion yen	1,500mx2,750 thousand yen = 4.1 Billion yen
Sea Wall	1,500mx2,400 thousand yen = 3.6 Billion yen	–
Sub-sand Filter	–	Construction Cost 1.4 Billion yen Operating Cost 0.3 Billion yen (=Annual Operation Cost x 35 yr.)
Total	7.7 Billion yen	5.8 Billion yen

Note: Sub sand filter method using a wave power will be spend a maintenance cost and personal expenses, so operation cost calculated for 35 years which is equal depreciation.

CONCLUTIONS

The collective collaboration of over 15 years of fairly large-scale joint R&D by both private and governmental organizations has led to near rationalization of design methods for constructing power extracting breakwaters and generating facilities. The results of case studies have confirmed the effectiveness of utilizing wave-activated power generation. However, with regard to the development of a network of wave power extracting breakwaters, several hurdles were pointed out that must first be cleared, i.e.,

1) Adoption of various comprehensive governmental policies, e.g., establishment of subsidies to reduce initial investment costs and promulgation of deregulation measures.
2) Reduction in costs associated with the energy converting system, particularly machinery and instrumentation.
3) Development of technology allowing parallel operation of generators.
4) Reduction in overall costs by multiple versus single utilization of generated wave power.

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FUNDAMENTAL STUDY ON PV SYSTEM FOR OFFSHORE FLOATING WAVE POWER DEVICE "MIGHTY WHALE"

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ABSTRACT

"Mighty Whale" is a device for power generation constructed with an oscillating water column (OWC) with an ability absorbing energy from ocean waves so as that the wave height be made dissipated behind it. While the wave energy may be converted so as to be able to be used, however it has such weak point as being supplied intermittently. Therefore, should such energy be intended to be used more economically, the feasibility of construction of a hybrid system for such energy might be studied. Herein this paper, an achievement accomplished through such study made on this time are presented.

INTRODUCTION

The Japan Marine Science and Technology Center (hereinafter referred to as JAMSTEC) as been engaging in research for and development and construction of an offshore floating device called as "Mighty Whale" with a system for collecting energy from the wave coming toward it more efficiently. This device is constructed for the purpose to be used for converting such wave energy into those of any mode to be able to be more easily used including but not limited to electric power and for turning the sea region behind them to be kept so calm as to be able to be used as the site for fishing and mariculture and any other similar purposes.

The wave energy is one of those existing in nature, a weak point on which is to be available always not continuously. The capability on wave expected for supplying energy will always be kept lower whenever it may be fine and calm. Therefore, it is desired for such device to be designed so as to form so called as hybrid type device with natural energy converters of different mode combined each other thereon.

In case of electric power to be output from the wave power device, the power generation by means of solar energy and wind force driven power generation may be considered to be the most promising process to be applied among all. Herein this paper, a fundamental study on the power generation by means with solar energy made on this time is reported.

OFFSHORE FLOATING WAVE POWER DEVICE, "MIGHTY WHALE"[1)]

The Mighty Whale (hereinafter referred to as M.W.) is a floating offshore structure made of steel as shown on Figure 1, at which there are the compartments called each as air chamber on its front side (on upstream of wave current) where wave energy to be absorbed and slope behind it to limit rolling by effect of wave motion, the general configuration of which is like an whale. This structure is kept moored with mooring chains connected with anchor above sea bed. On each of the said compartments, there are openings each called as nozzle. The compartments are kept open at bottom toward the sea bed, the sea level in which is made up and down when any wave is invaded therein, so that reciprocating air flows be generated to pass through the said nozzles at high speed. The energy on those air flows is converted by means with pneumatic turbine generator by being utilized. This device is called as wave power device of mode with pneumatic turbine of oscillating water column type.

JAMSTEC has a schedule for construction of a model of the prototype for this facility at the entrance sea area at entrance portion of Gokasho Bay in Nansei-Cho of Watarai District

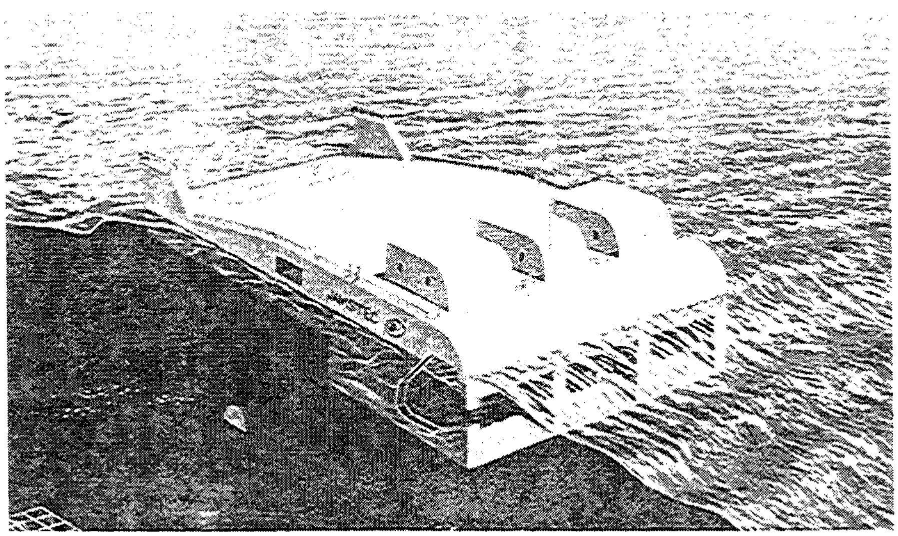

Figure 1. Offshore Floating Wave Power Device, "Mighty Whale"

in Mie Prefecture, Japan subject to practical marine commissioning for a period of 2 years from 1998 to 1999. The power generated through such commissioning is scheduled to be fully consumed within this facility for those including but not limited to measurement and any other activities. The power scheduled to be consumed there is so high as equal to any value around 15 kW.

(1) Main Structure

Major Dimensions	:	50m long x 30m wide, draft: 8m
Displacement tonnage	:	4,400 tons
Air chamber	:	3 numbers (8m wide x 10m deep)

(2) Pneumatic Turbine and Generator to be installed

Pneumatic turbine :

3 units of Well's turbine each with diameter of 1.8m, model NACA0021 and 2 sheets blade panel (arranged in tandem)

Generator :

3 units of synchronous generator comprised of 1 unit of the type to be used in parallel, capable to be mechanically changed over to 50 kW or 10 kW and 2 unit of the Generator with rated capacity being equal to 30 kW as high

(3) Offshore Location where to be installed

Location :

35° 13 ′ N, 136° 40 ′ E of Gokasho Bay in Nansei-Cho, Watarai District of Mie Prefecture, Japan

Direction of Installation :

The structure shall be moored as shown on Figure 2 so as for its bow to be kept toward South East direction.

PATICUTLARS OF STUDY

Over the M.W. mentioned in previous paragraph, study was carried out against the matters as mentioned hereunder:

(1) Arrangement of Solar Batteries

Solar batteries were designed so as to be installed on the sloped floor which had not yet been occupied. The inclination of such slope is so high as equal to approximately 7.6 degrees. Since the how is scheduled to be moored so as for the M.W. to be located toward SE Direction, the inclined face of slope should be directed

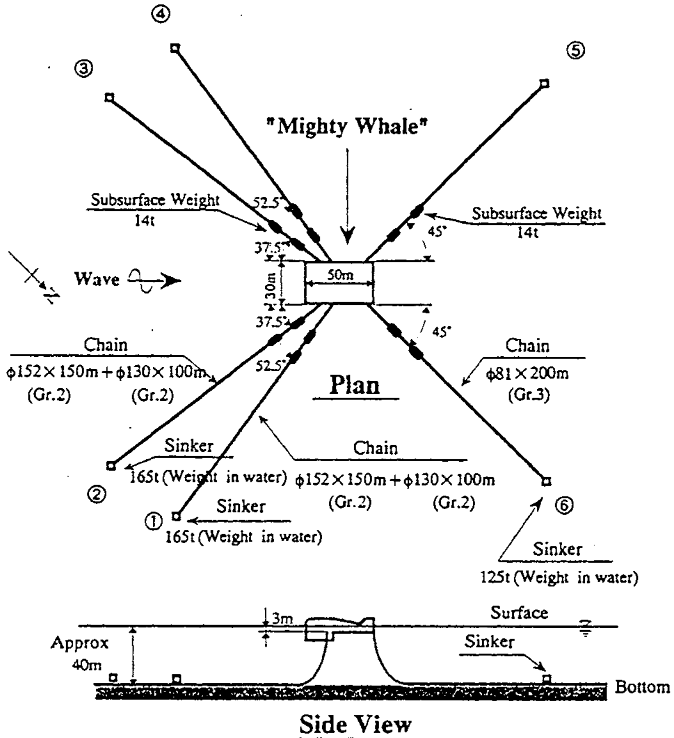

Figure 2. Arrangement for Mooring

on NW direction. 3 modes of 30 degrees on SE Direction, 10 degree on SE Direction and 10 degrees on NW Direction were considered and studied.

(2) Combination with Wave Power Generation System

Within a discussion for combination with wave power generation system, how to design and construct a fully equipped independent system was discussed based upon how and what the power generated therein to be consumed. Further in addition, a contribution of the generated power to the required loads and capacity of the batteries equipped thereon were discussed and studied.

(3) Capability of Power Generation in KWH

In respect of the 3 cases each with different arrangement of solar batteries, the available KWHs of the electric power through the generation thereat was estimated through calculation based upon the data from Owase City on the daytime when such light ray is available in the area near-by the Gokasho Bay.

ACHIEVMENT ACCOMPLISHED THROUGH STUDY

(1) Arrangement of Solar Batteries

The effective area for use among 600 m^2 of the slope was designed so as to be so large as equal to approximately 200 m^2 based upon a consideration of the effects due to the shadow formed during a period from 09:00 to 15:00 on the winter solstice when the Sun is at the lowest altitude. The feasible capacity of the solar batteries which may be installed thereon the said 200 m^2 was obtained through calculated to be so high as equal to approximately 20 kW subject to 2 sets of the array comprised of 96 sheets of single crystal silicon solar battery panel with rated capacity of maximum output of 108.2W. In respect of cabling and wiring between modules for connection, since the rated voltage applicable to the main feeder in power system at the M.W. under discussion on this time is at DC 264V, 189 sheets among 192 sheets of module were decided to be arranged 9 lines in series and 21 liens in parallel and the remaining 3 sheets were decided to be allocated to be kept in dummy. From such arrangement, maximum 20.4 kW of power would be made available.

In respect of an arrangement on floor of the slope, the direction of 2 arrays on which to be equipped was decided to be limited to SE or NW from the direction on which the M.W. to be installed. The wind velocity expected at design was taken so as to be equal to 60 m/sec. In respect of the angle at which the arrays to be mounted, the angle of 30 degrees which is nearly equal to 30 degrees at the latitude at the sea area where the M.W. scheduled to be moored was decided to be applied to what to be on SE direction and the angle of 10 degree was decided to be applied to what the resistance against wind pressure and reduction of the cost were taken into consideration and the 10 degrees was decided to be applied to what to be on NW direction. An arrangement for mounting on 10 degree on SE direction is shown on Figure 3 as an example. Further, a comparison of weights of the arrays at each of different conditions for mounting is shown on Table 1.

(2) Combination with Wave Power Generation System

Since the M.W. is to be kept floating offshore, the system to be installed thereon shall basically be any system which is independent from the commercial system. The design for concept of combination of the M.W. with the power generating system to be installed thereon now under discussion is as shown on Figure 4.

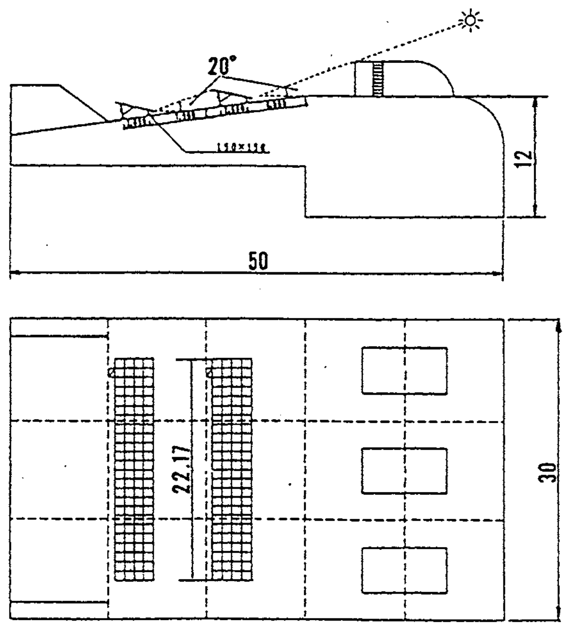

Figure 3. Arrangement of Solar Batteries for Mounting (on 10 degrees on South East)

Table 1. Comparison of Weights on Different Mounting Angles

	30° on SE	10° on SE	10° on NW
Solar Batteries (kg)	2112	2112	2112
Mounting Base (kg)	2000	1700	1520
Steel Material for Foundation (kg)	2800	2800	2800
Total (kg)	6912	6612	6432

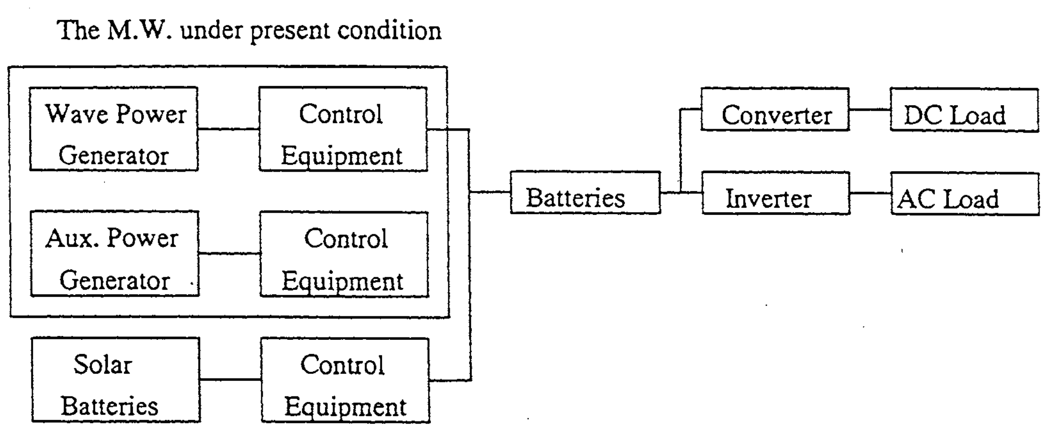

Figure 4. Design for Concept of Combination of M.W.
with Power Generating System to be installed thereon

The procedure for supplying electric power within the combined system is as mentioned hereunder:

① Power to be always supplied to batteries in parallel from wave power generating system and solar power generation system

② Power from the both systems to be limited when the batteries have fully been charged

③ Emergency power to be supplied from stand-by power generator, whenever the power may have come not to be able to be supplied from the both systems due to any unexpected reason

(3) Capability of Power Generation in KWH

The expected capacities of power to be able to be supplied from 20 kW solar battery system at various angles of inclination taken therefor at mounting were determined in trial through calculation based upon the actual data in past from Owase City in respect of quantitative solar radiation available around or near-by the Gokasho Bay. Solar radiation available in Owase City on various inclinations were as shown on Figure 5.

An electric power available from solar battery system may be determined through calculation with the following equation based on any of those quantitative solar radiation on inclined faces:

$$Q_m = (P_p \times Q_d / P_o) \times K \times S \quad \text{..............................(1)}$$

where,

Q_m : kWh of Power Generation in kWh/month

P_p : Capacity of Solar Battery System: 20.4 kW_p

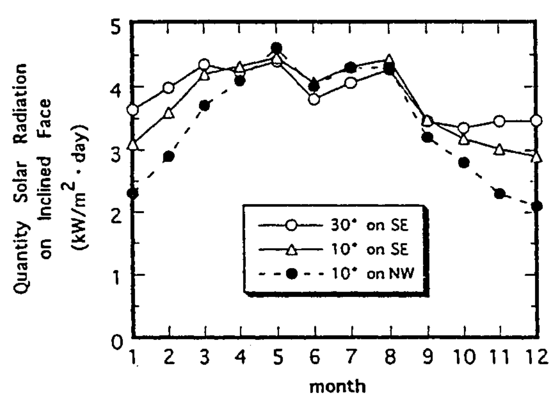

Figure 5. Quantiny Solar Radiation on Inclined Face

Q_d : Quantitative Solar Radiation per Day in kWh/m ^{2}·day

P_o : Reference Value at Solar Battery System in respect of Quantitative Solar Radiation : 1 kW/m ^{2}

K : System Efficiency : 0.65

S : Days in Month

Remarks : The system efficiency is formed in particular by those including but not limited to efficiency of equipment and devices, power loss through cables and wires and contamination on surface of panel.

The results obtained through calculation in trial by means with the equation (1) above were as shown on Table 2, and Figure 6. When the Power generated at the M.W. is supplied to the loads thereon, it was considered reasonable to understood that 60% of full power be feasible to be used, after those including but not limited to loss due to available efficiencies at inverter and batteries when it may be charged or inverted having taken into a consideration. Therefore, the time per day when the possible power may be supplied was assessed respectively to be equal to approximately 2.5 hours subject to an inclination being equal to 30 degrees on SE direction, approximately 2.0 hours on SE direction, approximately 2.5 hours on 10 degrees on SE direction and approximately 1.8 hours on NW direction.

With regard to any influence of inclination given to each solar battery panel at mounting over quantity of power available through the generation therefrom, there is no any difference in summer season. However, there is an difference in quantity so much as equal to approximately any value around 70% subject to an inclination of solar panel at mounting in quantity so much as equal to 10° on NW direction. Further, the total capacity required of the batteries was determined through calculation in trial by means with the following equation based on any inclination given over each solar panel at mounting. The results obtained through calculation in trial by mean with the equation (2) below were as shown on Table 3.

$$B_c = \frac{P_L \times h_o \times X \times \beta}{\eta_i \times E_B \times \alpha \times \gamma} \quad \text{..............................(2)}$$

where,

B_c : Capacity of Battery System in Ah

α : Depth of Discharge: 0.5

β : Safety Factor to be taken on System Design

γ : Ratio of Capacity after Stabilization: 0.8

X : Number of Day without Solar Radiation to be compensated: 1 day

E_B : Voltage at Battery System in V

P_L : Power consumed by Load in W

h_o : Duration of Time when Load to be used in hour/day

η_i : Efficiency of Inverter

Table 2 Quantity of Power Generated per Day in Each Month (at Owase in kWh/day)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
30° on SE	48.3	52.8	57.7	56.1	58.3	50.4	53.8	56.6	45.9	44.4	45.9	46.0	51.3
10° on SE	41.1	47.6	55.7	57.3	59.1	53.8	57.2	46.1	46.1	42.2	40.0	38.5	49.8
10° on NW	30.5	38.5	49.1	54.4	61.0	53.0	57.0	57.0	42.4	37.1	30.5	27.8	44.9

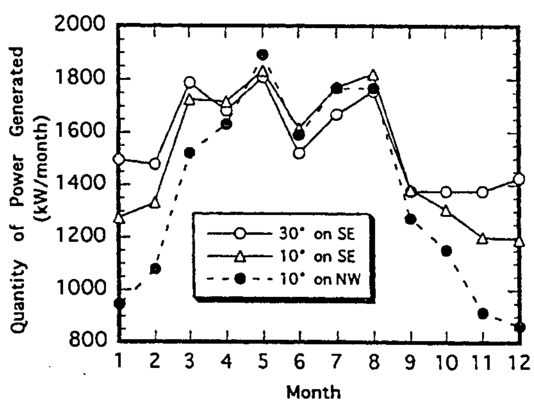

Figure 6. Quantity of Power Generated per Month in Each Month (at Owase in kWh/month)

Table 3 Comparison of Capacities of Solar Battery System

30° on SE Direction	10° on SE Direction	10° on NW Direction
264 V	264 V	264 V
600 Ah	450 Ah	400 Ah

FUTURE SUBJECT TOBE STUDIED FROM NOW

The study was carried out on this time over those focused on the capacity of the solar battery system to be constructed on the M.W. and the power available therefrom. It is considered necessary to study those including but not limited to the following subjects in future from now:

(1) Study for establishing the special procedure for installation and construction of solar battery system and the best suitable layout of the battery cells over which such external forces as those including it from waves have been satisfactorily considered.

(2) Study for developing any counter-measures against those including any danger from salt and any other similar risks toward assurance of reliability offshore at sea.

(3) Study for establishing the procedure for the best suitable operation and control of the wave power generation system through the simulation over which those including but not limited to the service conditions of the load equipment thereon have been considered.

CONCLUTION

On this time, studies were carried out from a point of view on combination to be made between the different natural energies. In parallel to this study, the experiment on smaller scale for same purpose is now in progress under way at the marine site near-by the scheduled site for the M.W. Those are hoped to help natural energy further used after a comprehensive assessment including evaluation of the cost thereof having finally been performed. it is hereby acknowledged by the author that a cooperative assistance was given by Mr. Masahiko Hasunuma of Sanyo Solar Energy System Co., Ltd. for execution of this study, to which much appreciation is officially expressed.

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A PILOT PENDULAR OCEAN WAVE POWER STATION

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ABSTRACT

Ocean wave is rich in power resource. The wave power is clean and reproducible. But the exploitation of this rich resource is very difficult due to its low density and harsh environment. Various technologies have been used to convert the wave energy into electricity, but this problem remains unresolved yet.

A pilot pendular ocean wave power station was designed and built at Xiaomaidao, Qingdao City. A concrete water chamber with tapered inlet faced to the dominant direction of wave was constructed on a natural small granite steep wall ditch. The length of water chamber was so calculated that the wave would become stationary. An oscillating pendulum was put at the node of the stationary wave. Then the wave energy pushing the pendulum would be enhanced. Efforts were made to protect the pendulum against collision during stormy time. The vacillation of the pendulum produced on its shaft alternating torque. In order to simplify the drive mechanism and improve the reliability, the shaft was mechanical coupled only by a speeder gear-box. A patented system, tripolar transducer STS, consisting a rare-earth alloy synchronous generator and computer-regulating battery charger is selected to convert the mechanic energy into electric one. The efficiency of the total system was about 0.33.This pilot station could generate 8kVA AC power at 0.9m mean wave height and 5.2s mean wave period. Considering the local wave condition, annual generated energy would be about 41,000kWh.

In this paper the principle, calculation, modeling, design, construction, testing of the pilot power station are presented.

INTRODUCTION

Ocean wave is rich in power resource. The wave power is clean and reproducible. The UN Conference on Environment and Development held at Rio de Janeiro in 1992 proclaimed the principle of sustainable development. The resource of fossil fuels is limit and exhaustible in the near future. In addition, conbustion of fuels causes tremendous pollution problems such as green-house effects, acid rain. Mankind has to seek new power resources. Decisionmakers and scientists in coastal developed countries have paid good attention to generate the reproducible ocean energies. Ocean wave seems to be abundant power resource in coastal region and isolated islands. But the exploitation of this rich resource is very difficult due to its low density and harsh environment. Since 1970s, scientists in Japan, Norway and UK have studied the problem of conversion the ocean wave energy into electricity easily to supply through the conventional grid lines. Various technologies have been used to convert the wave energy into electricity. An international symposium on ocean energy development for overcoming the energy and environmental crises held in Aug. 1993 at Muroran, Japan reviewed these works. The Norwegian designed a shore-based horizontal tapered channel to convert wave energy by means of submerged lens structure. Other Norwegian scientist constructed bottom-standing structure to contain oscillating water column and Wells air turbine. A phase-controlled power buoys of the point-absorber class has also tested. The OSPREY system was developed by Sea Energy Associates Ltd, UK in 1995. It was known as the first industrialized ocean wave generation station. But unfortunately it sank during its virgin deployment. Tomiji Watabe has studied his pendulor wave power converter for 15 years. The principle is to make a generator run by means of hydro-static power transmission of the pendulum motion excited by horizontal water flow in stationary waves formed in the water chamber. All of these stations faced the problems of how to keep the structure safely in stormy condition and reduce the investment to an acceptable level. Watabe came to a conclusion "several wave power converters have been proposed through, no converters have come into a practical stage except small scale devices. "(Watabe,1997).The problem of ocean wave generation remains unresolved yet.

There are 6500 islands along the coast of China Seas. The population on the land of more than 80,000km^2 amounts 30 million. Although the wave is not very high in China Seas, the wave energy near the isolated islands is still worth to exploit. Combined with tide, wind, solar, tidal current energies in whole, it should be an optimal path to solve the power supplying of island and coastal zone in future.

The research of ocean wave generation started in China in 1970s.The scientists with the Institute of Energy Conversion, CAS, developed small size OWC device for lighting of navigation buoy and 20KVA OWC wave power plant at Dawanshan Island.

The research of a pilot pendular ocean wave power station rated 8KVA was funded by the State Science and Technology Commission of China. A pilot station was designed and built at Xiaomaidao, Qingdao city. This station could generate 8KVA AC power at 0.9m mean significant wave height and 5.2s mean wave period. Considering the local wave condition, annual generated electricity would be about 41,000kWh. In order to simplify the structure and increase the safety of the device, new technology was used.

CONDITION OF STATION SITE

An Oceanographic Observation Station(OOS) of State Oceanic Administration (SOA)is situated at Xiaomaidao, Qingdao City. Near the station, there is a small natural ditch. The direction of the opening of the ditch is south south-east and coincides approximately with the dominant direction of wave during summer and autumn. The length of the ditch is 8m and width is 3.2m.The mouth of the ditch is somewhat widening. The wall of the ditch is very steep and about 7m high. Both wall and bottom are of strong granite. This site is appropriate for constructing a water chamber of pendular wave power station.

Xiaomaidao OOS recorded following data: mean sea level above Yellow Sea Level 2.39m,height of high water 3.81m,height of low water 1.02m, maximum height in 50 years 5.35m, minimum height in 50 years -0.75m,mean tide range 2.79m; average wave height 0.7m, frequency of wave height between 0.5m and 1.4m 57%, average wave period 4.2s,maximum wave height 9.2m, maximum wave period 11.1s.

MODELING

Modeling of water chamber with pendulum has been done in advance in the National Ocean Engineering Lab, Shanghai Jiaotong Univ. A model similar in geometry, gravity and inertia on the scale of one-eighth made of plexiglass with foamed plastics to adjust the floating and gravity center was used to simulate the pilot station. Hydrodynamic characters have been recorded and analyzed. It was found that this device could provide power 1.7-13kVA at wave height 0.5-1.5m (period 3.6-4.7s relatively), and converting efficiency of wave power would be 34.4—90%.

DESIGN

In order to save the work load and expenses, we did our best to patch up the natural granite ditch as the water chamber. The hydraulic construction are shown in Figure1. The wave-mechanic power converter is a pendulum oscillating around a horizontal axis above the water chamber. The width of the chamber was selected 3.20m,and length 7.90m,approximately 3/8 average wave length (8.10m). Then the wave in the chamber would become stationary. The widening mouth of the ditch was utilized as tapered inlet of the chamber for focusing the incident wave energy to enhance the wave energy pushing the pendulum. The opening angle was about 60.° The level of the axis was calculated to avoid submerging and was 7.64m. The axis was fixed at the node of stationary wave on The chamber, i.e. 5.40m from back wall. the width of the pendulum B_p was 3.00m.

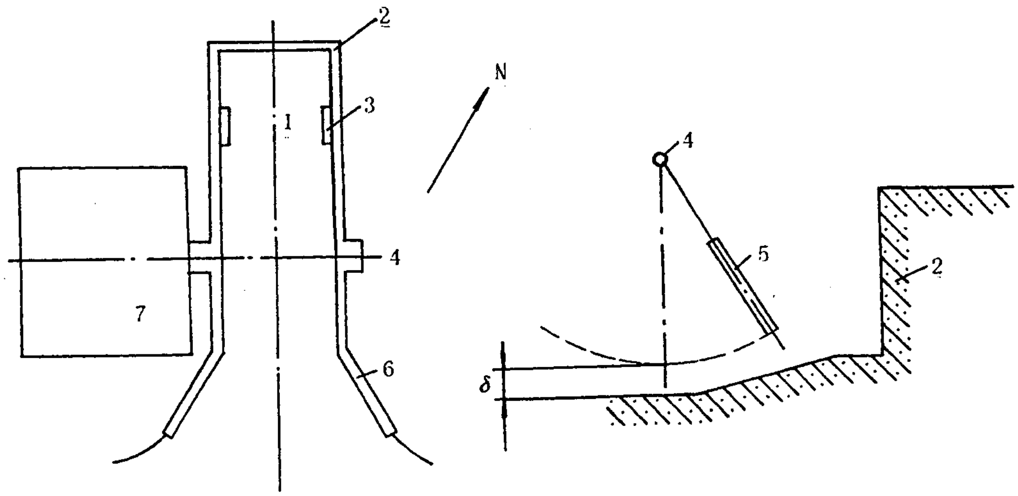

Figure 1. The hydraulic construction

1. water chamber
2. wall
3. stopper
4. axis of pendulum
5. pendulum
6. tapered inlet
7. generater

The motion function of the pendulum is (Watabe, 1993)

$$\Sigma I \frac{d^2\theta}{dt^2} + (N_0+N)\frac{d\theta}{dt} + (K_0+K)\ \theta = M\sin\omega t \qquad (1)$$

where ΣI: moment of inertia of pendulum and adding water

θ : angular displacement of pendulum

t: time

N_0/N: load factor of mechanism /wave

K_0/K: restoring coefficient due to gravity center displacement of pendulum/water elevation behind pendulum

M: exciting moment

ω : angular frequency

The solution of the linear function is

$$\theta = A\cos\omega t + B\sin\omega t \tag{2}$$

where A and B are constant decided from ΣI, N_0,N,K_0, K and M.

Energy absorbed by the pendulum in a wave period $T= 2\pi/\omega$ is written as

$$W=\int_0^T N_0\left(\frac{d\theta}{dt}\right)^2 dt = \frac{1}{2}N_0\omega^2 (A^2+B^2)\ T \tag{3}$$

Incident wave energy come into pendulum in a wave period is

$$E = \frac{1}{2}TB_p\frac{H}{2}^2 \ \rho g C_g \tag{4}$$

where H: wave height

ρ : density of water

g: acceleration of gravity

C_g: group speed of the incident wave

And the converting efficiency

$$\eta_1 = \frac{W}{E} \tag{5}$$

$$\eta = \eta_1\ \eta_2\ \eta_3 \tag{6}$$

where η_2: efficiency of mechanism

η_3: efficiency of generator

We assumed $\eta_1= 0.5$, $\eta_2= 0.8$, $\eta_3 = 0.9$,considering the angular difference between the chamber and prevailing direction of incident wave (20°), η=0.33, substituting B_p and average wave parameters, the output of the pilot station was estimated to be 2.03kVA(0.5m height and 4.2s period during winter and spring)to 8.18 KVA(0.9m height and 5.2s period during summer and autumn).According to the statistical data of wave parameters from Xiaomaidao OOS, annual generated energy would be about 41,000 kWh.

The wall of the water chamber was made of fast setting cement concrete on natural granite bedrock. The pendulum was welded with steel plate and measured 3.00m×4.00m ×0.30m.

Efforts were made to protect the pendulum against collision during stormy time. Stopper was added nearly at the restoring angle of oscillating motion of pendulum. Some methods of absorbing the impinge force has been compared, at last special rubber protector was fitted on the lower part of the pendulum to decrease the deformation of the latter. In addition, various deepness chamber shown in Figure 1 also can discharge the surplus wave energy.

The vacillation of the pendulum produces on its shaft alternating torque. Our design principle concentrated on how to simplify the drive mechanism and improve the reliability. With respect to this, we selected a patented new technology product, developed by Shihang Lab Inc, tripolar transducer STS which could generate electricity with very low fluctuating motion. This system is consisted of a rare-earth alloy synchronous generator, computer digital process-regulating rectifier and sufficient batteries. A battery equilibrium protector was provided to ensure the battery units work safely during pulsed charge. A DC-AC reverser was used to output stabilized AC power at rated voltage although the wave energy was undulating randomly. By using this technology, we coupled the shaft of pendulum and STS only with a simple speeder gearbox.

TEST

After the pilot station was constructed, we tested the characters of wave power generation in 5th-6th Feb.1996. Wave parameters were recorded with a wave buoy. The angle of pendulum motion was read from a protractor, its period was timed with stop watch. Instantaneous output voltage and current after bridge rectification shown in Figure 2 were sampled and recorded on PCS-1 industrial real-time process control station (ME Inc).

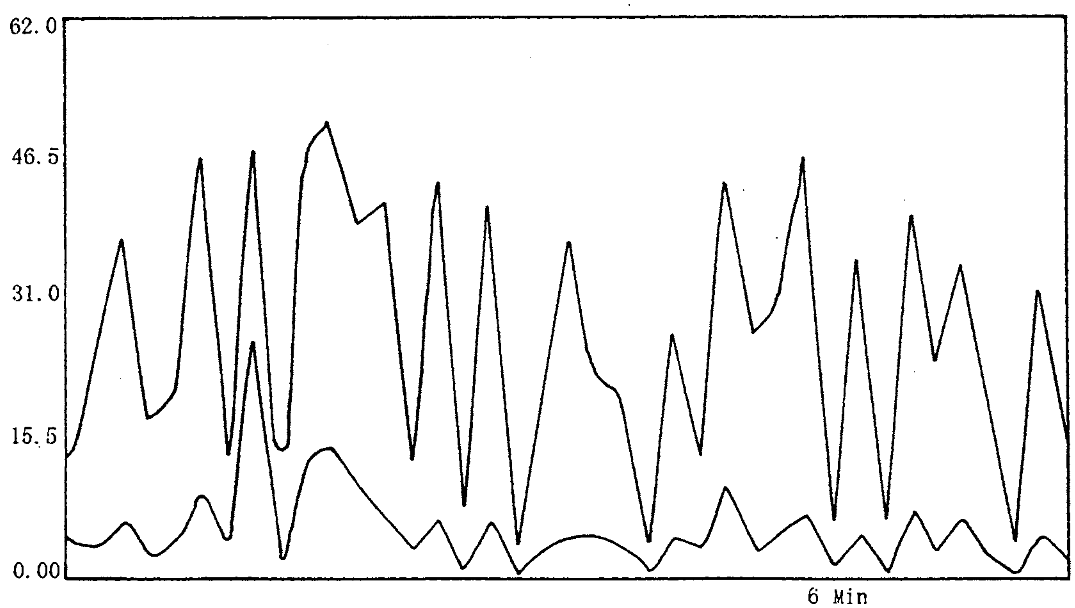

Figure 2. Record of output voltage and current

In Feb. the wave was not very high. We obtained on 5th Feb, the wave height was 0.2m, period was 7.5s, estimated output power was 880VA. Actually we recorded 916 VA from 1 min averaging. This results looked to be closed. It is expected that the pilot generator would provide rated output during summer and autumn.

DISCUSSION

In Xiaomaidao pilot station we utilized natural granite ditch to build water chamber, tripolar transducer system as generator directly coupled with pendulum shaft without complex mechanism. It seems that this system is simple and rather reliable.

ACKNOWLEDGEMENT

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GEOTHERMAL RESOURCES OF THE MARGINAL SEAS IN THE NORTHWEST PACIFIC

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ABSTRACT

The marginal seas in the Northwest Pacific belongs to the Circum-Pacific active zone which is a strong volcanic belt, active structural zone, strong seismic zone and a subductive zone, also is a geothermal anomaly zone. In the area of deep trench and outside of the island arc, heat flow values are very low, most of which is less than 20 mW/m^2. But from the inside of the arc to the back-arc area, heat flow becomes very high.

Very high heat flow, very strong volcanic activity and very strong submarine hydrothermal eruption indicate abundant geothermal resources in the marginal seas of the Northwest Pacific. It is very significant for investigating and exploring geothermal resources. It is also very important for submarine environment research and petroleum exploration. Heat flow data reflects the activity of crust and also implies the depth of oil reservoir. Hydrothermal activity forms very hot water flowing from deep crust and produces valuable minerals.

INTRODUCTION

The marginal seas of Northwest Pacific Ocean include the Bering Sea, Okhotsk Sea, Japan Sea, East China Sea, South China Sea and Philippine Sea. It is located at the margin between the Eurasian plate and Pacific plate, and is also a transitional zone from continental crust to the ocean crust (Fig. 1). This area is the important part of the Circum-Pacific active zone. Earthquakes, volcanic activity, hydrothermal activity are very strong.

Heat flow is the most important parameter to explore geothermal resources. Since the first measurements of heat flow were made in the south Africa in 1939, the role of heat flow in geothermal resources research is more and more important. Since the first measurement of heat flow in the ocean floor of the Pacific in 1952, heat flow plays an important role in geothermal resources. We discuss the heat flow distributions, their characteristics and geothermal resources of active volcanoes in the marginal seas of Northwest Pacific.

1. HEAT FLOW MEASUREMENTS

The first measurements of heat flow in the marginal seas is in Bering Sea in 1961 (Foster, 1962), then many scientists made heat flow measurements in this area. Till now, more than 2,600 heat flow data were abstained.

1.1 The Bering Sea

The first measurements of heat flow in this marginal sea is performance by Foster et al. in 1961. With the accumulation of more than thirty years, the heat flow data is more than 100 in

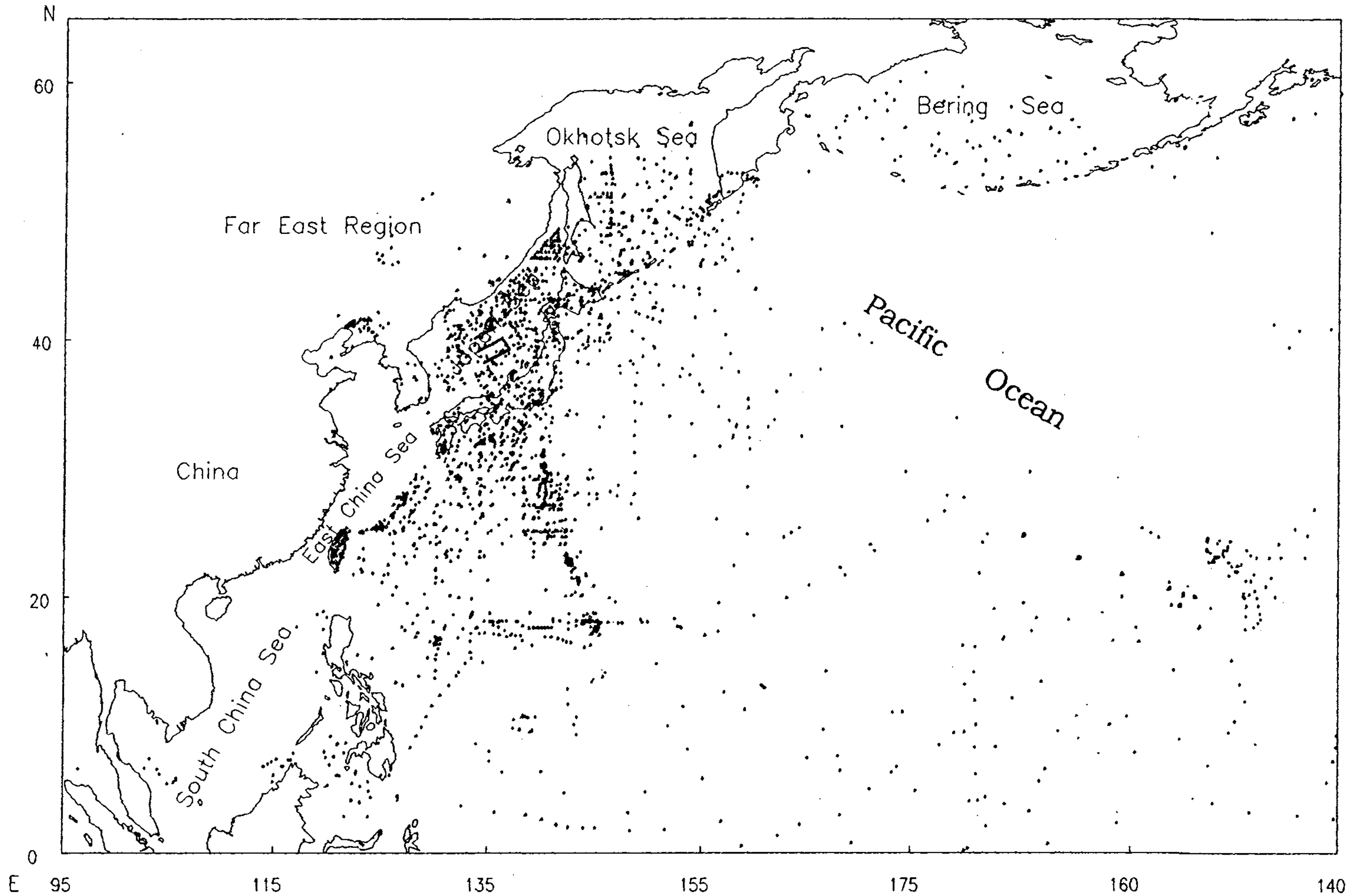

Fig. 1 Locations of the marginal seas in the Northwest Pacific

the whole Bering Sea. There are several heat flow data in Bering continental shelf and Bowers basin., about 27 heat flow values in Aleutian Basin. In Komandorskaya (kamchatka) basin, there are 94 heat flow data. Most of heat flow data concentrates in deep water area.

1.2 The Okhotsk Sea

The investigations of heat flow in Okhotsk Sea started in 1960's. Later, USSR, Japan, USSR-USA-Japan cooperative investigations increase the number of heat flow data, Smirnov (1995) compiled 224 heat flow data in the Okhotsk Sea. The data distribute mostly in the area deeper than 300m.

1.3 The Japan Sea

The first measurements of Japan Sea were taken by the Japan Meteorological Agency and Earthquake research Institute, University of Tokyo in 1964 (Yasui and Watanabe,1965). Later, Japan, USSR, USA and their cooperative investigations had done much work in this area. Yamano et al (1996) published the total number of heat flow in Japan Sea is more than 360 in 1996.

1.4 The East China Sea

The East China Sea is shallower mostly and most of the heat flow data is concentrated in the Okinawa Trough, except some from exploring well on the continental shelf. The first heat flow measurements in this area were carried out by R/V "Seifu Maru" in 1969. Later, Watanabe, Herman et al., Lu, Yamano et al., Yu et al. and Li have reported the measurements of heat flow in the Okinawa trough. In the statistics of Li (1996), the reliable heat flow number in Okinawa trough is about 237 (Fig.2).

1.5 The South China Sea

Heat flow measurements in South China Sea began from 1970's. The first report was given by Watanabe et al.(1977) in 1977. Anderson also compiled heat flow data of this area. During 1979-1982 and 1985-1987, Sino-USA had two cooperative cruises to do geological and geophysical investigations including the measurements of heat flow. Sino-Japan joint took some measurements of heat flow on the continental shelf of the South China Sea in 1988. Up to now, the number of heat flow in this area has been 580 among which more than 350 from exploring drills, the others comes from the heat flow probe. Figure 3 shows the heat flow contours in South China Sea.

1.6 The Philippine Sea

The heat flow investigations start in 1960s (Watanabe et al.,1970), from then, more heat flow cruises were carried out by scientists. Scalater et al.(1976), Watnabe et al.(1977), Anderson (1975,1980), Bibee et al.(1980), Hobart et al.(1983), Jemsek (1988), Kinoshita et al.(1991) and Yamano et al. reported the measurements of heat flow in this area, more than 1200 heat flow values were accumulated in this area.

2. HEAT FLOW DISTRIBUTIONS

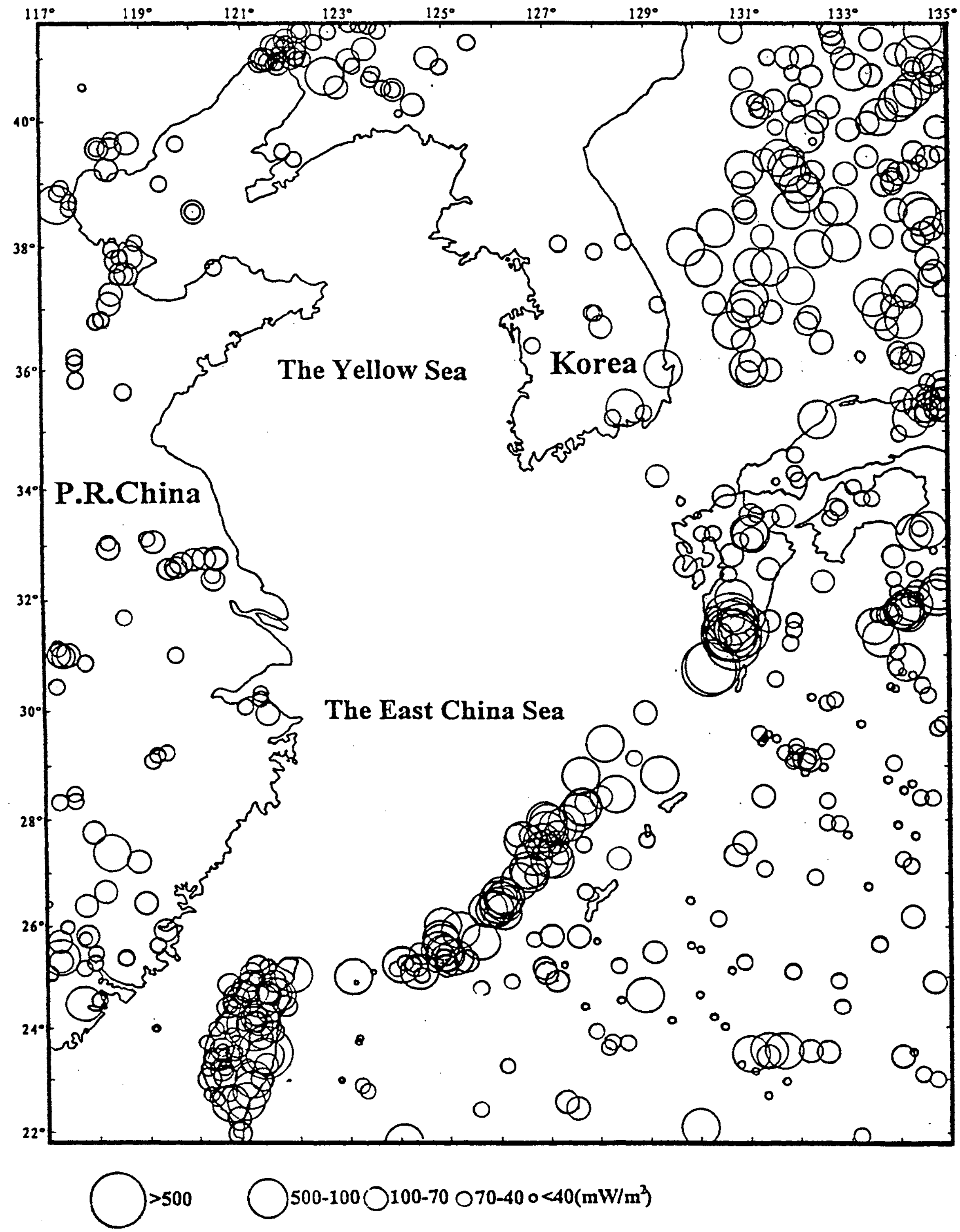

Fig. 2 Heat flow distribution of the Okinawa Trough and its vicinity

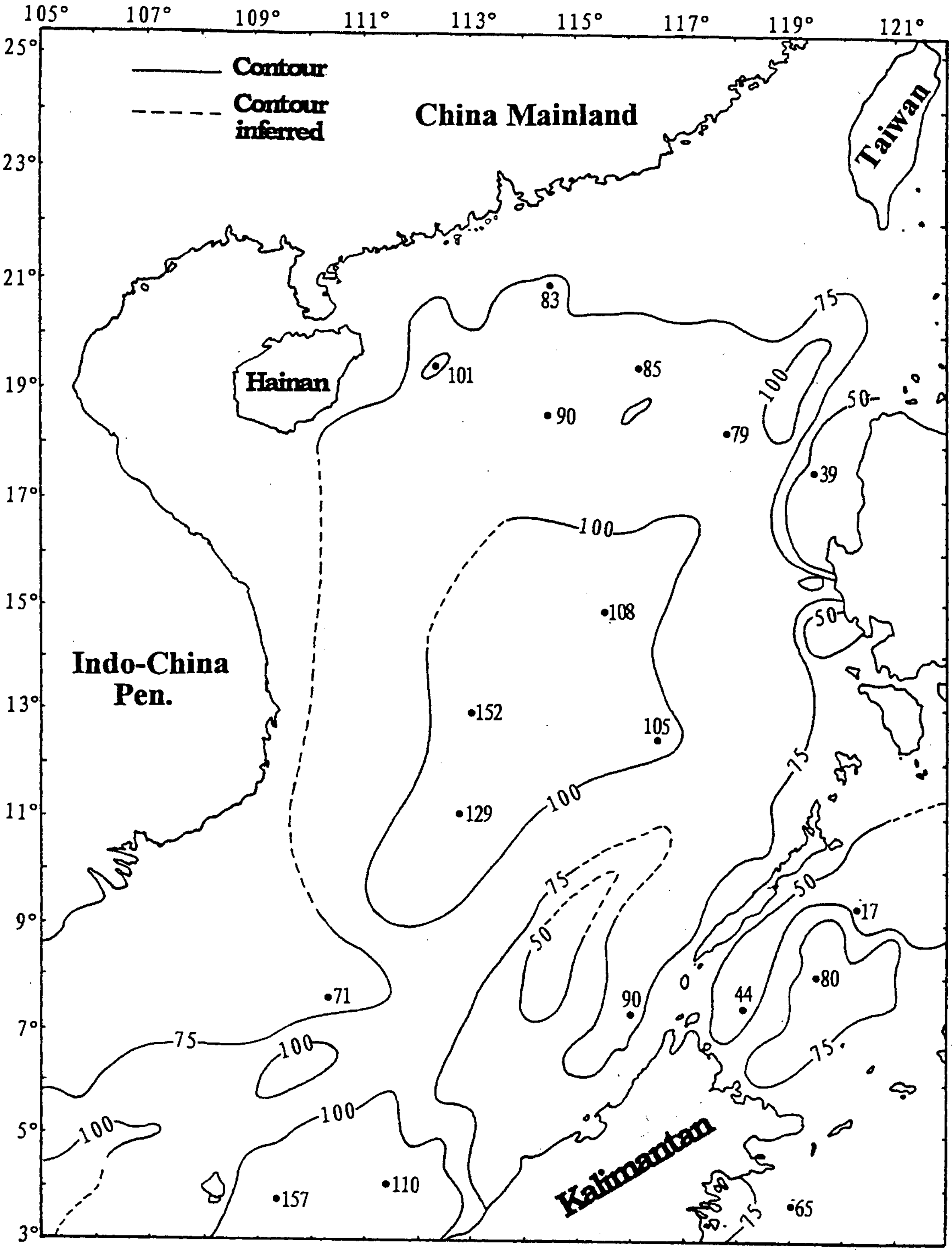

Fig. 3 Heat flow contours of the South China Sea

Overall the heat flow distribution of northwest Pacific marginal seas, the heat flow data varies much in the area of trench-arc-back basins (T-A-BA), which means in the Pacific sides, the heat flow shows stable and equal to the mean value of the earth; in the trench and outside of the arc zone, heat flow is extremely low; in back-arc basins, the heat flow are higher than any other places. On the continental shelf, the heat flows are normal and equal to the mean value of the earth.

2.1 The Bering Sea

On Bering continental shelf, there is no heat flow measurement. The mean heat flow of Aleutian basin is lowest in the whole Bering Sea. In the Bowers basin heat flow measurement concentrates in the middle of three basin, among which, Komandorskaya basin has the highest heat flow(Langseth et al.,1980). In the Komandorskaya basin, the heat flow becomes high from north to south. The highest mean heat flow lies at the back-arc trough, near the Aleutian arc and between the Bering and Alpha.. Another high heat flow area is between the Alpha and Gamma, which extends in NW direction, the geothermal gradient in west is bigger than that of east. To the north, that is in the continental shelf, the heat flow becomes normal. Most heat flows in Komandorskaya basin are higher than 75 mW/m^2.

2.2 The Okhotsk Sea

Heat flow in the Okhotsk Sea shows high in three small sub-basins of Kuril basin and low in Kuril-Kamchataka trench. Along the Kuril island, there are four 100 mW/m^2 highest flow values. In Deryugin basin, Academy rise and Okhotsk depress, the heat flow values also are higher. The abnormal of 80 mW/m^2 shows the range of these tectonic units. Compared to the heat flow in Komandorskaya basin, that of the Okhotsk Sea is lower, which indicates Komandorskaya basin is an more active than the Okhotsk Sea.

2.3 The Japan Sea

Heat flows in the Japan Sea are uniformly high, most of them are more than 80 mW/m^2 in the whole Japan Sea.. The 80 mW/m^2 contour lines comprise the Japan Sea and Japan islands except the fringe of Sikhote Alin. In the Japan Sea, there are six 100 mW/m^2 abnormal and scatter distribute. Although the tectonic in this area effects on the values of heat flow in some way, but the morphologies of the abnormal heat flow contours show no significant tendency.

2.4 The East China Sea

Heat flow in the East China Sea concentrates in the Okinawa trough, which is similar to the mid-ocean ridge. In the whole trough, the mean heat flow of more than 200 stations is as high as 458 mW/m^2 which is extremely high in the ocean area. The Okinawa Trough is a typical high heat flow province in the earth, which is much higher the that of the mid-ocean ridge, even higher than that of the "new ocean" as the Red Sea. Fig. 4 shows a very good example of heat flow changement in the T-A-BA System. From Fig. 4, it is clear that the heat flow is very low in the Ryukyu trench and in front of the Ryukyu Arc, the iso-heat-flow lines of 50 mW/m^2 indicate the location of the trench. But in the back-arc

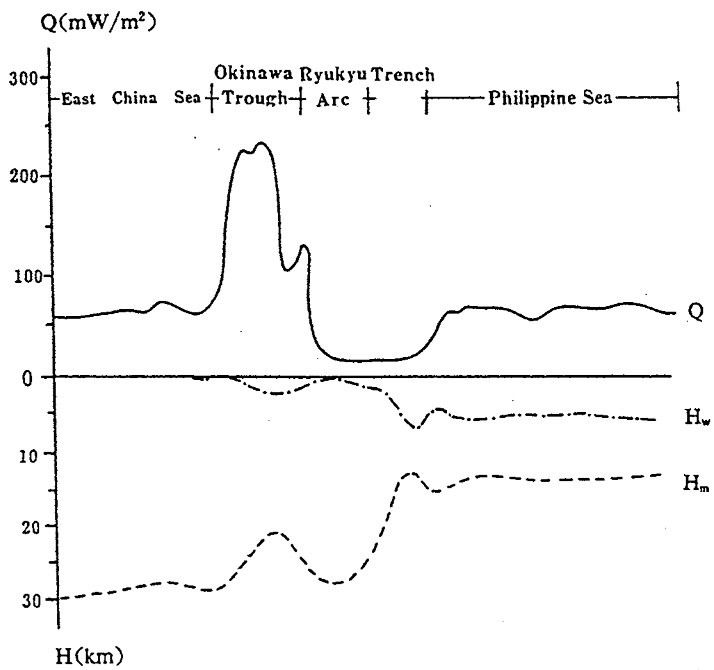

Fig. 4 Heat flow profile across the Ryukyu T-A-Ba System
Q: Heat flow; Hw: Water depth; Hm: Moho depth

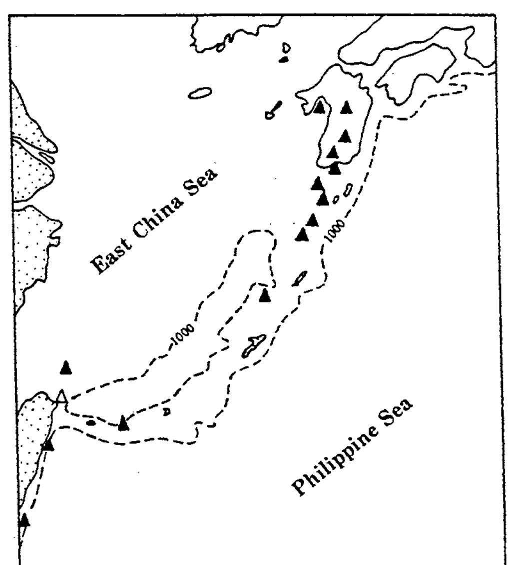

Fig. 5 Active volcanoes in the Okinawa Trough and its vicinity

area, from the inner are to the Okinawa Trough, heat flow becomes very high. This model of heat flow changement in the T-A-BA System implies the heat geodynamics of the subduction.

2.5 The South China Sea

Heat flow in the South China Sea is corresponding to the tectonic features of. The heat flows in the Manila trench and Nansha trench are lowest, the mean value of which is lower than 50 mW/m^2 . The 80 mW/m^2 contour line traps the whole Central South China Sea Basin (Fig. 3). In the north continental shelf, the heat flow values become normal, but in the south continental margin of the South China Sea, heat flow changes much, which is little bit of higher in the Zengmu sedimentary basin.

2.6 The Philippine Sea

The Philippine Sea consists of four main basins, the most famous of volcanoes develops in the Mariana Trough, which is also a high heat flow basin. The others are west Philippine, Shikoku and Parece Vela basins. In the West Philippine basin, heat flow is not high and shows the features of increasing from west to east. The mean heat flow in Shikoku basin is 106 ± 18 mW/m^2 , which closes to the theoretical values 110 to 130 mW/m^2 of the age from 15 to 13 Ma. The heat flow in Parece Vela basin is different between the east and west. In the east, the heat flow is normal, about 76 mW/m^2, but in the west part, heat flow is significantly low, even as well as that of trench area. Heat flow in West Philippine basin is normal with the age of 40 to 60 Ma. The mean heat flow in the basin is 68 ± 22 mW/m^2 (Anderson et al.,1978). Mariana trough and Izu-Bonin back-arc rift are the most active area of this marginal sea. Their tectonic activity is very strong, earthquakes and volcanic outcrops are very frequently. Heat flow in these zone is very high. In the back-arc spreading center, heat flow shows a very high zone.

3. ACTIVE VOLCANIC AND HYDROTHERMAL ACTIVITY

3.1 Volcanic activity

The marginal seas of Northwest Pacific is a important part of the circum-Pacific volcanic zone, there develops a active volcanic island chain between the trench system and the marginal seas. The strong volcanic activity implies much geothermal energy and abundant geothermal resources under the marginal seas.

Komandorskaya basin has been reported to find out one outcrop of volcanic seamount which is called Piip Volcano (Baranov et al.,1991), other volcanoes also can be found from the seismic profiles, but no observations of the volcanic outbreak was reported. From the high heat flow values of this basin, it is inferred there is perhaps more active volcanoes developed. In Kamchatka region, the geothermal energy is abundant. Sugrobov (1995) reported the geothermal resources of Kamchatka, more than 10,000 mW of heat is calculated in the volcanic peninsula.

The active volcanoes in the Okhotsk Sea lie along the Kurile islands chain. Avdeiko et al.(1991) studies these volcanoes and reports there are 105 subaerial and 96 submarine volcanoes in this islands. The 42 volcanoes are activity. The volcanic activity in the island arc is distributed in two zones parallel to the Kurile-Kamchatka deep-sea trench, they are thought relative to the subduction of the Pacific.

The volcanic activity of Japan Sea and its vicinity is very strong, from the north to the south, the active volcanoes set out huge energy from high temperature water. In the sea floor, there are also many seamounts, which sometimes outbreak under water.

In the East China Sea, the volcanoes concentrate on the Kyukyu islands and seamounts under the water of the Okinawa trough. Fig. 5 is a example which shows a active volcanic island-arc in the east slope of the Okinawa Trough. Another active volcanic zone develops along the back-arc rift center of the Okinawa Trough. Seismic profiles reveal many volcanic knolls in the bottom of the Okinawa trough.

Not much more active volcanoes were reported in The South China Sea. From seismic data, some dead volcanic knolls were revealed in the spreading center. In the Philippine Sea, the most active volcanoes lie in the Izo-Bonin back-arc rift and Mariana trough. Many active seamounts and volcanoes on the island arc were studied.

3.2 Submarine hydrothermal activity

In the marginal seas of the Northwest Pacific. hydrothermal activity is very strong. Generally, the hydrothermal vents develop along the back-arc rifting center. The Okinawa Trough is typical hydrothermal active zone. Up to now, Japanese submersible "Deep Sea 2000" has dived more than 500 times and found 7 active hydrothermal vents in the Okinawa Trough. The hot water from the erupting vent is higher than 300℃. The Mariana Trough is another active hydrothermal zone.

4. CONCLUSION

From the studies of heat flow, volcanoes and submarine hydrothermal activities in the marginal seas of the Northwest Pacific Ocean, we can know there are huge energy hide in these area. Three back-arc basins, such as Komandorskaya basin, Okinawa trough and Mariana trough have much more high values, and are thought as spreading rift. These conclusions also need more work to be testificated.

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RELIABILITY OF SEA-SURFACE TEMPERATURE DATA TAKEN DURING WAR TIME IN THE PACIFIC

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With particular regard to the Pacific Ocean, this paper discusses whether sea surface temperatures taken during World War II can be subject to corrections or should not be used at all. Calculation and use of correction figures require a uniform baseline, a comparable basis for observing ships in time and space. During the war a common factor was deeply affected. Although the war in the Pacific started two years later than the war in Europe in 1939, the Pacific region nevertheless saw 'political' changes and with them sea communication diverted from the pre-war shipping practice. The investigation of 'reliability' is based on the past and present handling of these data and the different circumstances during the war and uncorrected data anomalies for some Pacific regions in accordance with published graphs. The paper concludes that the World War II data series indicate a strong relation to war-related conditions and can generally not be corrected but require critical review in climate change and El Niño research.

THE RETURN OF SST BUT WITH CONSTRAINTS

With the onset of interest in "global warming", historical sea surface temperature observations (SST) gained new prominence two decades ago. They were sampled by merchant ships sailing the seas in international trade. The principle pattern of global shipping existed throughout this time with only a single exception. During World War II (WWII) shipping practices changed profoundly as did the SST data series indicating a big "jump" (Figure 1, from Folland and Paker 1990) attributed to a sudden but undocumented change in the methods used to collect sea water from unisolated to isolated buckets or engine cooling water intake, to make measurements of SST (Folland et al. 1984). Barnett (1984) was the first to observe this inconsistency and expressed the view that studies already undertaken may soon show ways of overcoming nonsensical or instrumental biases. Only the latter has received any attention, not the "jump". Thus restricting the investigation on the reliability of SST over a very brief period of time seems to be a small issue. This first impression does not hold if seen in the context of global climatic changes or temporary weather fluctuations as El Niño Southern Oscillation (ENSO). Actually, the end of the 1930s was a turning point in mean temperature values in the Northern Hemisphere (Jones et al. 1982). After rising for 20 years, global mean temperatures became significantly lower for three decades (Folland, Karl et al. 1990). Furthermore, this `turning point` moved along with fluctuations in the tropical Pacific. Some researchers assume that two El Niño's occurred during WWII, one from 1939-41 the second from 1942-44 (Bigg et al. 1992), while others proposed viewing the anomalies as one prolonged ENSO incident of a previously unknown state (Copper et al. 1989). As historical observations cannot be repeated, the ultimate proof of whether

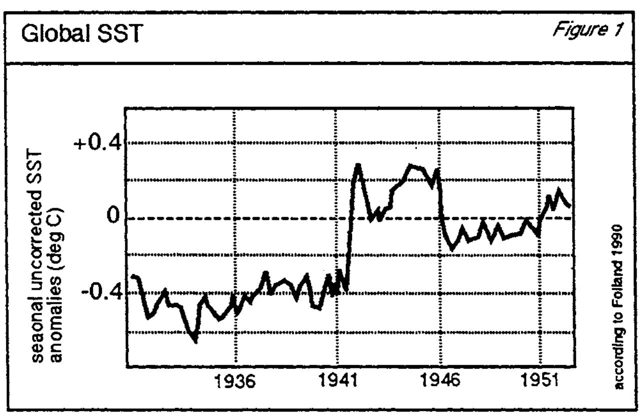


Figure 1

historical SST can be depended on is only available once the mechanisms of natural common changes are well understood. As it goes without saying that this is a long and painstaking process, even an initial review of a data series over a short time period is anything but a straight forward task.

THE SST DATA SERIES

Systematic ship observation started in 1854 (Folland and Parker 1990); data collection was established 75 years later with about 500,000 items of data per annum as of 1920 (Folland and Parker 1995). They served the purposes for which they were collected reasonably well, i.e. the improvement of pilot charts initiated by US Navy Admiral Matthew F. Maury at a conference in Brussels attended by the representatives of ten navies in 1835 and to assist meteorological services through daily ship observation as discussed and implemented by the International Meteorological Congresses in Vienna in 1873 and in Rome in 1879 (Cannegieter 1963). As climate was regarded as static and defined as the "average weather over a substantial period of time" there was little left to complain 60 years later. The monthly average of the oceans was well documented in pilot charts and hundreds of ships reported daily their meteorological observations for improved weather forecasting. But in 1939 the situation suddenly changed. "The Weather Goes to War" reasoned a The New York Times (NYT) commentary by pointing out that the war's first effect was felt by the US Weather Bureau as ships of warring nations ceased to record weather conditions for fear of revealing their positions (NYT Oct/03/39). The annual number dropped to a fraction of pre-war figures during the war (Folland and Parker 1995). Although World War I saw an even bigger drop in annual numbers of SST than WWII (Folland and Parker 1995) the general situation was different. The war at sea remained, with the exception of some world-wide operating raiders, closely confined to European waters from August 1914 to November 1918. A temporary success of German submarines to sink a monthly average of more than 500,000 tons ship space started in late 1916 but was sufficiently 'counter attacked' by the introduction of a convoy system in summer 1917.

But the problems of the weather services at the commencement of the war in 1939 and the quality of marine observations during the subsequent years until 1945 would not give any reason for concern if SST did not serve a very different purpose recently. Even in the 1960s their use was still based on a static climate approach (Brown 1963) although the possibility of the influence of variable sea-surface temperature on atmospheric centers of action was already being considered (Namias 1963). With the start of discussions on "global warming" in the late 1970s there was renewed interest in historical SST. As the archives contained millions of SST observations from the world's oceans, it was felt that they are "virtually the only hope of getting a globally comprehensive view of long term surface temperature changes" (Barnett 1984). Observational studies became an essential component improving understanding of climatic mechanisms and SST was regarded as one of the most important climatic variables (Folland and Parker 1990). From now on SST were used to identify dynamic processes within the global natural commons and not only to record its actual status as it used to be.

But it soon became evident that the use of SST was not without limits with regard to instrumental bias as already mentioned. Pre-WWII SST values were too low relative to post-WWII (Figure 1).

While Barnett (1984) considered a need for a positive correction in the order of 0.2 to 0.4 °C more recently it has been suggested to raise buckets based data series from 1900 to 1941 by about 0.4 °C (Bottomley et al. 1990) or to apply staggered figures over the period (Folland and Parker 1995). Also data from engine intake were found to require corrections as a recent special observation project for the North Atlantic showed that thermometers on ships in the North Atlantic trade produce biases of plus 0.3 °C (Kent et al. 1993). Whether these efforts can increase the understanding of dynamic processes in the natural commons is outside the subject of this paper, although one may wonder whether it is possible to summarize the many facets of shipping, seagoing and marine observations in one status. But without a 'uniform' picture at a given time, any instrumental correction figure applied in general, risk beeing speculative. In this respect no period is likely to be subject to greater uncertainty than WWII. This war at sea and its effect on shipping was so rich in events, alterations and constraints that it is difficult if not impossible to form a 'uniform' background picture for SST corrections.

THE GENERAL SITUATION 1939-1945

Actually, at the advent of WWII not every Pacific shore rested in peace. Japan had been sustaining its undeclared war on China since July 7, 1937, which caused ten million casualties by February 1940 (NYT Feb/11/40). Trade in and to the Far East was effected. On September 1st 1939 Germany invaded Poland forcing Great Britain and France to take up arms against Germany and its subsequent allies two days later. As the means of warfare regarding ships, submarines, airplanes, weapons and manufacturing of military goods had improved in many respects since the last war, this war immediately developed its own pattern. The world merchant fleet numbered 31,000 vessels with about 70,000,000 tons of which roughly one third sailed under British and French flag. The convoy system was immediately re-introduced. On September 8, thirty British merchant ships which took refuge at Gibraltar resumed their voyage under escort of a squadron of destroyers (NYT Sep/09/39). Until July 1940 naval convoying in the North Atlantic was provided up to 15 % West, then extended to 17 % West and provided for the whole transatlantic route as of summer 1941. Convoying meant that up to 50 ships sailed in four to five columns, frequently altering course by 90 % simultaneously (zigzagging) while naval escort vessels formed a shield around them. Thus most of the vessels permanently sailed in the keel water of other vessels. Measurements taken no longer consisted necessarily of 'sea surface water'. But the threat by submarines and raiders was feared everywhere. Ships zigzagged the seas on their own as the British cruise liner "Andora Star" for ten days to cross the Atlantic (NYT Sep/13/39) or several ships joined and convoyed from ports in the South Atlantic (NYT Oct/06/39) northbound until they received naval and air protection in the Western approaches. The US liner "Manhattan" sailed from Bordeaux to the States escorted by two US Navy destroyers in mid September (NYT Sept/17/39). Britain announced that it would arm 2000 merchant ships with guns (NYT Oct/1/39). The German merchant fleet was swept from the oceans within weeks. All navies were on alert, patrolled the oceans and seas, bombed, battled, torpedoed and depth-charged the enemy, the Axis often neutral parties also, mined coastal waters, seized or delayed ships in search of counterband, escorted particularly threatened vessels in 'out-war' areas and prepared for the worst. And the worse did come, much worst than ever imagined. Although the Pacific was isolated from major war activities until December 7, 1941, its political, economic and trading patterns nevertheless changed on September 1, 1939 and with it the 'picture' of seagoing in the Pacific.

THE PACIFIC IN WWII

The sources of marine data series and data 'consciousness'.
Pre-war SST data were mainly provided by European ships (Barnett 1984) while Japanese data only began in 1933 (Folland and Parker 1995). They were substituted by US Navy logs and US Merchant Navy observations from the early 1940s but how they were taken, "no one knows for sure" (Barnett 1984). Towards the end of WWII the number of observations was twice as high as at the best previous sampling peak around 1935 (Wright 1986).

In 1939 'everyone' knew that a profound knowledge of meteorological conditions would play an important part in this war (NYT Sep/ 03/39). Sea surface temperatures had become an important weather forecasting tool. Only twelve months earlier the US Weather Bureau was shaken by misjudging the movements of a hurricane which devastated New England on September 21, 1938. Observation capabilities were immediately increased (NYT Sep/22/39). The first two Coast Guard cutters took mid-Atlantic station as 'weather ships' in early 1940 (NYT Feb/11/40). The Bureau's Monthly Weather Review notes since September 1939 frequently Coast Guard ships "on survey" near Aleutain and that it received regular information on weather conditions in the Pacific from a number of US and Japanese merchant ships until June 1941 after which the publication of the names of weather reporting vessels was deleted. Aware of the need for sufficient weather data the US Navy and Airforce started to train personnel in thousands and soon became the biggest weather service ever (Bates et al. 1986).

Politics, shipping and war in the Pacific 1939/41 and 1942/45
The Allies needed as much ship space as they could get to fuel their war efforts in Europe, their liner trade ceased. Japan's costly war in China and its pursuit of a "new order" for East Asia continued. Since June 1938 the United States had attempted to deter Japan's aggression through measures which would curb her economic and military power. The US-Japan trade treaty of 1933 expired in January 1940. As of June 1941 Japan was embargoed and only weeks later Japan assets in the US was put under US Government control. Still in 1939 the United States Navy strengthened its fleet at Manila, had plans to construct a naval air base on the Palmyra Island group midway between Hawaii and Samao (NYT Dec/13/39), sent 29 scouting vessels to Hawaii (NYT Oct/06/39) were the largest two dry docks east of Singapore went into construction (NYT Dec/22/39), subsequently barred Hawaii coal supplies for merchant vessels (NYT Jan/25/40) and required fortification of Pacific Islands, while the whole structure of the US shipping industry changed completely within months on implementation of the US Neutrality Bill of November 1, 1939. Ships were laid-up, flagged-out or sold. The Allies bought and chartered ships whenever they could. On the other hand in 1937 a ship building program, the predecessor of the famous `Liberty` series, was introduced (NYT Jan/13/40). Two years later, when tankers of 19,000 tons could be built in four months, the US fleet had 1200 ocean-going vessels, 38% tankers (NYT Dec/14/41), and a program for 1200 more by 1943 but severe recruiting problems as well (NYT Dec/07/41). Actually, in 1943, US shipyards dilivered 1,896 ships totaling 20 Millions deadweight tons.

On December 7, 1941 a Pacific area image "Japan Rattles Sword - But Echo Is Pianissimo" (NYT Dec/07/41) ceased with the ambush on Pearl Harbor. The US Espionage Act of 1918 was invoked regarding information as to movements of transports (NYT Dec/09/41) and warnings on "loose talks" published (NYT Jan/23/42). Weather data became secrets. The weather maps had to go, and were accompanied by the comment "meteorologically we are living in the year 1800" (NYT Dec/16/41). The movement of all US merchant ships came under Navy reglementation (NYT Dec/14/41) and ship safety standards were eased (NYT Dec/18/41). As a convoy system could not be set up immediately ships were warned of raiders (NYT Dec/08/41) but Japan claimed to have seized 200 ships within the first war days (NYT Dec/10/41) while large scale sinking of ships commenced between the shores off San Francisco and Singapore. During the battle for the Philippines the first escorted resupply convoy of seven ships (which sailed from Honolulu on 29 November with reinforcements for the Philippines) arrived in Brisbane on 22. December 1941 and in January 1942 the United States began to rush garrisons to Pacific islands that would form staging and defence posts along the line of communication between Australia and Hawaii. Panama and the US West Coast. The main battle area remained West of the line Anchorage, Honolulu, New Hebrides and Darwin/Australia. Although Japanese naval forces remained concentrated in the Western Pacific navigating the Eastern parts of the Pacific was not free of considerable risks. Particularly during 1942 submarines, surface raiders and air planes posed constant dangers. Convoying was the order everywhere.

WWII REGIONAL SST SERIES

The material used is based on graphs of uncorrected SST anomalies as given by Wright (1986) for 1930 - 1960 for the North East, Central North-, North West, and Equatorial Pacific (Figure 2) and Folland and Parker (1995) for 1938 - 1948 for the North and Equatorial Pacific, but are only selective and simplified by the Figures given below. As the aim of the paper is restricted to discussing the reliability of WWII-SST in general the events mentioned should not be regarded as conclusive let alone proven. As each SST series is dealt with separately some repetition may occur.

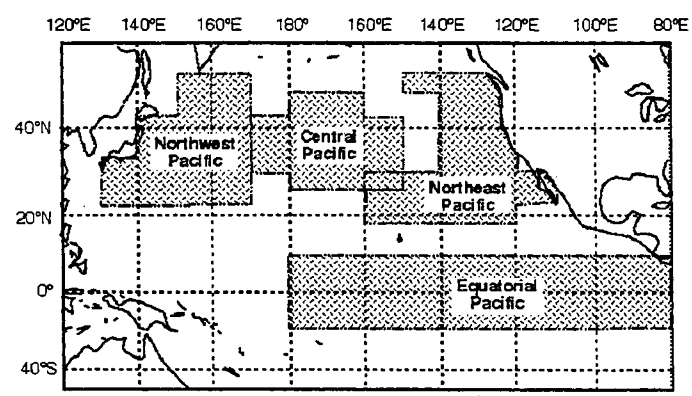
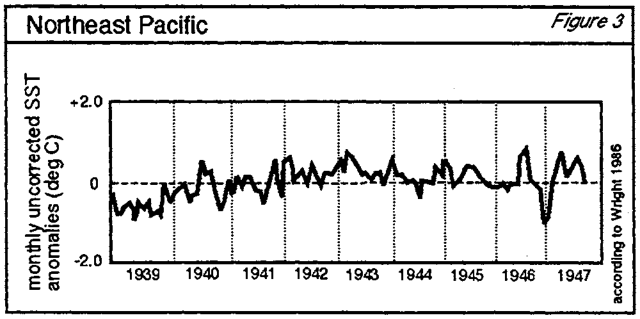


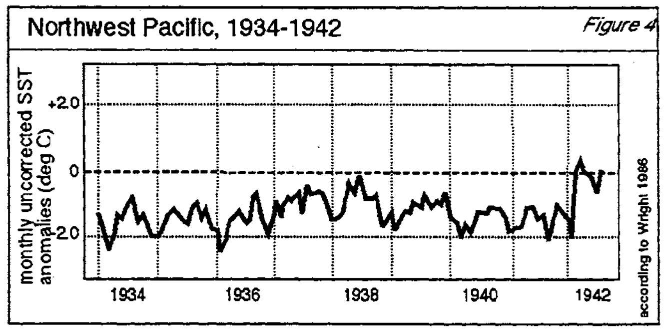
Figure 2

Northeast Pacific (NEPac)

The generally unremarkable running of NEPac-SST from 1943 to 1954 (Figure 3) is the most interesting aspect of this series. If the "jump" (Fig.1) had been caused by a sudden change in measurement methods, it should be very pronounced in this region. As of late 1939 US naval and transport traffic increased permanently and the region had never been as 'congested' as from 1942 to late 1945. Yet, the only deviation between pre- and post war anomalies is a slight temperature increase during the Pacific war period which can be attributed to convoying or escorted sailing. Further indications: a) mid-1938 to late 1939, the temporary decrease could be

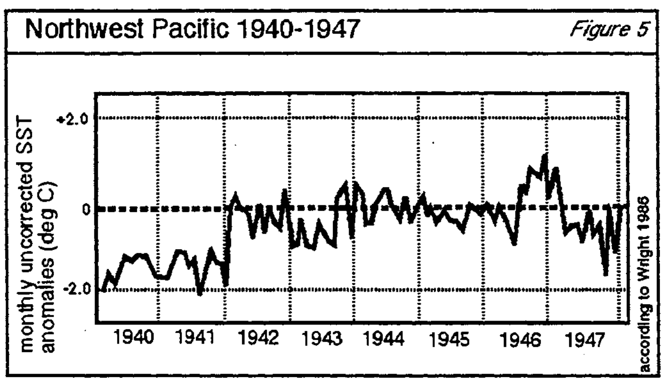


subject to reduced and changes in liner traffic of commonly observing ships (British, Netherlands, Japan, see above); b) late 1939 to late 1941, the small increase may be due to greater US Naval presence, while the "summer peaks" in 1940 and 1941 (not identifiable in previous years) could be related to measurements by buckets (see: NWPac) e.g. naval scouting vessels; c) late 1941 - early 1942, the brief 'zigzag' may stem from some immediate changes and increased activities along the US East coast after Pearl Harbor. Shipping was restricted to San Diego, San Francisco and Columbia River. The US tanker "Emidio" was torpedoed and sunk north of San Francisco on December 21; d) 1946 to 1947 could be related to still strong military transport but relaxed circumstances with pronounced "summer peaks" as in 1940/42.



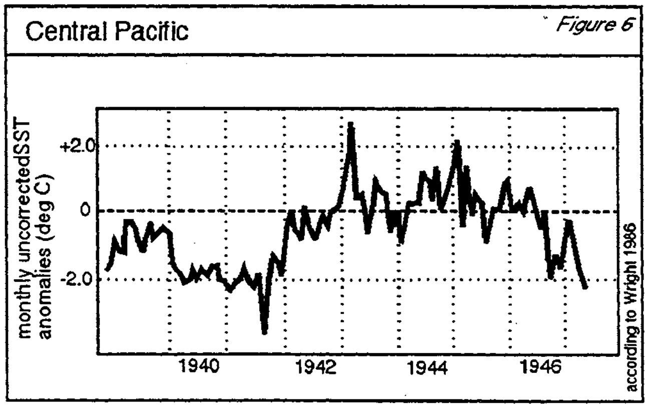
Northwest Pacific (NWPac)

The NWPac series 1934 until 1941 (Figure 4) clearly indicates a seasonal sampling error (Wright 1986) by buckets during winter. The time it took between the withdrawal of the bucket from the sea and reading the thermometer influenced the initial temperature of the water for a number of reasons. This is well established (Folland and Parker 1995). However, the pronounced repetition of seasonal 'peaks' in the NWPac may be due to the data input by Japanese observations as of 1933, which ceased by December 1941, when the series "jumped". But the different SST values from 1942 to 1945 (Figure 5) can hardly be attributed to mere methodical changes. There was no Japanese transport in NWPac except for some convoys to the Aleutain and coastal waters off the Japanese coast. On the other hand Japan could hold enough military control over the NWPac during the war to prevent any type of surface naval traffic or a longer stay. Most of the time during the war in the NWPac only submarines could have provided SST frequently. If they took SST by buckets, the more unlikely case, the "jump" should have been much less pronounced, if they recorded engine inlet data it would be necessary to know how deep the boat had been at that time, 5, 10, 20 or more meters.



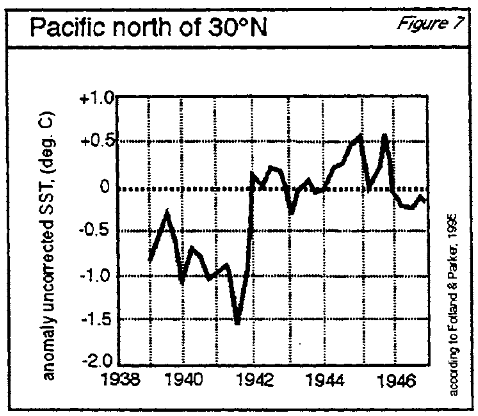
Central North Pacific (CNPac)

The data from CNPac (Figure 6) are particularly pronounced and could be explained as follows: a) late 1939 - late 1941, increased naval presence in the region; b) the deep 'crack' in summer 1941, in May 1941 a number of US and other ships sail to Vladivostok (Monthly Weather Report, May 1941), in June 1941 an embargo on Japan is declared; c) since January 1942 the introduction of convoying increases the data values during the war; d) the peaks in 1943, the US Aleutian compain on defense and recapture of islands started in full. US supply line partly runs through CNPac. Admiral Nimitz ordered the invasion of Attu on March 11, 1943. On March 26 the battle of the Komandsorski Islands took place. During the recapture of the Kiska Island in August an escort by almost 100 naval vessels was employed to protect the troop transporters; e) 1944 to 1945, Japanese access to the Aleutain area by sea is confined to submarines, but as military activities continued under war conditions the war time series remained high until mid-1945 thereafter decreasing to the pre-war level.



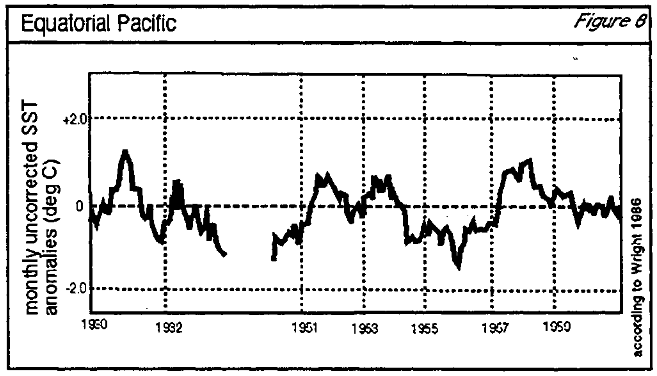
North Pacific north of 30 N (NPacN)

For the time series, NPacN (Figure 7) from 1939 to 1941 the remarks a)-c) for CNPac (Figure 6) apply accordingly. Due to the Lend-Lease Act passed by Congress in March 1941 supply convoys began to reach Vladivostok by May 1942, most by departing from Portland, Oregon. Despite the Soviet-Japanese non-aggression pact of April 1941 the Japanese Navy often harassed the convoys sinking at least 25 Soviet ships. The peaks in late 1945 and 1946 are of some surprise. As these peaks are not clearly supported by the material discussed here (Figures 3,5,6), the situation in the most northern part of the Pacific could be the reason, e.g. traffic to Russia, mine sweeping operations and the huge decommissioning of military bases and weather services in the Aleutian. The fact that the series peaks in winter could be an indication that observations north of CNPac are based on engine inlet water as the contrast between 'sea surface temperature' to deeper water would be most pronounced in sea areas off the Aleutian Islands.

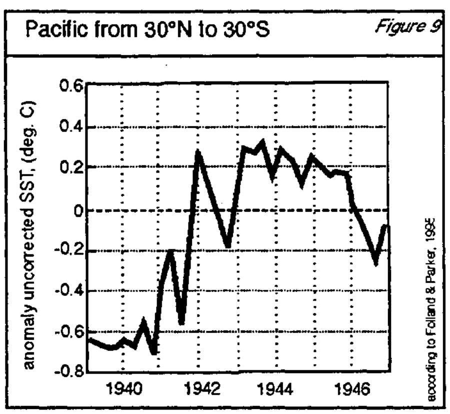


Equatorial Pacific (EquPac)

The advantage of elaborate SST in this region is the known rise of temperature subsequent to an El Niño event. The typical feature of SST of the established ENSO 1930, 1932, 1951,1953 and 1957 is given in Figure 8. EquPac-SST frequently peak within a year after the event. The picture is different for the ENSO during WWII as given by Wright (Figure 10) whether there was two, 1939-41 and 1942-1944, or only one prolonged event (see above), while the data series from Folland and Parker (Figure 9) seem to support the latter at first glance. But neither of these figures clearly supports the strong El Niño in 1939 and the subsequent running values may have been effected by the war situation.



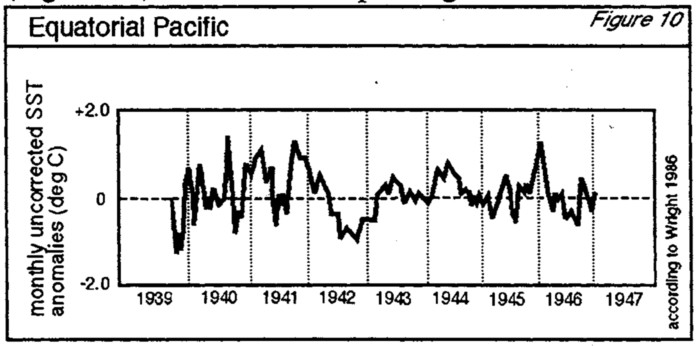
With regard to Figure 9 the coverage of more than half the Pacific from 30° N to 30° S must be questioned. From 1942 to 1945 the situation East and West of Hawaii/New Hebrides was different. In one half of the Pacific navigation was generally confined to military activities, while in the other half sea transport in convoys continued. The sudden increase in late 1941 may thus be mainly due e.g. to data from submarines (West) and convoying (East). The substantial data decrease after the war ended supports this view.



Of greater importance for a discussion are the data deviations in Figure 2 confined to the tropical sea from 10° N to 10° S and 80° W to 180° W. But as the pattern of navigation in this area from 1939 to 1945 varied extremely and information on transport was concealed as of December 1941 there is little room for a picture on conduct to any sufficient degree. The impact of the El Niño years, in particular the strong one in 1939, may nevertheless provide some indication as to the impact of WWII.

The data for late 1939 to Dec.1941 (Figure 10) do not indicate a typical ENSO event (Figure 8) in 1939, but a possible one in 1940 with a temporary 'cooling' during summer 1941. While the brief 'irritation' in late 1940 can only be commented as being "extraordinary", the drop in late 1939 can be due to the immediate 'confusion' when WWII started and the 'cooling' in 1941 could be subject to the embargo on Japan. On the other hand, the insignificant temperatures during 1940 may be due to the fact that European shipping in the Pacific was considerably reduced and often replaced by old (steamship) tonnage while the increase in early and late 1941 could be due to new freighters, greater data 'consciousness' and particularly by the growth of naval activities and transport of construction and war material. That the series 1939-1941 was effected by a mix of many circumstances can not be excluded. If so, a thesis of a continued ENSO from 1939-1941, instead of one in 1939, needs to be founded on additional or other sources than EquPac-SST.

The subsequent series from 1942-1945 (Figure 10) with a second prolonged ENSO 1942-1944 according to Grant et al. also arouses suspicion. The war and supply machinery got into full gear. Escorted convoys became the rule. The second US convoy arrived in Australia on February 1,1942. Routing changed as did the frequency of sailings. The drop of SST value over two degrees in 1942 could be due to SST taken by the engine inlet of big ships. If so, the very modest 'summer peaks' during 1943 and 1944 would require a positive correction. On the other hand, after the first twelve months of war, navigation in the East Pacific became more routine and might have caused a more frequent use of buckets.



The use of this tropical SST can not be easily applied for two separate ENSO events from 1939-1941 and 1942-1944 or as one prolonged event over the period of war. Figure 10 does not exclude it but as support it is a weak mean as well. The pre- and post war ENSO (Figure 8) are reflected too differently in the SST series as to dispel doubts. At least tropical data for ENSO research would need a closer review on an individual basis to be used as evidence or strong support. Whether the efforts would be worth the investment is difficult to say. After all, the first WWII winter 1939/40, with extreme weather conditions in the Northern Hemisphere, was accompanied by a significant shift from rising to lower global temperature values, lasting three decades. Thus any assumption or proof that the 1939 ENSO lasted until 1941 or even 1944, would need to account for the sudden shift in the Northern Hemisphere as well. The notion alone that the WWII ENSO(s) are a result of a previously unknown state (Copper et al) is too narrow a view, but if based on tropical WWII SST series more attention needs to be paid to the circumstances of navigation during the period.

CONCLUSION

A review of Pacific SST data series from 1939 to 1945 together with WWII seagoing conditions indicate detectable impacts. As one source for climatic changes and ENSO research the many facets of navigation during WWII require either a comprehensive review of the individual observations in question, or, if used as presently compiled, interpreted with extreme caution. WWII conduct at sea differed to greatly from other times.

The established difference between pre- and post war SST series is based on a comparable picture on seagoing operations and can be explained as a result of change in the methods of measurements but not the sudden "jump" by a sudden change in sample taking in late 1941. The immediate drop at the end of WWII (Fig.1) indicates the interplay of a different force but not a systematic one.

Historical SST are now evaluated and used to indicate climatic variations and dynamics. They can provide reliance as proved by pre- and post war ENSO signals in the tropical ocean (Figure 8) but in this respect corrections are not required. However, WWII produced a sea change of variations as well, defying attempts to draw a uniform background picture of observing ships sailing the seas. "Sea surface water" was not necessarily "sea surface water" (e.g. convoyed ships, submarines). As there are no sufficient means of establishing comparability between the data during WWII or between the war period and series during peace time, mere compiling and averaging of war-time marine observations cannot improve the reliability of the input. The average run of 'freak' data gives an average run of 'freak' results. Any use of SST series covering 1939 to 1945 requires due consideration of WWII conditions.

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NUMERICAL SIMULATION OF WAVE SLAMMING BY TURBULENT MODEL

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ABSTRACT

The present study is to investigate numerically the impact pressure on structures above sea level due to wave slamming. The governing equations are Reynolds time-averaged equations and two equation $k-\varepsilon$ model. Based on the volume of fluid method(VOF), the numerical wave flume with active absorption wave-maker is established. Third order upwind difference scheme is applied to convection term to reduce the effect of numerical viscosity. Appropriate moving contact-line boundary conditions are introduced to model wave in contact with and separation from the underside of structure.

Parametric studies have been carried out for different incident waves and structure geometry. The pressure distribution on the structure and velocity fields are obtained. The numerical results show that the ratio of the distance between underside of structure and still water level(s) to the wave height(H), s/H, has significant effect on peak pressure. The statistical properties of peak pressure at initial contact and the negative pressures at the later stage are predicted by numerical model.

INTRODUCTION

The safety of coastal and offshore structure such as a pier or an offshore drilling platform has much to do with wave slamming. When waves propagate beneath the underside of the structure and in contact with it, the significant impact pressure may inundate the deck structure or cause local failure. The negative pressures may endanger the durability of the structures when waves separate from the structure. Because wave slamming on structures in splash zone is related to nonlinearity of wave 、 air entrapment 、 fluid viscosity and turbulence, only few results are obtained so far and mostly are experimental investigation.

Many of the present research work are limited to wave slamming problems of slender horizontal circular cylinders. Kaplan (1976) developed an analytic solution by using incompressible potential flow theory and assumed that the diameter of the cylinder is small compared to the wave dimensions. Miller (1977) and Sarpkaya (1978) express the relation between the impact wave force and the vertical velocity of water particle as: $F_s = \frac{1}{2}\rho D C_s W^2$, the slamming coefficient of C_s is determined from experiments. Due to the difference of their experimental conditions and methods, the values of the slamming coefficient differ much. Kaplan (1992) extended the treatment for horizontal circular cylinder to flat deck structure. However, all the methods above are based on potential flow theory, neglecting the existence of the structure 、 wave transformation and breaking. Garrison (1996) recently developed a new method based on the energy principle. Subsequent to initial impact the next peak in the stress is shown to be primarily a function of the Froude number. The method is shown to agree well with experiments and is convenient for application. However, this method is also limited to wave slamming problems of slender horizontal circular cylinders.

It is the intention of this paper to study the wave slamming by numerical simulation. The Reynolds time-averaged equations and two equation $k-\varepsilon$ model are used as governing equations. wall function method is applied to the boundary cell. Appropriate moving contact-line boundary conditions are introduced to model wave in contact with and separation from the underside of structure. By numerical simulation, the distribution of impact pressure along the underside of structure, the statistical properties of peak pressure and the negative pressure at the later stage of slamming are obtained.

GOVERNING EQUATION

Governing equations are continuity equation, Reynolds time-averaged equation and two equation $k-\varepsilon$ model from Eq.(1) to Eq.(5):

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$\begin{aligned}\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=g_x-\frac{1}{\rho}\frac{\partial p}{\partial x}+v\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+v_t\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+\\ 2\frac{\partial v_t}{\partial x}\frac{\partial u}{\partial x}+\frac{\partial v_t}{\partial y}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)-\frac{2}{3}\frac{\partial k}{\partial x}\end{aligned} \tag{2}$$

$$\begin{aligned}\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=g_y-\frac{1}{\rho}\frac{\partial p}{\partial y}+v\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+v_t\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\\ 2\frac{\partial v_t}{\partial y}\frac{\partial v}{\partial y}+\frac{\partial v_t}{\partial x}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)-\frac{2}{3}\frac{\partial k}{\partial y}\end{aligned} \tag{3}$$

$$\begin{aligned}\frac{\partial k}{\partial t}+u\frac{\partial k}{\partial x}+v\frac{\partial k}{\partial y}=\left(v+\frac{v_t}{\sigma_k}\right)\left(\frac{\partial^2 k}{\partial x^2}+\frac{\partial^2 k}{\partial y^2}\right)+\frac{1}{\sigma_k}\left(\frac{\partial v_t}{\partial x}\frac{\partial k}{\partial x}+\frac{\partial v_t}{\partial y}\frac{\partial k}{\partial y}\right)+\\ 2v_t\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2\right]+v_t\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2-\varepsilon\end{aligned} \tag{4}$$

$$\begin{aligned}\frac{\partial \varepsilon}{\partial t}+u\frac{\partial \varepsilon}{\partial x}+v\frac{\partial \varepsilon}{\partial y}=\left(v+\frac{v_t}{\sigma_\varepsilon}\right)\left(\frac{\partial^2 \varepsilon}{\partial x^2}+\frac{\partial^2 \varepsilon}{\partial y^2}\right)+\frac{1}{\sigma_\varepsilon}\left(\frac{\partial v_t}{\partial x}\frac{\partial \varepsilon}{\partial x}+\frac{\partial v_t}{\partial y}\frac{\partial \varepsilon}{\partial y}\right)+2C_{\varepsilon 1}\frac{\varepsilon}{k}v_t\\ \left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2\right]+C_{\varepsilon 1}\frac{\varepsilon}{k}v_t\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2-C_{\varepsilon 2}\frac{\varepsilon^2}{k}\end{aligned} \tag{5}$$

In which u and v are velocity component in x and y direction respectively, p the pressure, ρ the fluid density, ν the coefficient of kinematic viscosity and $\nu_t = C_u \dfrac{k^2}{\varepsilon}$ the coefficient of turbulent viscosity, parameters in $k-\varepsilon$ model are chosen as $C_u = 0.09$, $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$, $C_{\varepsilon 1} = 1.43$, $C_{\varepsilon 2} = 1.92$, $C_L = 0.1643$.

The free surface is treated by introducing a function F(x,y,t) that is defined to be unity at any point occupied by the fluid and zero elsewhere. Thus, F=1 implies a cell full of fluid, while F=0 denotes an empty cell. A cell with F values between zero and one are partially filled with fluid; they are either intersected by a free surface or contain voids (bubbles) smaller than cell mesh dimensions. A free surface cell is defined as a cell containing a non-zero value of F and having at least one neighboring cell that contains a zero values of F. The time dependence of F is governed by

$$\frac{\partial F}{\partial t} + \frac{\partial (uF)}{\partial x} + \frac{\partial (vF)}{\partial y} = 0 \tag{6}$$

The fact that F is a step function requires special care in computing these fluxes to preserve the sharp definition of a free surface. Here a donor-acceptor flux approximation(Hirt and Nichols, 1981) is used to flux the F function at each interface.

NUMERICAL METHOD

The staggered cell, which is of length δx_i and height δy_j, is used in numerical computation(in Figure 1) with velocity $u_{i+1/2,j}$ at the right face of the cell, velocity $v_{i,j+1/2}$ at the top face of the cell, and $\phi_{i,j}(p_{i,j}/\rho)$ and $F_{i,j}$ at the cell center.

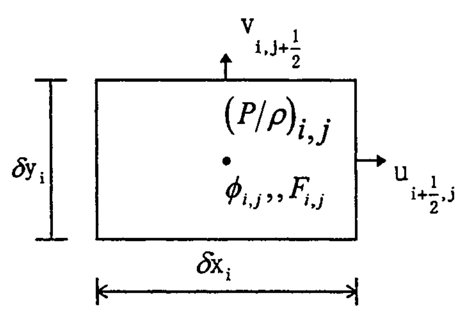

Figure 1 Definition of Dependent Variables

In order to reduce the effect of numerical viscosity, third order upwind difference scheme is applied to convection term(Yoshiaki,1992).

$$U_x = \frac{1}{\delta x_i}\left(u^L_{i+\frac{1}{2},j} - u^L_{i-\frac{1}{2},j}\right) \qquad u^n_{i,j} > 0 \tag{7}$$

$$U_x = \frac{1}{\delta x_{i+1}}\left(u^R_{i+\frac{1}{2},j} - u^R_{i-\frac{1}{2},j}\right) \qquad u_{i,j}^{\ n} < 0 \tag{8}$$

in which

$$u^L_{i+\frac{1}{2},j} = u^n_{i,j} + \phi_1^L \delta u_{i-\frac{1}{2},j} + \phi_2^L \delta u_{i+\frac{1}{2},j} \tag{9}$$

$$u^R_{i+\frac{1}{2},j} = u^n_{i,j} + \left(1-\phi_2^R\right)\delta u_{i+\frac{1}{2},j} - \phi_1^R \delta u_{i+\frac{3}{2},j} \tag{10}$$

$$\delta u_{i+\frac{1}{2},j} = u^n_{i+1,j} - u^n_{i,j} \tag{11}$$

$$\begin{aligned}
\phi_1^{\ L} &= \frac{\Delta_0\Delta_1}{\left(\Delta_{-1}+\Delta_0+\Delta_1\right)\left(\Delta_{-1}+\Delta_0\right)}\\
\phi_2^{\ L} &= \frac{\Delta_0\left(\Delta_{-1}+\Delta_0\right)}{\left(\Delta_{-1}+\Delta_0+\Delta_1\right)\left(\Delta_0+\Delta_1\right)}\\
\phi_1^{\ R} &= \frac{\Delta_0\Delta_1}{\left(\Delta_0+\Delta_1+\Delta_2\right)\left(\Delta_1+\Delta_2\right)}\\
\phi_2^{\ R} &= \frac{\Delta_1\left(\Delta_1+\Delta_2\right)}{\left(\Delta_0+\Delta_1+\Delta_2\right)\left(\Delta_0+\Delta_1\right)}
\end{aligned} \tag{12}$$

The SOLA-VOF algorithm (Hirt and Nichols, 1981; Fuxi Ma,1992) is employed to satisfy the difference equations in each control volume. The basic solution procedure consist of the following operations:

1. At each time step we must solve for the $u_{i+1/2,j}$, $v_{i,j+1/2}$ and $F_{i,j}$ in each control volume. Explicit approximations of the velocity field are obtained from the momentum equations by using previous time level values for the advective, pressure, viscous, and body force terms.

2. In order to satisfy the continuity equations, the pressure (and velocities) must be adjusted in each computational cell occupied by fluid. In each cell containing fluid, except for a free surface cell, the cell pressure is adjusted until continuity equation is satisfied to a prespecified level of accuracy. This procedure is modified for cells containing a free surface. For these cells, the free surface boundary condition is satisfied.

3. $k_{i,j}^{n+1}$ and $\varepsilon_{i,j}^{n+1}$ are calculated by newly obtained velocity through two equation of $k-\varepsilon$ model.

4. After the velocity and pressure fields have been obtained by the above iteration process, the volume of fluid function F is then computed for the new time level to give the new fluid configuration.

It is noted that the dissipation rate equation requires much smaller grid than momentum equation and kinetic energy equation. The wall function method is used for boundary cell to keep proper cell dimension and satisfy certain accuracy(Changgao Zhang,1990):

$$l_m = \beta_0 L\left(\exp\left(\frac{ku}{u_*}\right) - 1\right) \quad (13)$$

$$k = {u_*^2}\Big/{\sqrt{C_u}} \quad (14)$$

$$\varepsilon = {u_*^3}\Big/{l_m} \quad (15)$$

$$\nu_t = C_u \frac{k^2}{\varepsilon} \quad (16)$$

where, β_0 is constant coefficient that is related to roughness of the wall and L the characteristic length. In our numerical model, L is chosen as the distance from the center of boundary cell to the wall and β_0 is equal to 0.0005.

The contact-line boundary condition embedded in VOF method is developed to model the wave in contact with and separation from the structure. When the wave approaches the underside of structure but not in contact with it yet, the cell next to structure is a free surface cell. As long as the initial contact occur, the free surface disappears and the previous free surface cell becomes the internal fluid cell that satisfies the continuity condition. The impact conditions are set by considering the value of F(i,j) in the neighbor of the structure as:

$$\begin{cases} F(i,j) \geq 0.96 & impact \\ F(i,j) < 0.96 & no\ impact \end{cases} \quad (17)$$

RESULTS OF NUMERICAL SIMULATION

The computation region is shown in Figure 2. A mesh of 230 cells in the x-direction and 28 cells in the y-direction are used. The space increment are δx=6cm in x direction and δy=5cm (for cells above topography δy=3cm) in y direction. Water depth is 60cm. The structures are represented by blocking out appropriate mesh cells. Wave maker boundary is set on the left end and open boundary on the right end. water density, ρ=1g/cm^3; gravity acceleration, g=980cm/s^2; kinematic viscosity, ν=0.01002cm^2/s.

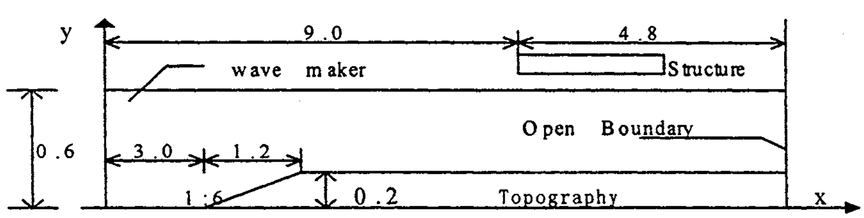

Figure 2 Sketch of Computational Region

A number of numerical runs have been carried out for various incident wave and structure geometry. Figure 3 shows the typical velocity field for H=12cm, T=1.5s, S=2cm and L=60cm. Here, H is wave height, T the wave period, S the distance of underside of structure above still water level and L the length of structure.

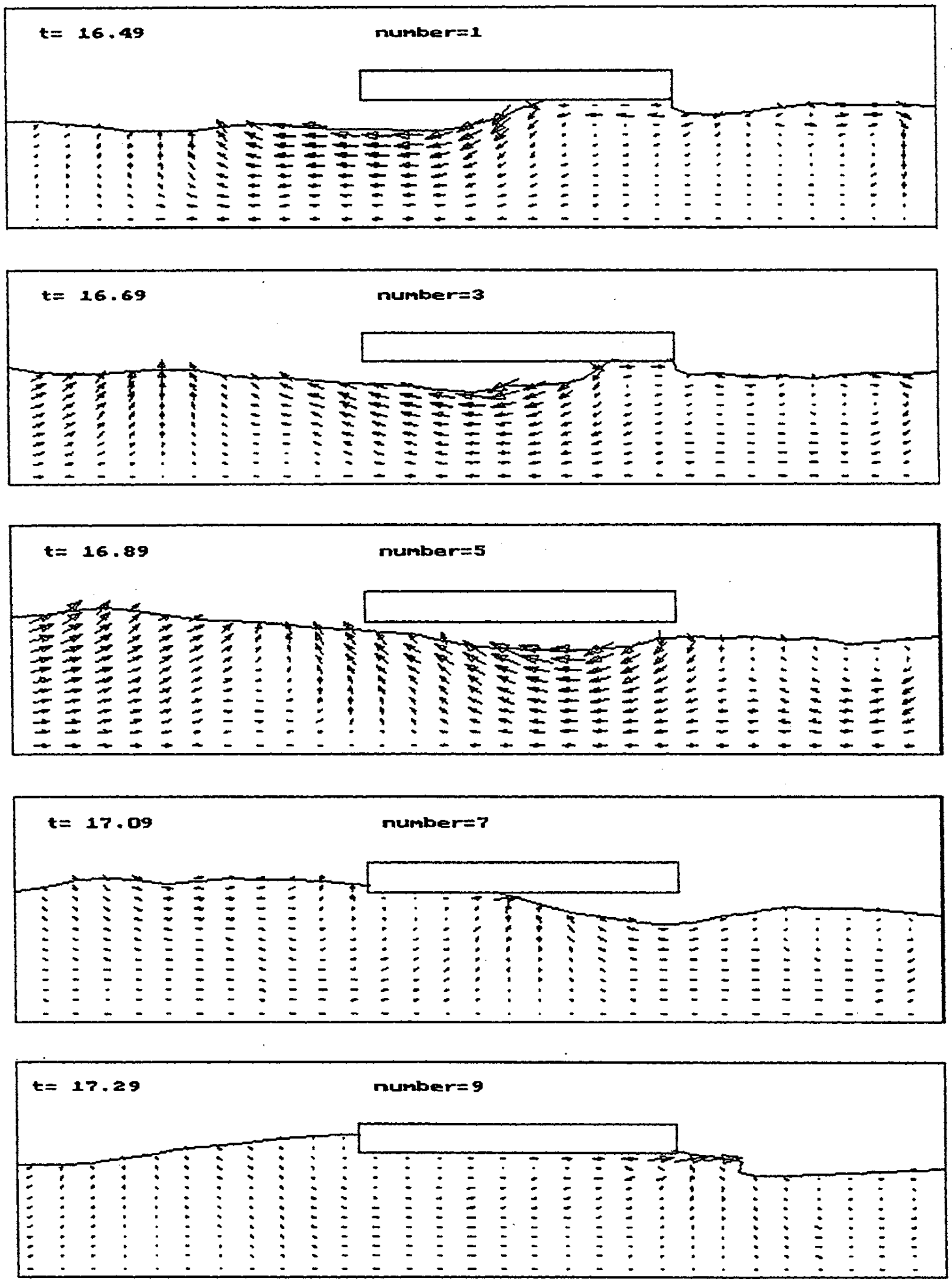

Figure 3 Flow Field of Wave Slamming Process
(H=12cm, T=1.5s S=2cm, L=60cm)

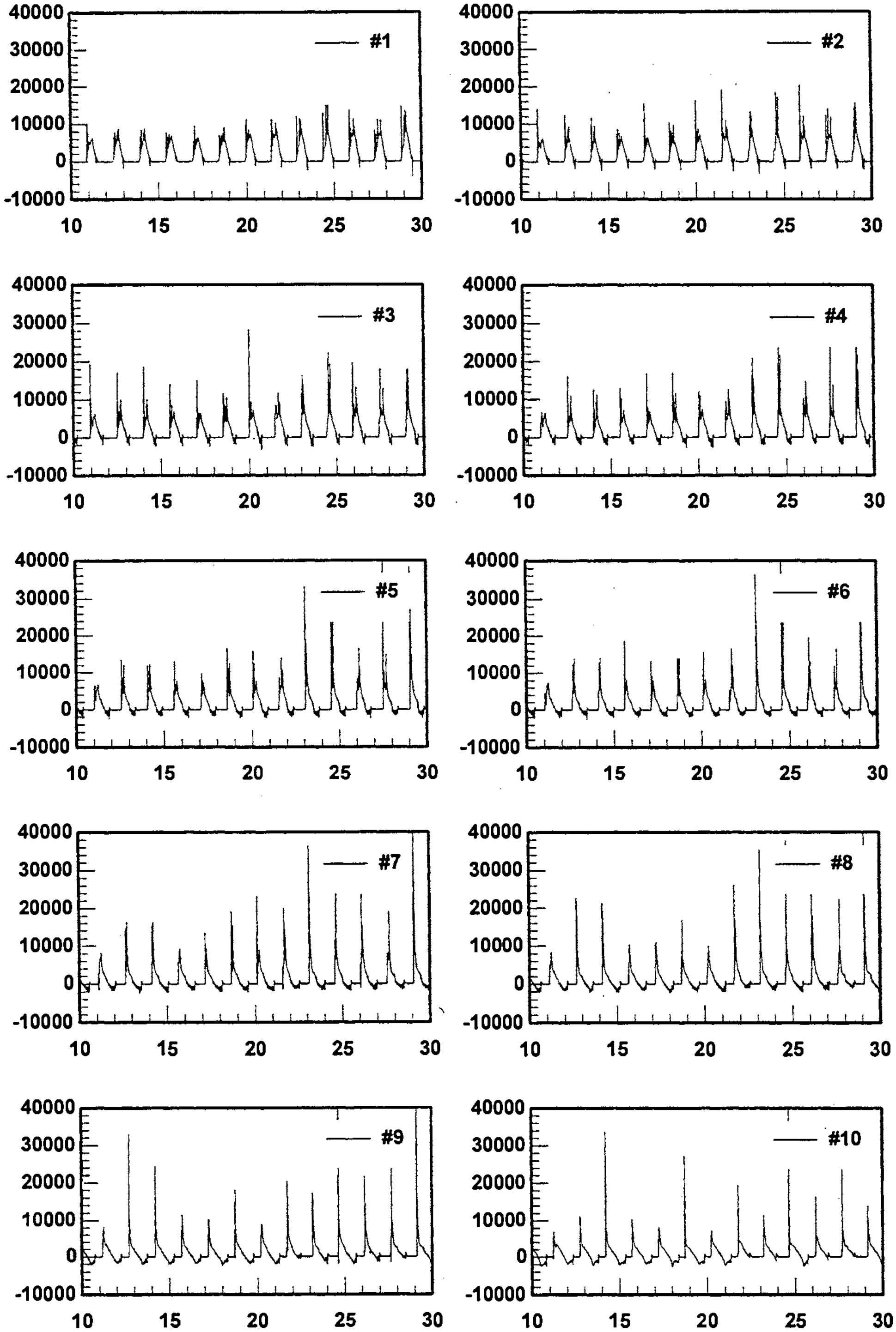

Figure 4 Time History of Impact Pressure(H=12cm, T=1.5s, S=2cm, L=60cm)

The time history of impact pressure for large structure length is shown in Figure 4 (H=12cm , T=1.5s and S=2cm) . The pressure units is dyne /cm^2. Ten pressure sampling points are located along the underside of the structure from the left to the right. Numerical results shows that the underside of structure is subjected to significant impact pressure. The large peak pressure occurs at initial contact and varies randomly from cycle to cycle even under regular wave action. It is indicated that slamming pressure has considerable magnitude and a much shorter rise time, followed by a slowly-varying pressure of less magnitude, that varies from positive to negative, and then becomes zero.

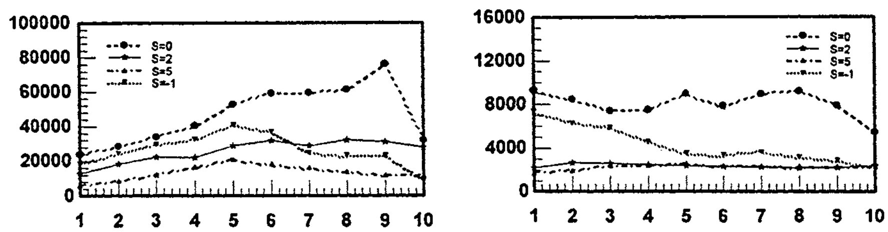

Figure 5 Distributions of Impact Pressure (H=12cm, T=1.5s, L=60cm)

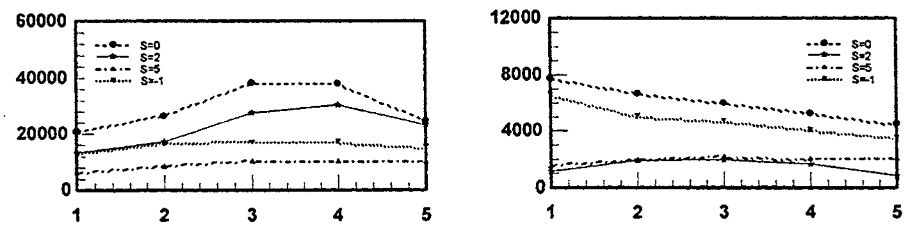

Figure 6 Distributions of Impact Pressure (H=12cm, T=1.5s, L=30cm)

Figure 5 and 6 are distributions of peak pressure. In the figure abscissa represents the number of pressure sampling location along the underside of structure. The peak pressures are represented by significant pressure $P_{1/3}$ due to it's statistical properties. It is shown that the distance between underside of structure and still water level has significant effect on impact pressure. The high impact pressures are obtained when the underside of structure is just above the still water level.

CONCLUSION

The wave slamming process is studied numerically by Reynolds time-averaged equation and two equation $k-\varepsilon$ model. High impulsive pressures with statistical properties acting on structure at initial water contact and the pattern of positive and negative impact pressure have demonstrated qualitatively. The predicted impact pressure and velocity fields obtained by numerical computation are very informative to understand the nature of wave slamming on offshore structures. Verification by laboratory experiments is needed in further research.

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CURRICULUM STUDY OF CHINESE MARINE SCIENCE EDUCATION FOR POST-GRADUATES

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ABSTRACT

In the past decade, Chinese post-graduate education in marine science has developed rapidly. However, through case study and comparative study, it has been observed that the curriculum development and course structure are rather conservative compared with that of the USA. For many research institutes, the curricula are not designed by the institutes according to their special needs. In terms of the course structure, the curricula are lack of variety and inter-disciplinarity. The courses on research methodology and experiments are extremely insufficient. In addition, no seminar participation and investigation cruise are required in the curriculum. As a result, although the students usually have a good grasp of examination skills, they are not so good at doing independent research. The student's knowledge structure is relatively loose, narrow and out-dated. The is reflected in the content of dissertations which normally concentrate on data presentation with inadequate data analysis, discussion and detailed presentation of justifying the methodology adopted. The reason for these problems is connected with the general Chinese educational tradition and the background of the primary, secondary and university education which the present post-graduates have received.

INTRODUCTION

The history of Chinese post-graduates education can be traced back to the early time of this century. In "*The Regulations of the Great School*" which was issued by the last emperor of the Qing dynasty, it was legislated that in the "great school", the "Faculty of Confucius Study" could be established. The "Faculty of Confucius Study" was virtually the early form of the school of post-graduate education. In 1935, the government of Nationalist Party issued the first regulation of academic degrees in Chinese history. In the regulation, three levels of degrees are introduced: Bachelor, Master and Doctor In the subsequent years, more regulations about the related examinations were issued. However, due to the poor science and education conditions, and the anti-Japanese war, the regulation was not actually executed. Up to 1949, the total number of post-graduates who completed their study was 143; none of them obtained the doctoral degree. In 1952, along with the establishment of the State Department of High Education, a series of rules and regulations of post-graduate education and academic degree construction were issued, and subsequently, the high education developed rapidly. However, the "cultural revolution" interrupted the development. So the post-graduate education and the degree regulation construction did not revive until 1978. In the new year's day of 1981, "the Regulation of Academic Degree of People's Republic of China" was issued, which was a signpost of the new stage of Chinese post-graduates education (Liu, 1994). At that time, China started to educate its own post-graduates on a large scale and independently. Up to now, the total number of Ph.D. students is over 20,000 (Yin *et al.* , 1996). Meanwhile, the theoretical research for post-graduate education commenced. Most of the research papers have been published in *Academic Degrees and Post-graduate Education,* first issued in 1984. This is the most important journal exclusively about the post-graduate education,

In the field of marine sciences, Chinese post-graduate education started in 1978 on its full scale. For the doctorial degree, however, it has a history of only fifteen years. For the largest oceanography institute of the state, *i.e.* the Institute of Oceanography, Chinese Academy of Sciences (IOCAS), its total enrolment of post-graduates since 1978 is 126. In terms of the largest marine science university in China, *i.e.* Qingdao Ocean University (QOU), its total enrolment since 1960 is around 650.

Compared with the high education system of the America, the Chinese post-graduate education system has some similarities. Both have their admission examinations, course credits system, and comprehensive examination before viva. However, their outputs are very different. In recent years, Chinese educational authorities have noticed that the student's knowledge domain is very narrow and the knowledge structure is rather loose. They are largely good at doing examinations, but not good at doing research independently. This study will explore the reasons of these problems through inspecting the curriculum development and course structure of a representative university and a research institute in China.

METHOD

To investigate into the Chinese curriculum for post-graduates, this study employs the case study method by use of two cases: the curriculum of physical oceanography in QOU and the curriculum of the same subject in the IOCAS (Tables 1 and 2 list the courses and the number of their credits and lectures in the two institutes). Further, a comparative study between the cases in China and in the America (see Table 3) is undertaken. The case for the American is the curriculum of physical oceanography in Rhode Island University (for the case of Rhode Island University, the authors had some contact with the Chinese oceanographic students who study there).

In addition to the document analysis, the authors had several interviews with the head of the Department of Post-graduate Education in QOU. The interviewees also include some students and supervisors in IOCAS and the university. The authors also investigated the structure and content of many dissertations and theses of the graduated students in IOCAS. Moreover, one of the authors recently organized a student seminar, which provided some special information for comparison with the case in the America.

In the curriculum of QOU, the requirement of the master degree is: the thesis; the courses Nos.1-5 (see Table 1); at least eighteen credits of the rest courses relating to the research subject of the student. Course selection is mainly decided by the supervisor. For the doctorial degree, the credit system is not applied any more; study and research tasks are arranged by the supervisor. However, there are a few compulsory courses, which are Nos. 1, 2, 6, 31, and 32 (see Table 1).

Table 1. Course structure of physical oceanography in QOU (1997)

1. Marxism and The History of Science (3/72)	2. English Language (4/144)
3. Geophysical Fluid Dynamics (6/144)	4. Random Processes and Oceanic Data Analysis (4/72)
5. Numerical Method in Oceanography (4/72)	6. Wave Theories and Computerising Principles (3/54)
7. Introduction to Internal Waves (3/54)	8. Introduction to Storm Tides (3/54)
9. Liquid Oscillation Principles (3/54)	10. Tide Dynamics (3/54)
11. Non-linear Fluctuation (3/54)	12. Environmental Dynamics of Shallow Sea (3/54)
13. Estuary Dynamics (3/54)	14. Estuarine Mixing and Material Flux (3/54)
15. Coastal Engineering Dynamics (3/54)	16. Mechanics of Sediment Transport (3/54)
17. T/ S Structure & Water Mass Analysis (3/54)	18. Transition Layers and Marine Fronts (2/54)
19. Ocean Circulation and Water Mass (2/54)	20. Air-sea Interaction (2/54)
21. Marine Turbulence (2/54)	22. Ocean Current Dynamics (2/54)
23. Marine Boundary Layer Dynamics (2/54)	24. Marine Thermodynamics (2/54)
25. Sea Temperature Theory (2/54)	26. Fuzzy Analysis (2/54)
27. Finite Element Methods (2/54)	28. Perturbation Methods (2/54)
29. Equatorial Sea Current Dynamics (2/54)	30. Satellite Oceanography (2/54)
31. Second Foreign Language (2/54)	32. Ocean Oscillation I (No)
33. Ocean Oscillation II (No)	

Note: (1)The courses number 32 and 33 are for Ph.D students. There is no credit system at the Ph.D level in China .
(2) Laboratory experiment is not designed in the course; they are determined by the supervisors.
(3) Arabic numerals in parenthesis indicate credit scores and number of lectures for the course.

Table 2. Course structure of physical oceanography in IOCAS (1997)

1. Marxism and The History of Science (3/60)	2. Foreign Language 3/(240)
3. Application of Computer Science (3/60)	4. Oceanography (3/70)
5. Physical Oceanography (3/60)	6. Numerical Methods (3/80)
7. Fluid Dynamics (3/60)	8. Geo-physical Fluid Dynamics (3/60)
9. Probability and Statistics (3/60)	10. Fluid Dynamics (3/60)
11. Ocean Circulation (3/60)	12. Dynamical Oceanography (3/60)
13. Advanced Meteorological Dynamics (3/60)	14. Air-sea Interaction (3/60)
15. Turbulence Theory (3/60)	16. Second Foreign Language (No)

Note: (1) The course number 16 is for Ph.D level, which is not in credit system as master level.
(2) The arabic numerals in parenthesis indicate credit scores and number of lectures for the course.

For the master degree in IOCAS, the requiement is that apart from the dissertation, the total credits should be no less than 36. In addition, at least 15 credits hould be from the courses listed in Table 2, and the rest credits should be resolved by the supervisor, which may be from the courses outside of Table 2. For the doctorial degree, the credit system is not applied any more. No courses are compulsory except Nos 1, 2 and 16.

Table 3. Course structure of physical oceanography in Rhode Island University (1996)

1.Physical Oceanography (3/3)	2.Descriptive Physical Oceanography (3/3)
3. Chemical Oceanography (3/2+II)	4. Organic Geochemistry of Natural Waters (3/3)
5. Chemistry of the Marine Atmosphere (3/3)	6. Synoptic and Dynamic Meteorology (3/3)
7. Geological Oceanography (3/2+II)	8. Biological Oceanography (3/3+1)
9. Biology of Marine Mammals (32+2)	10. Marine Microbiology (4/3+3)
11. Topics in Tectonic Geology/sem (3)	12. Master's Thesis Research (S/U)
13.Dynamical Oceanography (3/3)	14. Aquatic Community Ecology (3/3)
15. Geophysical Models (1-4/II-VIII)	16. Geophysical Fluid Dynamics (I3/3)
17. Geophysical Fluid Dynamics (II3/3)	18. Waves (3/3)
19. Tides (2/2)	20. Chemical Distributions (3/3)
21. Physical Chemistry of Seawater (3/3)	22. Organic Geochemistry (3/3)
23. High-temperature Geochemistry (3/3)	24. Seminar in Marine Chemistry (1/1)
25. Geology of Continental Margins (3/3)	26. Subduction Zones (3/3)
27. Global Palaeoclimatology (3/2+sem1)	28. Petrology of the Oceanic Crust (3/3)
29. Deep-see Sediments and Processes (3/3)	30. Recent Sedimentary Environments I (3/3)
31. Recent Sedimentary Environments II (3/3)	32. Plankton Paleoecology (3/3)
33. Marine Stratigraphy (3/2+I)	34. Marine Geophysics (3/3)
35. Seminar in Plate Tectonics (3/sem3)	36. Palaeomagnetism and Geomagnetism (3/3)
37. Phytoplankton Taxonomy (3/1+IV)	38. Phytoplankton Physiology (3/3)
39. Phytoplankton Ecology (3/3)	40. Marine Bio-optics and Remote-sensing (3/3)
41. Zooplankton (3/1+IV)	42. Advanced Phytoplankton Seminar (1/sem2)
43. Productivity of Ocean Margins (3/3)	44. Marine Fish Ecology and Production (3/3)
45. Fish Population Dynamics (3/3)	46. Marine Zooplankton Ecology (3/3)
47. Marine Invertebrates and Environment (3/3)	48. Low-temperature Geochemistry and Isotope Geology (3/3)
49. Animal Communication (2/2)	50. Marine Pollution (3/3)
51. Coastal Marine Ecosystems (3/2+I)	52. Doctorial Dissertation Research (S/U)
53. Student's Seminar in Oceanography (S/U)	

Note: (1) The capital Roman numbers indicate the number of laboratory experiments per week; "sem" means in the seminar form; S/U means number of credits is determined each semester in consultation with the major professor or program committee.

(2) In China, some items in Table 3 are not counted as courses. They include individual study of assigned topics or special problem involving literature search, participating staff seminars and/or original investigation under one or more members of the staff.

(3) The arabic numerals in parenthesis indicate credit scores and number of lectures per week for the course.

In the Rhode Island University, the program requirement for the master degree is: thesis; the course No.53; participating in a regular ocean research cruise; the courses Nos.1 & 2 and any two of Nos. 13, 16, and 18.

For the doctorial degree, the requirement is: comprehensive examination; dissertation; the course No.53 as that of mater degree; participation in a regular ocean research cruise; six credits of any courses among Nos.13-52 (excluding problems and research courses and Courses Nos. 13&18); Courses Nos.1,2,13, and 18, and any six credits of the courses Nos.3-12 level outside of the physical oceanography discipline. A Ph.D. qualifying examination is required for all doctorial students. This requirement is satisfied by completing , with a grade of B or better, courses Nos.1,2,13 and 18.

RESULTS

The main differences between the curriculum devélopment and execution in China and America can be summarized in ten aspects:

(1) examination and the credit score systems;
(2) number of lectures;
(3) variety of selections of the courses;
(4) requirement of seminars;
(5) inter-disciplinarity of the courses;
(6) methodological courses;
(7) amount of experiment courses;
(8) requirement of investigation cruise;
(9) curriculum development processes; and
(10) amount of the courses of applied sciences.

Both Chinese and American systems have examination and credit score programs for the master degree level. The Chinese do not employ the credit score program for the doctorial level. This means that for Ph.D students there is not much compulsory requirement for course study. In addition, there is no specific grade requirement for candidating the academic degrees; they simply divided as " pass" or "fail" although the assessemnt of course examinations in China is still accounted in percentage. However, some famous universities, such as Chinese Science and Technology University, have started to consider the demand of certain grade level for applying the academic degrees in order to raise the standard of course study.

Generally speaking, a single Chinese course has more hours of lectures than that of the American. In other words, this "teacher-centred" phenoninon not only exists in the primary and secondary education (Jiang, 1996), it also exists in the higher education. Most of people believe that more lectures can have better rewarding of learning. Therefore, during the course study, good lecturers intend to explain the subject from every single concepts and facts to each step of reasoning, and very little time may be reserved for student discussion.

Relevent to this problem, an obviously missed course in the Chinese curricula is student's seminar which is a compulsary course for the American students. A new trial of a seminar course accross the subject areas in IOCAS shows some difficulties, although many students expressed eager anticipation for this activity. The dificulties are reflected by the behaviour of the students during the seminar. Some of them asked what was the significance of having a seminar; many of them felt extremely nervous when talking in public; and many of them do not have any idea about asking and answering a question properly. Few of them have the ability to carry out an academic discussion, and arrange an academic meeting.

In terms of the variety of the courses, the Chinese curriculum is much poorer than that of the America especially in the research institutes. It is extremely difficult for the research institues to have enough teaching staff and to have a series of teaching materials which are appropriat to the need of the students and the demand of the institute. Apart from having lessons by going to the central School of Post -graduate in Beijing for all students in IOCAS, another solution for this problem, which has being tested in IOCAS, is to offer the methodological and experimental courses. This might be an advantage of the institute system, because in China, universities normally have much fewer research projects and financial support than that for the research institutes.

Another problem of the Chinese curriculum is its narrow and isolated subject areas. The course of inter-disciplinarity (*i.e.* the courses crossing the four main areas: Physical Oceanography, Chemical Oceanography, Geological Oceanography and Biological Oceanography) are very rare (see Tables 1 and 2) compared with that of America (e.g. the courses of Nos. 4, 5, 14, 21, 22, 38, 39, 40, 43, 46, 47, 48 in Table 3). In the Chinese system, the compulsory courses did not include the courses in other subject areas until last year, *i.e.* 1996 when it was explicitly ordered by the State Education Committee that the objectives of doctorial level education should aim at a higher target which crosses the boundaries of the four main areas.

The courses on research methodology in Chinese curriculum can hardly be found (Tables 1 and 2). This is another general and traditional case of Chinese education. Many dissertations are full of data presentation and equipment explaination; few dissertations have a separated chapter for presenting the methods used and discussing the suitability and validity of the methodology.

The Chinese course structure lacks enough emphasis on direct experience of research such as experiments and investigation cruises. Some theses of former graduated students show nothing about field work, measurement and data of first hand.

In terms of the curriculum development, the Chinese system is rather conservative. Different from the primary and secondary education, for which the curriculum is decided by the State Committee of Education, the decision of course selection at the post-graduates education level is determined on staff's dominant subjects in universities or research institutes. Yet, most of the staff were graduates of the same university or the same institute, and in some subject areas, they were even from the same supervisor, which is a traditional Chinese style of research team construction for keeping good staff source at "home". Therefore, compared with many developed countries, the Chinese curriculum changed very little in the past twenty years. So the knowledge and the research methods in the content of a course are largely out-dated (Ding, 1997).

In recent years, the evaluation system for the post-graduate education has been established by the State Education Committee. However, the criteria of the assessment are largely concerned with the scale of enrolment, the time required to obtain the degrees for most of the students, the job-finding situation of the graduates, and the teachers' academic activities and achievements, *etc.* (Liang, 1991). But the curriculum development and re-construction is not considered.

Recently, Chinese market system of economy brings about some projects which need new knowledge structure and new method and techniques to deal with. Many research staff are busy in adapting themselves to the situation, so they hardly have enough time and sufficient knowledge and ideas to think about their students' course, even though they have intention to do so. Especially in the research institution, the main job of some students is busy in helping their supervisors to finish work, and many of them virtually have not had any formal course about their subject. Only the intelligent and diligent students may learn something new by self-study and working with their supervisors.

During past few years, there was a returning trend of Chinese students from the west. They brought back the newest information, knowledge, equipment, and most of all, new ideology of education. The curriculum needs to be put into the market system, so it should be revised as frequently as possible in order to fit the demand of the society.

There has been a significant change in the recent post-graduate eduaction of the America. The aim of the education becomes more practicable (Cheng, 1996). In terms of the curriculum construction, more courses of applied sciences are introduced to replace some pure sciences (in Table 3, courses Nos 41, 45 & 51 for example). Even many famous classical universities such as Berkeley, University of California, are also involved (Cheng, op.cit). However, from the three tables shown above, it can be observed that Chinese curriculum has not concerned with the issue of practicability yet.

The difference between the educational systems of research institutes and universities within China is also significant. There are a long-term of internal argument within the Chines educational system between the State Educational Committee and the Chinese Academy of Sciences. Due to the tradition that first post-graduates eduction organization is in the Chinese Academy of Sciences, Chinese research institutes have a special right of having their post-graduates and offering the diploma of Master and Ph.D degrees. In order to guarantee the quality of the education, it is compulsorily required that all "basic courses" (for the subject of oceanography, it can be understood as the courses outside of the subjects of marine sciences) for students of all research institutes in the Academy of Sciences must be fulfilled in the central Post-graduates School of the Chinese Academy of Sciences in Beijing where there is a special staff organization for teaching. However, this bring about a new problem: research and course learning are separated because the students in Beijing cannot join their supervisor's work for the whole year. Besides, the courses about their own subject, which are called "professional courses" are even more problematic, because they are not available in the central Post-graduates School.

Generally speaking, the students graduated from university system in China normally have a systematic structure of basic knowledge in their own subjects, but not good at doing experiments and having a poor research skills than those from research institutes.

DISCUSSION AND CONCLUSION

The differences between China and America are caused by complex factors. Here some of the reasons will be discussed and a few suggestions for improving the present situation are also provided.

First of all, the present graduate education has its root in the general Chinese edcuational tradition, and is closely connected with the primary and secondary edcation practice. One of the implication of the problem of the post-graduate education is the need for a general educational reform at all level. In fact, the educational reform in primary and secondary level is taking place, which aims to abandon the traditional style of "teaching for scores", and adopt a new style of "teaching for ability and personality" (Jiang, 1996). If at the stage of primary and secondary edcation, children have not had an experience of independent learning, being encouraged to produce creative ideas, being helped to be practical, it is hard for them to learn when they entering into universities,. It is not easy for Chinese Ph.D. students to broaden their own knowledge domain and to grow the ability for doing independent research. The problems revealed by the new trial on seminar in IOCAS has provided an example.

At the present, approaches to executing the objectives that doctorial level education should aim at a higher target of crossing the boundaries of the four main areas have being broadly discussed in conferences and educational journals. It is realized that the old situation cannot be improved substantially in a short time. Concerned with the present situation of the separation of teaching and learning, the separation of course study and research work, the separation of literature investigation and field work, along with the poor staff condition, an instant prescription for Chinese students to broaden their knowledge domain can only be "self-study" and "study through research" (Gao and Zhang, 1997).

In conclusion, Chinese curiculum development and course structure for gost-graduate education need further research and improvement, although the general education system has developed rapidly. One of the most serious issues is to construct a practical model for the education in resaerch institutes, which is differnet form that in universities. This is a special Chinese case, for in the America no research institute has the right to issue academic diploma. Further, both the institutes and universities should do research on the following aspects: the variety of the courses, the inter-disciplinarity of the courses, and the practicability of the courses. Both students and supervisors should open their mind to be more active in study and research. The addministration authorities need to modernize the regulations for course learning, research participation including experiment and field work, and thesis writing. It might be predictable that Chinese post-graduate edcaution can be much improved in the next ten years or so since a significant reform is taking place in the system of primary and secondary education.

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EDUCATION FOR MARITIME TRANSPORT MANAGEMENT

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ABSTRACT

This paper looks at the changing requirements of education for future managers of the maritime transport industry, as the industry becomes more specialised, more competitive, and more conscious of both its legal and moral responsibilities. Such responsibilities include the control of environmental pollution, the efficient and effective use of resources, and the safety of both employees and society in general. International and national legislation will be discussed, particularly with respect to the latest requirements for the recruitment and training of ship's crews (STCW '95) and to the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code). Emphasis will be given to the fact that, in developed countries, traditional sources of recruitment to the industry, such as persons with sea-going experience, are reducing in number as more non-flag-state crews are employed on board ships. The paper also outlines the educational curriculum which, it is felt, the modern industry requires.

INTRODUCTION

Until the 1960's the world's shipping industry was dominated by the Western nations, who previously had also either directly controlled, or had had considerable influence on, many of the world's ocean routes and coast lines. These nations were also the greatest producers of manufactured products and hence the greatest importers of raw materials. With respect to shipping itself, protectionism was rife, and the employment of such nations' ships was guaranteed for both export and import cargoes. In general, ships were owned, registered, operated and manned in a single country - in most cases trading from and to that country. "Flag" was important, and "flag" administrations kept things in order - at least within the jurisdictional area of that flag.

Maritime Transport Management

The majority of shipping companies tended to be long established. Many were still, quite literally, family businesses and others were the transportation areas of larger parent organisations such as British Petroleum, Shell, Mobil, etc. Shore-side management was in many respects distant from sea-going operational management.

In those areas of shore-management where knowledge and experience of sea-going aspects of the industry were desirable, such middle-management personnel would be selected from the Company's long-term sea staff. This maintained, within the shore-side offices, an up-to-date knowledge of the routes, hazards, meteorological conditions, ports, stevedores and cargoes with which the company would deal.

With respect to the Company's seafarers, the great majority of whom, particularly at Officer level, were Company Contract men, the arrangement gave an optimism, often misleading, of having their own colleagues within the management structure. Port authorities, national administrations, stevedoring companies and other industries within the maritime transport infrastructure would also recruit from their own pool of flag state seafarers.

Legislation

Until the 1960's, legislation tended to concentrate on the safety of life and property, starting with Samuel Plimsoll's Publication "Our Ships" (1873) concerning the dangers of unseaworthy merchant ships, and instrumental in the passing in the U.K. of the Merchant Shipping Act of 1876, requiring load-lines to be painted on ship's sides. Shipowners in the U.K. had already had an awakening to their liabilities in the 1846 Fatal Accidents Act. Particularly for those companies involved in the huge emigration trade, this had enormous implications. Although shipowners' liabilities were limited by the first Merchant Shipping Act of 1854, this applied to a lesser extent to death and personal injury claims, where potential liabilities could be much greater than the value of the ship itself. To protect themselves, shipowners created the first of the P & I (Protection and Indemnity) clubs. This was the "Shipowners Mutual Protecting Society", formed in 1855.

Environmental Protection

The environment, and those people, flora and fauna who lived on, near or in the marine environment were not so protected. There were a number of reasons for this. Firstly in the era of sailing ships, the environmental impact of ship losses were minimal. Secondly, when steamships were introduced - even when oil and chemical cargoes began transportation - the comparatively small size of both vessels and cargoes tended to limit the damage when ships were lost, or when waste was thoughtlessly pumped overside. The third reason, of course, was the lack of conscious thought or action by both seafarers and the public in general on the effects of damage to the environment by shipping. Much of the present consciousness is due to the expansion of communications media, people have now an awareness of the world's fragility which, even for most of their parents, let alone previous generations, would not have been possible. Notwithstanding all the foregoing, there did exist, for the most part at least, a sense of discipline, pride in the flag, commercial competition, fear of losing work - **something** which maintained reasonable standards in the industry until the late sixties.

Contemporary Changes

Many things had changed by the end of the sixties - not the least the practical end not only of colonialism, but of the captive markets which latterly were the real prize of empire, markets not only for manufactured goods but also the ships in which to carry those goods. In developed countries the old-style shipping companies were becoming marginal in terms of profits. Better investment opportunities offered themselves in other markets ranging from hotel ownership to commercial airlines.

Many companies sold their shipping interests to new owners, particularly new owners in those developing countries which previously had been the captive markets for the developed colonising nations. Amongst those who did not sell out, many opted to register, operate and crew their ships under "Flags of convenience" which offered benefits not only of reduced taxation, but also, more importantly, in crew manning scales and in crew qualifications. Many union difficulties could also be overcome by such a change in flag.

Developing countries themselves could operate their own shipping companies, with their own crews, trained in their own countries, at even lower costs, and this began what many concerned with the industry considered to be a downward spiral. In response, developed countries' shipowners hired ship management companies to manage their ships and they in turn hired manning agencies to recruit crews from various sources - and various countries.

The Present

The result? We now have ships which are owned by organisations in one country, but whose registered offices may be in a second, whose ships may be under a variety of flags, managed by organisations based somewhere different, and mostly manned by crews from at least two different countries, recruited by a manning agency, and using at least two different languages in their daily work.

The results of this are easy to check out simply from the increase of insurance premiums and excesses, U.K. P & I club claims, for example, increasing by a factor of more than three in the past two decades, but are also identifiable in terms of the content of the international conventions and Protocols since the '60s. Crew morale and standards also give a good indication of the present situation.

MARINE POLLUTION CONVENTIONS & PROTOCOLS

The "Torrey Canyon" disaster off the Scilly Isles, Southwest England, woke the world up to the fact that severe environmental and ecological damage could be suffered by a coastal state, but which, in 1967, could do little to recover its losses. Neither limitation of liability principles, nor P & I clubs could respond to risks of this magnitude.

Thus the International Convention on Civil Liability for Oil Pollution Damage (CLC 1969) met in that year, and was followed by two Protocols in 1976 and 1984. In 1969 also was the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, with a Protocol Relating to Intervention on the High Seas in Cases of Pollution by Substances other than Oil in 1973. In 1971 was the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, with its two Protocols of 1976 and 1984. Then in 1972 was the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.

In 1973 the Regulations for the Prevention of Pollution by Oil ("MARPOL") with its Protocols of 1978 and 1984. And in 1976 was the Convention on Limitation of Liability for Maritime Claims. Although it might be argued that the 1969 Liability Convention was simply redressing past omissions, that was not really the case. Things were getting worse! For example, the 1978 Protocol was triggered by the "AMOCO CADIZ" loss off Northern France, and this has been followed by an almost continuous series of ecological catastrophes. Management by catastrophe and subsequent financial penalty is not a good management model to follow.

NEW STANDARDS OF TRAINING?

By the late '70s, seafaring had the unenviable distinction of being second only to the construction industry in terms of occupational injuries and death. The greatest cause of alarm, in a worsening situation, was the huge disparity in abilities of those persons operating ships, i.e. the seafarers themselves.

In an attempt to rectify this by producing international standards which theoretically would create uniformity amongst the world's ocean-going fleet, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978 was adopted, coming into force in 1984.

The Convention failed for two reasons.

Firstly it specified training requirements only at "minimum knowledge" levels, and even then only in very broad terms.

More importantly, article V1 stated that :

"Certificates for masters, officers or ratings shall be issued to those candidates who, to the satisfaction of the Administration, meet the requirements for service, age, medical fitness, training, qualification and examinations ....".

The telling phase here is "to the satisfaction of the Administration", the "Administration" being "the Government of the Party whose flag the ship is entitled to fly".

Some Governments were far more easily satisfied than others, and the Convention made little, if any, difference to the operation of what have been described as the "Ships of Shame" trading around the world.

The New STCW Code

Three amendments have been made to the Convention, in 1991, 1994 and the latest, in 1995, termed the "STCW Code". This contains mandatory provisions in addition to recommended guidance for those parties responsible for implementing, applying or enforcing the Code.

Training and competence requirements of ships' crews are now much more specific, minimum standards of competence now being defined in terms of :

1 The competence required for a particular task
2 The knowledge, understanding and proficiency required for that level of competence
3 The methods used demonstrating the competence of a candidate
4 The criteria for evaluating that competence.

Administrations are now required to ensure that the training and assessment of their seafarers is properly structured, conducted, monitored, evaluated and supported by appropriately qualified instructors, supervisors and assessors.

Importantly, for administrations - and for shipowners - by August 1st 1998 each administration must communicate to the Secretary General of the International Maritime Organisation (IMO), "The steps which it has taken to give the Convention full and complete effect".

The required report is precise in terms of the information each administration must include. The steps which must be taken are rigorous in their coverage, including quality standards auditing by "competent persons". Those administrations which do not comply with the Code's requirements will not be blacklisted as such, but however will not figure in I.M.O.'s "white list" of approved administrations. Port state control officials should, in theory at least, deny entry into ports of those vessels whose crews are qualified by "non-white-list" administrations. To what extent this will happen, only time will tell, but the possibility is enough to make shipowners around the world more concerned with training and certification than they previously had been.

One disappointment, for those people who saw the Code's potential for rectifying competency problems in world shipping, is that the "competent persons" evaluating various administrations' education and training arrangements would not be an international team, but would, largely, be recruited from within the administration State itself - i.e. would probably, in some States, not be impartial.

Another concern is that approved seagoing service, a prerequisite for qualifications as Master, deck officer or engineer may be reduced substantially. The requirements for officers in charge of a navigational watch on ships of 500 gross tonnage or more are that the candidate "has approved seagoing service of not less than one year as part of an approved training programme which includes on-board training ....". Seagoing service for Chief Mate on ships of 3,000 gross tonnage or more is reduced from 18 months to 12 months. There is now an additional element of confusion in that both seagoing service for Chief Mate and Master appear to be combined, giving a total service for Master - of a ship of any size - as 36 months, but with a possibility of reducing this to 24 months. Many people are concerned that this is lamentably insufficient.

Shipowners Responsibilities

Shipowners' responsibilities for ensuring that their seagoing personnel are adequately trained have, until now, mainly been concerned with ensuring that they hold valid and appropriate

Certificates of Competency. If shipowners wish to employ, and retain, good personnel, they will be expected to expedite the qualifications route of such persons. In other words, they will be expected to provide the on-board training as required for "fast lane" officers.

Again, the STCW Code, in its guidance section, is quite specific about the Company's responsibilities, saying that, "The programme of on-board training should be managed and co-ordinated by the Company which manages the ship ...". Companies must also have "... a person nominated by the Company, referred to as the Company training officer, who should have an overall responsibility for the training programme and for co-ordination with colleges and training institutions".

This, as they say, is a whole new ball game for shipping companies, and one in which the ball is firmly in their court. If shipping companies were still as described in the first few lines of this paper, such training could be implemented, and, indeed, in the better companies was in place in the '60s. But, as we have seen, ships now may be owned by organisations in one country, with registered offices in another, whose ships may be under a variety of flags, managed by organisations based somewhere else, and mostly manned by crews from at least two different countries, recruited by a manning agency, using at least two different languages in their daily work.

Who - from all the above - is going to provide, implement, coordinate and monitor such on-board training? The logistics of such an exercise alone will be very involved, but companies which do not implement programmes will suffer the consequences. Companies need educating in the requirements of their new responsibilities.

THE ISM CODE

Although quality assurance and the ISO 9000 series codes have been around for a number of years, the majority of the world's shipowners have not implemented such systems. Ships themselves, like the crews which man them, very often only just meet minimum standards. Shippers and consignees of cargoes are usually unconcerned with either of the above, the prime consideration being solely whether or not consignments reach the place where they are supposed to go, in good condition, within an agreed time scale, and at competitive freight rates. Quality assurance amongst shipowners has therefore largely been concerned with meeting these four criteria.

Therefore the adoption of IMO's International Management Code for the Safe Operation of Ships and for Pollution Prevention (the International Safety Management (ISM) Code) in November of 1993 was something of a shock. Even more of a shock was its rapid implementation. The stated purpose of the Code is "to provide an international standard for the safe management and operation of ships and for pollution prevention". The Code also states that "the cornerstone of good safety management is commitment from the top. In matters of safety and pollution prevention it is the commitment, competence, attitudes and motivation of individuals at all levels that determines the end result".

Unlike the STCW Code, the ISM Code also specifies just who the "Company" is, stating, "Company means the owner of the ship or any other organisation or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the shipowner and who on assuming such responsibility has agreed to take over all the duties and responsibilities imposed by the Code."

Objectives of ISM

The objectives of the Code are broad reaching, ".... to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular the marine environment, and to property."

Safety-management objectives of the Company should inter alia :

"(1) Provide for the practices in ship operation and a safe working environment.
(2) Establish safeguards against all identifiable risks, and
(3) Continuously improve safety-management skills of personnel ashore and aboard ships including preparing for emergencies related both to safety and environmental protection.

The safety-management system should ensure :

(1) Compliance with mandatory rules and regulations; and
(2) That applicable codes, guidelines and standards recommended by the Organisation (IMO), Administration, Classification societies and maritime industry organisations are taken into account."

The Company must develop, implement and maintain a safety-management system (SMS), and establish a safety and environmental protection policy, links between the Company's ships and its shore offices being maintained by a designated person or persons in those offices. As with the STCW Code, the Company is given a direct responsibility for the training of ship-board personnel and for communications both on-board and from the ship to the Company.

With respect to the ship's themselves, the company must obtain a Document of Compliance (DOC) which is relevant to each ship. If the Company complies with the ISM Code requirements, then it will be issued such a DOC by the Administration, an organisation recognised by the Administration or by the Government of the country acting on behalf of the Administration in which the Company has chosen to conduct its business. Each ship should then be issued with a Safety Management Certificate (SMC) by the Administration or recognised organisation.

The ISM Code is unlike other quality assurance code such as the ISO 9000 series in that ISM compliance becomes compulsory for all shipping companies worldwide on 1 July 1998, by which time they should all hold valid Documents of Compliance (DOC) and each ship should hold a valid Safety Management Certificate (SMC). That time scale is some eleven months from now, and little more than 10% of the world's ships and shipping companies have thus far complied.

More so, it has been estimated that as high a proportion as 75% of the world fleet will not have obtained SMC by the implementation date. What would be - or at least should be - the results of that eventuality? In the spirit, if not the law, of the ISM Code, Port State Control officials should prevent such ships from operating within their waters - as for non-compliance with the STCW Code.

Will that happen? The answer to that hypothesis is yes, in that some States, particularly the developed countries, will enforce their rights, but that other countries will not. In a world where international trade is the maker and breaker of economies, and where economic power bases are in a rapid process of relocating from the centres of the '60s, safety and protection may still be forced to sit on the sidelines.

WHY MIGHT SHIPPING COMPANIES NOT COMPLY WITH INTERNATIONAL CONVENTIONS?

The facile answer to this is that some shipowners do not want to spend money, in a very competitive industry, on things which they see as non-profit productive. For many years, shipowners, when faced with such innovations, have complained: "It is we who bear the costs, but you who gain the benefits."

Some developing countries also complain that the Conventions we have discussed are simply ruses to make the developed countries' ships more preferable, and therefore more competitive. However, it can be argued that compliance with most of the required provisions requires more in the way of effort on the part of such companies than financial outlay, but that such effort requires company management which is educated to be conversant with the whole spectrum of the industry and the environment in which its business is conducted

New Managers

Of late, shipping management in newly established shipping companies appears to have been comprised of personnel with business acumen and skills, who see the potentials of the market, plus those people with sea-going experience who wish to relocate and pursue careers ashore - for a variety of reasons. The former might gain knowledge of the practical aspects of sea transportation by experience - some good, some bad! - as time goes on, and the latter, similarly, business skills. However, with respect to the latter, the pool of home-grown qualified and experienced sea-farers may well be drying up. Hong Kong is a prime example of this. No Class 1 Engineers have gained Certificates of Competency here for a least two years, and with respect to Class 1 Deck Officers (Master Mariners) less than a handful will gain their Hong Kong Certificates this year.

Hong Kong is going through the same set of circumstances as other developed countries, in that, firstly, few people want to go to sea when other attractive career opportunities are available ashore, and secondly, agreed Hong Kong rates of pay for seafarers are several orders of magnitude greater than those of foreigners. It is also argued that the traditional modes of entry into shipping management may now be less relevant to an industry which is becoming increasingly specialised. It is advocated that new entrants at the lower end of the management scale should enter the industry with a broad knowledge of all the aspects of that industry, such that rights, responsibilities and an overview of the marine environment and ecology are already inculcated in personnel before recruitment.

We identify the overall attributes which new entrants to the management of shipping companies should have as follows, on the basis that these will provide them with a wide knowledge of maritime transport within a general broad perspective of international transport and trade, and of the environment in which this takes place. We believe that, because of the commercial, technical, environmental, international and human factors involved, maritime transportation has requirement which are unique in industry. Modern technology and commercial practices demand that its personnel should also be unique, capable of functioning within management teams which collectively have the ability to perform these functions.

Function Attributes

(1) **International Seaborne Trade**
Understand the demand for, the distribution of, and the nature of, world trade.

(2) **International Maritime and Commercial Law and Conventions**
Understand the constraints of the legal framework of maritime commerce and transport and be able to operate within that framework.

(3) **Ship Operation**
Understand the external and internal influences that affect the safe and efficient operation of the ship, including all ships & port terminal systems, all ship types, functions and construction.

(4) **Ship Management**
Know how to conduct, delegate and monitor, the workings of the ship and its relationship with the shore.

(5) **Management of Cargo Operations**
Know how to access the sources of information, implement recommended procedures, and comprehend the legal and statutory requirements.

(6) **Seaport and Terminal Management and Intermodalism**
Understand the nautical, infrastructural and organizational characteristics of the port and its role as an interface between the ship and shore.

(7) **Management of Human Resources and Organization**
Relate the allocation of human resources to organizational strategy and monitor its implementation, in particular, that of the unique socio-technical ship unit.

(8) **Management of Financial Resources**
Understand the need for the proper provision of data; relate received data to the corporate plan; and monitor organizational progress against the plan.

(9) **Marine Insurance Practice**
Understand the concept of risk; the legal and commercial aspects of insurance, and the need for, and extent of, retained risk.

(10) Marketing and Chartering Practice
Understand market trends; analyse market conditions; and formulate marketing and chartering policy.

(11) Asset Management
Understand the role of marketing and operational influences in formulating policies on Lease, Purchase and Sale of ships.

(12) Maritime Safety and Pollution Prevention
Formulate organizational policy for ensuring the safety of life and protection of the environment.

(13) Shipping Strategy and Logistics
Define organizational strategies based on best assumptions to cover shortly term opportunities, and compatibility with long term goals.

(14) Maritime Research
Identify voids; direct research; critically interpret research data; and estimate validity of research conclusions.

I also have a personal belief that, in an ideal world, the education of personnel to be recruited into the shipping industry is best conducted in institutions which involve themselves in all aspects of marine education and research.

Many countries, both developed and developing, may argue that such institutions are luxuries they cannot afford, yet in all countries there are education, training, and research establishments which deal, usually independently and in separated locations, with commercial seafarer training, fisheries training, hydrographic surveying, offshore exploration and exploitation, meteorology, oceanography, aquaculture, marine biology, etc., etc.

Often there is, from a resource point of view, a wasteful duplication of facilities and expertise amongst the institutions, but, more importantly, a sad loss of transferred information, cross-fertilisation of ideas and innovations between these linked disciplines.

A higher progression rate of research in the field of resource development, environment issues, and the sustainable development of coastal water can be achieved, not only by symposiums such as this, but also, very often, by simple discussion with our peers in parallel marine disciplines.

National marine institutions are the best breeding grounds for integration. If we don't have such integration, sustainable development will remain an academic, rather than a practical, aim.

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UNDERGRADUATE RESEARCH AND GLOBAL ISSUES IN EAST ASIA

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ABSTRACT

This article suggests that universities throughout the United States and East Asia need to work more collaboratively to better educate their graduates on three levels: on research methodologies and practices in various fields, emphasizing interdisciplinary thinking and problem solving; on the achievement of a mutual understanding in part developed through a strong emphasis on student and faculty exchanges; and on the cultivation of an ability to identify and address significant global issues that are prominent in the Asia Pacific region. The discussion primarily centers on education in the United States, using a new campus of the University of Arizona to illustrate one route by which these levels might be reached. Within that general framework, an understanding of sustainable development (with a special focus on the centrality of water) is a key part of developing research skills for problem solving, interdisciplinary thinking, and intercultural understanding.

INTRODUCTION

In the United States many undergraduate students are poorly trained in three connected areas. First, they do not graduate with strong research skills. Second, they have a poor knowledge of the countries and peoples of East Asia, despite the fact that North America and Asia Pacific countries are inexorably linked, historically, culturally, and economically. Third, their lack of knowledge of East Asia is part of a larger gap in their education: American undergraduate students are inadequately prepared to evaluate critically problems that affect all people in the world and to understand why different nations may propose different solutions to the same problems. In other words, they do not embrace the global perspective necessary for them to be profound problem solvers in today's world.

As for the diverse nations of East Asia, undergraduate students are similarly ill-positioned, albeit perhaps for different reasons. Frequently unable or little inclined to travel outside their homelands, and often enrolled in technical or professionally-oriented programs, they are not well versed in the transnational issues affecting their lives and the nations' development. Many of them graduate with stereotypes about other peoples, sometimes the result of historical experiences and sometimes the result of an education that does not equip them to question these images. These students may have research skills, but they are often specific and one dimensional, based on a narrow curriculum that is exclusively disciplinary in focus. Finally, these nations' past dealings with imperialism and the contemporary problems of neocolonialism also may have fostered a strong nationalism that in part may mitigate against developing the global perspective necessary for meeting today's challenges.

While it might seem logical that U.S. universities and colleges could take the lead in initiating a trans-Pacific dialogue, they first must put their own houses in order. American colleges and universities have unresolved dichotomies: liberal/professional education; research/teaching; merit pay /equity; tenure/mutlti-year contract systems; community-focused/individual-centered; lecture format/interactive classrooms; practical training/intellectual and aesthetic leaning; global/national perspectives; and administrative/shared governance. (Astin 1993, Boyer 1987, and Byrne 1997) These dichotomies are becoming more potent and frequently dominate debates on education, especially in times of competition for limited resources. Millions of dollars are being channeled into attempts to settle the debates, as public and private funding organizations recognize that the nature of United States higher education hinges on the outcomes of these debates.

ARIZONA INTERNATIONAL CAMPUS OF THE UNIVERSITY OF ARIZONA AND UNDERGRADUATE EDUCATION FOR A GLOBAL PERSPECTIVE

Arizona International Campus (AIC), a new branch campus of the University of Arizona, was founded to address some of these controversies and to suggest at least one route by which these tensions can be resolved. Designed in part by renowned experts on education in the United States who drew upon the most significant research available, AIC is a quintessential undergraduate institution. While benefiting from being part of a highly acclaimed research university, AIC focuses its attention exclusively on the undergraduate student, the relationship between teacher and learner, and on individualized programs of study which emphasize development of a global perspective, acquisition of a high level of proficiency in a second language and culture, interdisciplinary thinking, and a strong emphasis on research methodologies geared to both aesthetics and practical application through problem solving. AIC seeks to meld the liberal arts and the world of work and to facilitate understanding of pressing global problems. In so doing it hopes to eliminate the dichotomy between liberal learning and professional goals and between teaching and learning and research. On this latter point, AIC faculty believe that undergraduates must be involved in research as a means to facilitate the demise of the tension. To enable students to satisfy, and in some cases cultivate, their taste for the arts, culture, and history, fulfill their professional aspirations, and become productive members of their society, AIC emphasizes that students must think comparatively and understand other cultures and histories in part through the study of problems that are global. AIC will also encourage students to understand that they have a fundamental responsibility to critically evaluate and work towards finding solutions to the world's most pressing problems.

AIC is not only focused on undergraduate education; it unabashedly promotes the liberal arts as important for developing the global perspective and interdisciplinary thinking so essential in today's world. It neither denigrates nor lionizes technical education or preparation for professional school. In fact **all** its students will graduate with good quantitative reasoning skills and strong abilities with information technology. Faculty do not see professional and liberal education as contradictory and they are convinced that if students are to be locally and globally productive, they must combine the practical and the aesthetic. It is not enough for them to appreciate the science of environmental degradation. Students must also know the role of political, cultural, and economic forces. For instance, damage to coastal water ecosystems through development is not simply an issue for science, as readers of these articles are readily aware. This fact, though, has been lost on most undergraduate students because they have little practical field experience with such issues. Environmental preservation, like hunting for deadly viruses, is not simply a matter for scientific inquiry. Both must involve an understanding that solutions are multi-faceted and multi-dimensional.

Structurally, AIC does not resemble the typical U.S. university. The basic academic units are not departments, schools, colleges, and divisions; but rather interdisciplinary academic houses with common core courses, the content of which varies according to distinctive themes that are local and global in intellect and practice. Through these themes, students will receive a BA in wide ranging bodies of inquiry: Humanities, Social Sciences, Natural Sciences and Mathematics, Second Languages and Cultures, Fine and Performing Arts, and Liberal Studies. It is significant that each of these themes, therefore, must be adaptable to these areas of inquiry and must be intellectually and practically sustainable over a very long period of time. Additionally, AIC will identify a very limited number of extraordinary issues to be introduced to all students in each house, regardless of a house's specific theme. This practice will enable all students to be articulate about specific, long-term issues affecting the development of humans and their contemporary condition.

The first academic house centers on the theme, "civic responsibility," and the second, currently being designed, focuses on "sustainable development." The latter is also one of those "extraordinary" issues in which the campus believes all students should be conversant. The selection of sustainable development as a key theme and as an issue for broad consideration signals AIC's commitment to reconciling many of the dichotomies nagging United States education. It is also a critically important global issue and provides the perfect entree for students to develop a global perspective and a familiarity with East Asia through key global debates. AIC has decided to initially focus its attention on Asia and Latin America and intends to educate students about history, culture, language, politics, and economics through practical issues.

SUSTAINABLE DEVELOPMENT, UNDERGRADUATE RESEARCH AND GLOBAL ISSUES IN EAST ASIA

The development of the curriculum for this program has been considerably facilitated by support from the Office of Sustainable Development and Intergovernmental Affairs, part of the United States Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). The Office provided seed money for founding AIC personnel and faculty to explore how to educate all faculty about sustainable development as an area of inquiry that fits the mission of the institution. The initial support also helped the campus introduce the concept of sustainable development into three of its required first year core courses. AIC is currently working on the design of a mechanism by which future faculty will derive the same educational tutelage about sustainable development. Strong emphasis during these training sessions is on the interdisciplinary nature of the field. While there is still a tendency to see sustainable development as a primarily scientific field of investigation, AIC eschews that idea, preferring a much more complex approach. Science, from biology to hydrology, will be very much a part of any undergraduate program, but AIC is committed to balancing this with the study of how development is strongly affected by history to economics, culture to psychology. A relatively new program at St. Francis Xavier University in Nova Scotia, Canada that focuses on aquatic (marine) resources takes this approach. AIC is carefully watching the progress of that program and is currently in the early stages of establishing a cooperative agreement for the exchange of faculty and students.

The second stage of NOAA's support is underway. During this stage AIC will establish the "Sustainable Development" Academic House. It is important to note that this thematic approach does not mean that students will be awarded a "major" or degree in sustainable development. What it means is that the theme in part will determine the content of the core courses which will emphasize an interdisciplinary approach to learning. The upper division curriculum will allow students to concentrate on sustainable development, while at the same time enabling them to obtain their BA degree in one of the five aforementioned areas.

Sustainable development as an area of intellectual inquiry is well suited for the mission of AIC. As one approach to many of the problems facing all nations, it is global in its application. It is interdisciplinary because the issues it addresses and the questions it raises can not be answered by any one discipline. As one prominent Chinese scholar recently told me, "sustainable development in China immediately raises the question of population, which in turn raises questions of history, culture, economics, gender studies, technology, and politics." Practically any issue that is investigated must be done from the confluence of disciplines. AIC will make water and sustainability one important area of inquiry, and it hard to think of an issue that can be more intriguing and raise more multidisciplinary questions. Along similar lines, sustainable development as a field of study also has the advantage of helping students from around the world recognize that what might be called the global "not in my backyard" attitude is counter productive to problem solving. Water purity and use, supply and depletion, regulation and free market, natural resource supply and species elimination are some of the transnational issues (to name only a few) raised by the study of sustainable development. As such it will help students understand that the issues taunt all nations, not simply "those over there."

Sustainable development also allows students to critically and empathetically understand other cultures and histories. To effectively do field work necessary for a practical understanding of sustainability as a global question, students have to become proficient in at least one other language. While I will not argue that any particular language or set of languages should be required, it seems wise that a student from the North would be best advised to learn a language of a nation in the South. I suspect that many educators in the United States would be overjoyed if students become proficient in any second language and culture. But for now, the emphasis of AIC will be on the languages of East Asia and Latin America.

Complementing the study of language and culture is the study of how other liberal arts disciplines facilitate understanding of global issues, and in particular those of sustainability. An increasing body of research is demonstrating how a cultural identity can be significantly altered by the decline of a natural resource or, conversely, how a cultural definition of development might self-destruct by destroying its supporting resources. (Nugent, Wellman, Lebovitz) These insights are replete with possibilities for study in the humanities, social sciences, and the fine and performing arts. The results of such investigations should temper the more "rational" disciplines, including scientific, technological and neo-classical definitions of development. This research, most prominently in the United States, often centers in part in focus groups and therefore has clear political implications derived from "stakeholders" decision-making. On a global scale this raises powerful questions, especially when linked with what many see as a clearly political agenda -- such as the recent International Monetary Fund's "conditional" offer to Argentina.

The Sustainable Development Academic House at will successfully advance AIC's mission by broadly defining sustainable development and at the same time identifying more specific avenues of inquiry. Graduates will be broadly trained, but they also must have the skills to allow for advanced study or employment in careers of their choice. In order to meet this duel responsibility, AIC, with the support of NOAA, will develop an undergraduate think tank for joint faculty/student research projects. The curriculum, expertise of the faculty, specifically designated issues, and AIC's current focus on Asian and Latin America will help determine where the research sites will be located. For now the sites will be located in Arizona, Mexico, Canada, Singapore and China, and we hope eventually in Japan. As the Campus grows we will expand the number of sites to include other nations in Asian and Latin America and specific nations in Africa. These sites and the think tank itself are essential if AIC is to graduate students versed in the complexity of sustainable development and with good field research skills.

CONCLUSION

The development of AIC's Sustainable Development Academic House and its think tank exemplify the kind of education that addresses many of the problems facing U.S. education, and it should serve as an example to other institutions in the United States and East Asia. The other academic houses at AIC will have similar components, requiring that students engage in interdisciplinary problem solving keyed to issues of significant intellectual depth and practical application. They will also stress the cultivation of a global perspective through the practical application of the liberal arts to complex issues around the world.

People in any country privileged enough to graduate from a university should develop a broader perspective on the world than those who could not or did receive an education. They might even be obligated to develop research skills tied to this broader perspective and therefore be able to contribute to local development and to influence events on a large scale. Pressing issues such as population may be at a critical stage for certain Asian countries (and not all readers would agree on this). Yet when combined with the increasing scarcity of precious resources like clean drinking water and the maldistribution and disproportionate use of what is left, it is clear that this one issue dramatically affects everyone. Students who graduate from today's universities should know how to make intellectual and practical connections between issues. Anything less is to risk business as usual, a dangerous proposition everyone and especially for coming generations.

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Interdisciplinary Teaching and Active Learning in Marine and Environmental Science

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ABSTRACT

As we approach the twenty-first century effective education in science and technology is more critical than ever before. Science graduates must be able to deal with complex and controversial issues, requiring the integration of knowledge and methods from technical and non-technical disciplines. All citizens must be science and technology literate, able to understand and appreciate the scientific process and its role in our society. Specific teaching methods can greatly improve the learning process in science courses. Active learning engages students more intensely, enhancing the learning process. By employing a range of different experiences and sensory modalities, a wider range of students can be reached. Interdisciplinary courses help students to see how science is relevant to other disciplines and to apply scientific skills and knowledge to a wider range of real situations. Both approaches have the potential to increase student learning, including content, skills, and attitudes. These techniques also have the potential to make science courses more fun and interesting for students, motivating them to stay involved and thus to learn more.

STATEMENT OF THE PROBLEM

In his last book Carl Sagan put his finger on the state of science literacy in the 1990's: We have come to a point where it is more and more necessary for members of our society to understand science and technology, and yet fewer and fewer do so (Sagan, 1995). Adults who have avoided science-related education and work now find that it is difficult to avoid. As consumers we must evaluate the importance of buying recycled products. As citizens, we must vote in elections where health care is a major issue. As workers we find that even in "non-technical" careers, every desk and checkout counter has a computer on it. Tags with bar codes are showing up on everything from library books to farm animals. Science literacy is critical to success in our modern world (Trefil and Hazen, 1991). In our universities and colleges, science education for non-majors is often described as "exposure". Sadly, this term is not only accurate, but hints at the same attitude that we take towards measles and chicken pox. It is no longer enough for a citizen to have been exposed to science. College graduates must be able to understand and evaluate science and technology-related issues.

Graduates in science and engineering are not immune from the challenges posed by an increasingly complex world. The United States has traditionally provided outstanding specialized education in the areas of science, mathematics, and technology. However work in these fields has become increasingly complex and interdisciplinary. Some of the most seminal discoveries of the future will be on the interfaces between individual disciplines, like molecular biology and artificial intelligence. Scientists and engineers must be more than experts in their own fields. These professionals must appreciate overlapping areas, and understand the impact of their work on society. If college and university graduates are going to be able to grapple with complex issues like environmental issues, population increases, and sustainable development, they must be more versatile and broadly educated than ever before. Now, as we approach the dawn of a new millennium, a different kind of science education is required. Educational institutions that want to prepare their graduates for success in the twenty-first century must ensure that all graduates are science-literate, and that science graduates are able to integrate their technical knowledge into the complexity of our rapidly changing world. This reality is expressed in the summary of the National Research Council-National Science Foundation Convocation on Undergraduate Education (1995, p. 17):

> "The needs of the work force are changing. Rapid shifts in the labor market are creating a paucity of jobs in some areas and exciting new opportunities in others. This dynamism in the labor market is putting a premium on students who have a broad knowledge of different subjects, skills in synthesizing and communicating information, and the ability to work in teams. Students educated with a narrow disciplinary focus and in solitary learning styles can have difficulties adjusting to such an environment. Indeed, such difficulties are a dominant theme in the complaints voiced by business leaders about contemporary undergraduate education."

The challenge of the twenty-first century is to develop science courses that fulfill three needs: to be engaging to students, to produce a genuine understanding of scientific principles, and to teach students integration across the sciences and beyond. These requirements apply both to courses for science majors and to those for non-majors.

NEW APPROACHES

I believe that the key to making science courses more effective, attractive, and relevant lies in two teaching strategies: Active Learning and Interdisciplinary Approaches. The use of active learning has the potential to increase knowledge gain, broaden the range of student skills, and reach a greater diversity of students. Employment of interdisciplinary approaches is the only way to create an environment where students learn skills from different disciplines and learn the skill of integrating knowledge. Both methods can make courses more interesting and relevant to students.

Active Learning

As more and more research results accumulate on the effectiveness of college teaching methods, one thing is clear: students gain more from active modes of learning than from passive activities like taking notes in lecture. In his book "What Matters in College?" (1993), Alexander

Astin urges: "active, self-directed learning by students; teaching and learning methods that support student-faculty interaction; learning communities and other collaborative learning models; active and 'hands-on' student participation; and the development and use of technological innovations that further those ends." One of the most critical outcomes of active learning methods is that they broaden the range of the things that are learned by students. When learning includes methods such as discussion, writing, presenting, or laboratory and field investigations, then students learn these skills in addition to the content matter of the course. This benefit goes beyond aptitude to also include attitude: Active learning has tremendous potential to excite students about the subject matter, about "doing science", and about learning in general. Ernest Boyer put it eloquently in his book: College: The undergraduate experience in America (Boyer, 1987, p. 159).

> "The undergraduate college at its best, is an institution committed to knowledge, backed by wisdom--a place where students, through creative teaching, are encouraged to become intellectually engaged. With this vision, the great teacher is challenged not only to transmit information but also to enrich and inspire students, who will go on learning long after college days are over."

Field and laboratory activities

One area where science students have traditionally engaged in active learning is through field and laboratory experiences. It is in these settings that students have the opportunity to learn by doing. They tend to learn the content matter better than in a classroom, they also learn the skills involved, and gain an insight into what it is to be a scientist. Working in teams and practical problem-solving are particularly valuable skills that are often not gained in the classroom. Many are the mature scientists who can trace the spark of excitement in their career back to an early experience with a field course or visit to a marine station. Personally one of my most striking memories from a field course in marine biology was that of seeing my professor have fun in his work--something that was not apparent to me in the classroom or on campus. Although laboratory exercises are a prime example of active learning, field experiences include the additional dimension of being in a natural setting, or perhaps even in a foreign country. This engenders another constellation of learning experiences and skills to be gained: appreciating the complexity and unpredictability of the natural world, operating in an unfamiliar setting, and learning to adapt to uncontrollable variables such as weather or the movements of animals. One of the outcomes that I have discovered with my students in the field and lab is a growing appreciation for how much work goes into elucidation of even the smallest scientific fact. Answering an extremely simple question like: "What is the area encompassed by the intertidal zone along a particular stretch of coastline?" or "How much difference is there between the weight of male and female animals of a particular species?" can prove to be a big job. Questions like this can be posed to a class of first-year students in a non-majors course. In finding the answer, students learn much about methods and data analysis. Perhaps most importantly, it begins to dawn on them how much scientific work is behind each of the statements and descriptions that they read by the hundreds in their textbooks.

Tied to this realization and to some extent motivating the process is the excitement of working in the field--seeing that along with the drudgery, analysis, and frustrations, scientific work can be fun and exciting. It is easy to see how all of these experiences benefit the development of a budding scientist. Less obvious is the realization that these are life skills. What professional could not benefit by having learned to be resourceful, to work with others, or to adapt to unexpected events?

Given that work in the field or laboratory is experiential and beneficial, there are ways to maximize the positive outcomes accrued from these exercises. Despite many common elements, field or lab exercises in courses are usually different from the pursuit of an actual research problem. Often the class exercises are set up such that the choice of student actions is limited, or there is an obvious correct set of steps to follow, or that the outcome is clearly predetermined. The difference is visible in the "culture shock" that many students express when they first begin doing research. Students who have had many field or lab courses are still often new to developing their own methods, or repeating a procedure again and again until it works. Sometimes it seems that students have gotten better at finding answers, but still are unsure of how to come up with the questions themselves. In response to this there is a new trend toward more genuinely investigative work in field and laboratory courses (Project Kaleidoscope, 1991; Tobias, 1992). This involves trying to create "research-like" experiences within courses. The idea is to move away from clear-cut field and lab exercises where the student's role is to follow explicit directions to reach a single correct conclusion. Instead, there are a number of ways to require students to be resourceful and creative or even to improvise. This can create an atmosphere of engagement and even mystery that comes with the possibility of multiple outcomes. A common approach is to incorporate one or more "projects" into the course. For instance, a class may include three-fourths of a term of regular exercises, followed by a project period in which students design and carry out their own investigations. The words "their own" are critical here, because the most significant thing that changes is a sense of ownership that comes with project-type involvement. Even if the only innovation is to let a class or each student team choose between two or more possible exercises, the stage has changed to one with more student ownership and the responsibility that comes with it. One component that is quite research-like is to give students an option to go back to a previous exercise and re-do it with improved design and execution in hopes of producing better results. This option, presented along with the choice of a more independent project, can allow a course to accommodate students or teams with a diversity of readiness for independent work. Other elements of the project option might be use of the methods learned in the class to answer a new question, investigation of an interesting result acquired during the semester's previous exercises, or a project requiring new methods which must be self-taught by the student team. One of the signficant lessons learned by this type of approach is that the conclusion of an investigation does not mark the end of the question. Instead, it usually raises new queries and sets the scientist off and running once again. All of these combinations help to produce a more realistic understanding of the role of investigative methods, that each method is a tool that a practicing scientist might use again and again. Students at all levels are capable of carrying out projects that, although simple, are genuinely investigative. The degree of challenge can be elevated with the level of the students and, importantly, the amount of experience that they have had with investigative work. In a program where many faculty and courses are utilizing investigative approaches, these exercises can be used to build up the student aptitude (and attitude) in a step-wise fashion. In an ideal program, a first-year course might include a taste of investigative work, with more in the second year and a totally project-based course in the third year. This could produce some students ready to apply their experience to a top-quality senior thesis their final year. Obviously independent research of the senior thesis or internship type is the capstone of "research-like" experiences for undergraduates. In these situations, students have the opportunity to work with a faculty member or other mentor to see the scientific approach in action, and participate in "real science" for a period of at least a term. Because of these kinds of opportunities, undergraduate colleges in the U.S. have become a bigger contributor of students to graduate programs in science than are larger universities. As Project Kaleidoscope wrote in their study: "What Works: Building Natural Science Communities"(1991): "Many anecdotes and some studies suggest that the greatest single influence that transforms a science student into a young scientist is an undergraduate research experience".

It is a mistake to think that laboratory and field exercises, particularly those involving investigative work are only appropriate or important to students planning majors or careers in science. First, the skills that students develop in active, investigative work are not only technical and specific, like how to use a plankton net or a GPS unit. Far more important is the training in problem-solving, usually coupled with teamwork. These talents are not only broadly applicable to academic and career success in a variety of areas. They also are talents that seem endangered by higher education's rush to mass-produce the undergraduate experience with larger courses, machine-scored exams, and distance-learning. Furthermore, if non-science graduates have experienced a "research-like" activity in college, and from it gained a little bit of the feel of what it is to "do science", we have made a significant contribution. These citizens will have a different appreciation for the process of scientific exploration that yields the many benefits to their lives. Furthermore, they will have a much more sophisticated view of the nature of scientific knowledge. The next time they read a finding in the newspaper, such as a link between a particular food and cancer, they will have a better appreciation for the significance of the scientific result, both in terms of the mountain of research work that supports it, and the complexity of the real world that adds some ambiguity to all of our acquired knowledge.

Classroom activities

Active learning can also be employed in the classroom. The traditional mode of classroom teaching in the sciences has been lecture-based, with an emphasis on the delivery of information to the students, whose job is to passively observe and record. There are a variety of ways to make the classroom more interactive. These include discussions, student presentations, simulations, or debates. These methods are most familiar in the seminar formats that are usually associated with graduate students or advanced undergraduates. In fact, these activities can be tremendously beneficial to students in lower-level courses, both to increase their learning and to prepare them for the afore-mentioned advanced courses. These methods and activities are clearly easiest to do with a very small group of students. However a number of authors have written about their experiences adapting them to lecture sections of a hundred or more students (see, for example McKeachie, 1980; Weaver, 1982).

A number of methods are combined under the name "cooperative learning". In this format, the class takes periodic short breaks from lecture to discuss a particular question in groups of four to six. These groups then rejoin and group leaders may report on the results of their discussions. Johnson and Johnson (1991) describe cooperative learning as including the following five fundamental components: positive interdependence, face-to-face promotive interaction, individual accountability, interpersonal and small group skills, and group processing. Heller, *et al.* (1992) compared problem solving skills of college physics students whose course had included work in cooperative groups and those who worked exclusively with individual problem solving. Not surprisingly, they found that solutions formed by groups were significantly better than those produced by the best students in the group. Furthermore, and more importantly, they found that the students in cooperative groups displayed more expert-like problem solving than those who had worked on problem-solving independently.

For many teachers, moving to a more interactive style is a philosophical change. This transition may be accompanied, or even driven, by a desire to expand the student outcomes beyond mere content to include a bigger impact on skills and attitudes. This often comes with an awareness of the rapidly increasing body of knowledge content considered critical. Once a teacher realizes that there is no way that they can "deliver" all of the critical content for their course, they often become more interested in building skills like managing information overload. The success of investigative exercises may seem like a paradox: If the professor does less for the students in the classroom, the students gain more from the experience.

Class assignments

Class assignments and exams are another learning experience that can be expanded by active learning. One method is to employ a diversity of media. Many professors prefer essay exams over multiple choice, because they challenge students to express themselves and create their own answers. Other assignments increase the diversity even more. Written essays and class presentations give students an opportunity to practice and develop their communication skills. These are crucial tools for graduates in all fields. Group projects create an environment where students learn and practice teamwork skills, again a necessity both in and out of the scientific world. Technology provides even more ways for students to develop and practice creativity and communications skills. A assignment to write a term paper might be expanded or changed to a videotape production, or the creation of a web page.

Thus active learning creates a different kind of educational environment, with a variety of benefits. Some of them have the potential to increase teaching effectiveness: when students play a more active role in a course, they become engaged in the process and thus more interested in and committed to the course. Another benefit is increased student accessibility. When a variety of teaching and evaluation methods are used, a more diverse group of students can be engaged. Perhaps most powerful of all is the increase in skills learned by the students. By their involvement in field methods, writing, speaking, group projects, etc.. they are not only learning the content of their discipline, but also important skills. Although repetitive, I cannot stress too strongly that these benefits are valuable both for students heading towards careers in science or technology and for those who have no intention of doing so. We as professors could certainly do worse than to produce a generation of college graduates who are markedly better at working on teams and solving real-world problems.

Interdisciplinary Approaches

One measure of the usefulness of a college education is how well it prepares a student for the world after graduation and off the campus. Active learning is useful because it employs many of the methods used in job settings in and out of science--few careers can be based on one's skill at taking notes and passing examinations. Similarly, few careers can be based solely on a single discipline. Many of the most exciting scientific breakthroughs in this century have occurred at the interfaces between disciplines. One example is the attack on pressing biological questions by scientists, knowledge, and methods from physics and chemistry, yielding the revolution in molecular biology. Major questions in environmental science are interdisciplinary by nature, dealing not only with the natural world, but how our human society interacts within it. The growing area of sustainable development expands this trend even further, considering economic, social, and environmental dynamics in order to chart a course for our species that doesn't jeopardize our success along any of these parameters (Reid, 1995).

Thus it is a fact of our world that important issues are complex and information is often ambiguous. It is understandable that we as teachers would like to shield our students from this complexity as long as possible, and that this strategy may hold up our short-term popularity with them. However if we want our graduates to be successful, and to have gained the skills and knowledge that will empower them to make a difference, we must prepare them to meet the challenge. Students must learn from a wide range of areas, and typically college education achieves this through general education requirements and electives. The missing part is the need for our graduates to integrate, to put together their learning from different disciplines and apply it to understanding relevant issues. The key is for all students to have a component of their education that is genuinely interdisciplinary. For a description of interdisciplinary teaching approaches with an extensive list of described programs, see Davis (1995).

Interdisciplinary education for non-science majors

Courses for non-majors provide an excellent opportunity for interdisciplinary learning. Because these courses are not typically required as pre-requisites for more advanced courses, there is more flexibility with the subject matter. Professors can select topics that illustrate the integration of different disciplines. Another factor in selection can be the identification of courses that match both significant contemporary issues and areas of student interest. For example, a course on "The Oceans" might combine a scientific knowledge of oceanography or marine biology with some of the literature of the sea (e.g. Melville's Moby Dick, Homer's Odyssey, or Coleridge's Rhyme of the Ancient Mariner). A course on "The Law of the Sea" might incorporate an understanding of international law and environmental issues such as pollution, whaling, or other fisheries. Ideally such courses would include subject matter from the component disciplines and also the associated methods. One bright spot is the appearance of textbooks written to accommodate interdisciplinary science courses (Hatton and Plouffe, 1993, 1997; Trefil and Hazen, 1995; and White, 1989).

Such courses are certainly different from the training that most of us have received. The challenge of offering them can lead to two solutions. One of them is that we educators take it on ourselves to become more broadly educated, learning from our colleagues and other sources. This makes us an excellent role model for what we would like our students to do: become broadly educated and continue through life as self-motivated learners. Another solution is team-teaching (Davis, 1995). By partnering with a colleague from another specialty to develop and/or teach a course, two different lives of experience, expertise, and approaches can be included in the students' learning experience. It is extremely valuable for students to see how professors from different fields might approach the same problem. How might a classicist vs. a marine chemist approach the question of what Homer meant by the "wine-dark sea"? Team teaching may also help students to see that for many questions there is no single "right answer." If they can observe their professors with different outlooks engaging in a civil discourse, this can result in tremendous learning.

The students are not the only ones who learn in this kind of endeavor. I have found team-teaching in interdisciplinary courses to be a tremendous education in the disciplines of my colleagues, and in different teaching methods as well. It is certainly a powerful message for students to see their professors working together with diverse colleagues, or demonstrating an openness to new ideas.

Interdisciplinary education for science majors

The need for interdisciplinary education by future scientists in certainly as critical as it is for non-science majors. If we expect our science and technology graduates to solve the problems of our society, they must have an understanding of how scientific knowledge and discovery is shaped by its context in society, and how society is or can be affected by the process and results of science. However interdisciplinary teaching for science majors is not common. Partly this is due to the many content and course requirements in the discipline, and partly to the prevailing emphasis on specialization. It is certainly true that one must specialize to reach an advanced level in science and become a researcher. However many of the greatest breakthroughs have been made by individuals who have broken into new areas, employing both the expertise of specialization, and also the perspective that comes from breadth. Thus it is critical that we give our science majors opportunities to learn to integrate and learn the role of their field in our society.

CONCLUSIONS

As researchers the very core of our existence has been to push the limits of our fields, to explore the unknown and take our knowledge into new areas. If we are going to be effective in educating students for the world of the twenty-first century, then it is necessary for us to exercise this same spirit of innovation in our teaching. One challenge is that active learning and interdisciplinary teaching may be different from the way that we were educated, and different from the *status quo* in our departments and institutions. Another major barrier is the prominence and spread of an institutional (and cultural?) mentality where faculty rewards depend much more on the experimentation and innovation that yield research productivity, and far less on innovation or experimentation in education. Thus the transition to a higher level of excellence in undergraduate science education requires new paradigms at both faculty and administrative levels.

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THE ROLE OF ASSESSMENT IN THE TEACHING AND LEARNING OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

The concepts of sustainable development are complex, involving interdisciplinary thinking and a global perspective. Assessment can serve an important role in ensuring that students and faculty are learning these concepts. A well-planned, ongoing assessment program provides (1) initial baseline measures, (2) feedback on faculty training, involvement, and teaching, (3) documentation of the learning/teaching process, (4) valuable feedback that can help shape the educational program, and ultimately (5) a measure of student learning outcomes. Initially, assessment also serves as an introduction to sustainable development terminology, language, and way of approaching issues. Assessment activities used at Arizona International Campus have included surveys, focus groups, and portfolios.

INTRODUCTION

Assessment plays an important role in implementing any academic change, whether the change involves use of technology or instituting a new subject matter into a college curriculum. Any major curriculum change, particularly with a subject matter that is somewhat complex, global in nature, and interdisciplinary, such as sustainable development, requires a comprehensive assessment strategy as well as a willingness by the faculty and administration to make necessary adjustments and to use assessment feedback for future planning.

At Arizona International Campus (AIC) sustainable development is being introduced into the curriculum at every level during its first year of operation. (In the following years, a "house" specifically dedicated to sustainable development will be established. This house will target those students who want to pursue careers related to sustainable development.) With its focus on global issues and service learning, AIC is committed to having *all* of its students learn about sustainable development --- not just those who wish to work specifically in that area. Therefore, all students will be exposed to at least some sustainable development concepts and methods regardless of their area of study. Similarly, all faculty, regardless of their major subject area, must be willing and able to incorporate some sustainable development components into their classroom teaching and all students will thereby receive instruction in this area throughout their college career.

Because of this comprehensive approach to incorporating sustainable development into the curriculum, the assessment plan must encompass learning across the entire campus as opposed to limiting itself to grades in specific courses. In addition, training, involvement, and teaching by faculty must also be a major focus of the assessment process. Timely feedback can help in guiding decisions for long-range planning as well as in correcting problems as quickly as possible.

This paper will describe the current assessment plan, which will undoubtedly be expanded and/or modified as AIC progresses in its curriculum implementation. The paper will also review the specific results that have been obtained during the initial phase of curriculum planning and development.

Assessment Plan

The assessment plan for AIC was designed to provide (1) initial baseline measures, (2) feedback on faculty training, involvement, and teaching, (3) documentation of the learning and teaching process, (4) feedback to help shape the educational program, and ultimately (5) a measure of student learning outcomes. Various methods have been designed to facilitate assessment. These methods include surveys, quizzes and exams, use of focus groups, and portfolios. The following sub-sections provide an overview of each of the above-mentioned assessment goals. The next section (Methods) describes work and results achieved so far in this program.

Baseline

The first phase of assessment is to establish a baseline for both students and faculty. At this time, both attitudes and basic knowledge are measured. This baseline assessment serves to establish a starting point, provide feedback, and to help draw attention to relevant issues --- people filling out the surveys are exposed to issues and concepts that are often new to them.

Assessing Faculty

All faculty training (e.g., workshops) is being evaluated through the use of pre- and post-quizzes on knowledge of the subject matter. Evaluations of the workshops by attendees is also being collected.

Faculty involvement is currently being measured by attendance and participation at sustainable development conferences, publications, and other relevant faculty output. Teaching of sustainable development will be judged by a review of faculty portfolios, which include syllabi, reading lists, and other materials used in their courses. In the future, efforts will be expanded to include peer review.

Learning and Teaching Process

An important component of this process is the dissemination of information --- in other words, what works and what does not in the learning and teaching of sustainable development. Over the coming year faculty will begin to present some of their experiences with teaching sustainable development material both in and out of the classroom during weekly faculty meetings. In addition, next spring a sustainable development conference will be given at AIC highlighting student projects that have been completed during that semester. The presentation will reflect the application of the learning that has taken place).

Feedback

Results obtained from the baseline measures have been presented to the relevant parties for use in future planning. For example, student feedback provides insights into the global experiences each student had had as well as their knowledge and attitudes about sustainable development issues. Faculty can use this information to adjust their teaching so that material will be at the appropriate level.

Similarly, results of the faculty baseline measures provide feedback to those planning the sustainable development workshops for the faculty during the coming year. Additionally, post-workshop surveys provide feedback so that future workshops can avoid similar pitfalls and problematic issues can be addressed.

Learning Outcomes

AIC is committed to providing a value-added education to its students. This means that students who graduate will have greater skills and competencies as well as knowledge in various substantive academic areas than they had when they were first admitted. Although it seems that this is an obvious goal of any educational endeavor --- it is not necessarily an easy one to achieve and certainly not to document. The approach taken by AIC is to measure students on targeted outcomes (e.g., communication skills, quantitative and analytical reasoning skills, technologically competent) when they first arrive at the university and then again at various time points during their college career (i.e., after completing their core curriculum, before they graduate).

The approach taken for sustainable development learning mirrors that of the other outcomes targeted at AIC. Part of the baseline data obtained on students is knowledge on basic sustainable development issues. It is expected that students' scores on this quiz will improve as they move through their academic program. Additionally, students will have to demonstrate competency in this area when they complete and present their capstone experience, which is required before they can graduate from AIC.

Methods

This section will describe the work that has been completed so far including any results obtained. In addition, work in progress will be discussed.

Faculty

Prior to any of the sustainable development workshops being given, a survey targeting attitudes and basic knowledge of sustainable development was administered to each faculty member. Items for this survey were modified from existing surveys. The survey contained five five-point likert-scaled items relating to general attitude about sustainable development (e.g., "I am interested in learning about sustainable development," "Students will benefit from learning about sustainable development") and five sections asking questions (e.g., "To what extent is each problem solvable?") about each of ten specific areas such as basic human rights, population growth, inflation, and environmental pollution. Each of the items in the sections were also five-point likert-scale ones. The knowledge items were adapted from a survey developed for the World Commission on Environment and Development (1987).

Results of this survey indicate that, in general, faculty are favorable about the topic of sustainable development. However, faculty appear to be more interested in learning about it for themselves than they are in using it to teach students (x = 1.43; x = 1.86).

Table 1 below shows that faculty are unanimous in choosing "basic human rights" as the most important issue at this point in time. "Inflation" was the issue rated least important, possibly because the faculty understand and are interested in this topic the least.

Table 1: Importance of various issues

How much do you know about each of these issues?	*Mean score (1=know a lot -- 5=know very little)*
Basic Human Rights	1.00
Unemployment	1.14
Intergroup Conflict	1.14
Depletion of Natural Resources	1.14
Environmental Pollution	1.14
Population Growth	1.57
Inflation	2.57
Poverty	1.29
Malnutrition and Inadequate Health Care	1.29
Regional and International Conflict or War	1.43

Results on the knowledge part of the assessment reveal that faculty know quite a bit of the background level information on sustainable development. This is not surprising given the level of this exam, which is at the high school level. Overall, the average number of correct items (out of a possible 16) is 14.1. The scores range from 13 to 15 correct.

Prior to each of the three workshops given, a short quiz covering the upcoming workshop topic, was given to each faculty member. The quiz was created from materials sent to AIC prior to the workshop by the workshop presenter. After the quizzes are returned, readings are then distributed to all faculty. The quizzes serve to measure specific knowledge prior to the workshop and also to (hopefully) interest faculty in finding out the answers.

Results of these quizzes reveal that the faculty did not know very much about the topics to be highlighted in the workshops ahead of time. Scores ranged from 2 to 8 correct (out of a possible 10 items) and the average was 5.25.

Students

Methods

The Global Survey was developed to measure students' experience and attitudes about global issues and to obtain baseline information on their knowledge about sustainable development concepts (sixteen multiple-choice items). Some parts of the survey mirrored those on the survey given to faculty. The survey was distributed to students during a required first semester course.

Results

Only 24% of all students report watching local or world news (on television) on a regular schedule (at least five times a week) although only 12% report watching it less than once a week. Even lower percentages were reported for reading the newspaper (17% reported at least five days a week; 38% reported once a week or less).

When asked what their main source of information was concerning current events, the largest category was television (59%), with newspapers (29%) and school (27%) following next. Most students (88%) report talking about current events at least one to two times a week to either friends or family members.

Ninety two percent of all students reported visiting other countries, although for most, these visits were vacations as opposed to extended stays.

When asked whether they knew what sustainable development meant, 65% of the students report that they did not. Of those who did claim to know what the term meant, 88% (n=15) provided their definition. Table 2 below displays the types of responses provided by the students.

Table 2: Student definitions of sustainable development

Definitions of Sustainable Development	***N***
Maintain resources without depleting them	4
Preserve the environment while being able to grow and develop	4
Constant change or improvement	2
Ability to sustain a certain amount of people and animals in one location	2
Business and environment work together to better both	1
A country that is developing	1
Work to sustain a society	1

Students were also asked to describe the difference between having a global and an international perspective. Eighty percent of the students provided an explanation of this difference. Table 3 below shows that most students believed that having a global perspective is a more broad one ---

one that includes all countries, as opposed to an international perspective, which is usually referring to separate individual countries.

Table 3: Students' explanations on differences between global and international perspectives

Difference between having a global and an international perspective	*N*
Global is more broad and includes all countries; international is more political and narrow and involves only a few countries	27
Global deals with the environment; international deals with people	8
There is no difference	3
Seeing the entire (global) versus a part (international) of the picture	1

For the knowledge part of the survey, students, on average, checked the correct answer about half of the time (X=8.3 (out of a possible 16); s.d.=3.9). The range of correct responses is from 1 to 14 correct, indicating a great deal of variability in students' background and understanding of sustainable development.

CONCLUSIONS

So far, AIC's assessment plan has provided useful feedback to planners as they continue to develop the curriculum and create new developmental opportunities for faculty. In order to maintain interest and involvement of all faculty in the teaching of sustainable development concepts, regardless of their own substantive academic interests, it is important that AIC begin to tie student learning to the faculty reward system. This process has already been initiated for all student learning at AIC and will continue to be implemented throughout the coming year. During this time learning about sustainable development will also be incorporated into this process.

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Engaging Students in Watershed Study of Coastal Regions: Serving Science and Community

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ABSTRACT

Coastal regions are of great importance to many countries' environmental and economic health. They also provide opportunities to involve students in planning for sustainable development, while learning technical scientific and social scientific methods of investigation. A multi-disciplinary course is described in which students develop indicators of community sustainability, gather data, and present results to community leaders in order to contribute to coastal area management.

I. IMPORTANCE OF COASTAL AREA MANAGEMENT

Coastal areas are vital to the lives and livelihoods of more than half the world's people. There are 217 sovereign and semi-sovereign nations in the world with coastal regions, about half of which have scientifically-based efforts underway to protect and manage their coastal areas, according to U.S. AID. Encompassing a diverse array of resource and human activity, coastal areas provide tremendous biodiversity and productive environments that attract human settlement and economic activity. Unfortunately, the impacts of human activities can be degrading and destructive of the very resources on which they depend. The preservation and protection of these valuable and beautiful areas has become a high priority in international discussions.

Agenda 21 includes a special section (chapter 17) that discusses the protection of oceans and coastal resources. Such protection must take into account the needs and future well-being of the people who depend on these resources for their livelihood, as well as those who wish to enjoy the natural environment of coastal regions. Sustainable coastal management will involve an understanding of social, cultural, environmental and economic issues and values. Chapter 17 of Agenda 21 urges development of scientific and technological know-how, human resource development, data collection and information management, and local and international collaboration.

Successful programs to manage coastal area resources will include some common features, adapted to individual locales. They include:

- clear, broad-based objectives from which can be derived specific policies
- local decision-making through a process of stakeholder involvement
- scientifically-based data and information that is maintained and updated
- public education to create trust in the process
- adaptive management that responds to changed conditions and needs

II. ENVIRONMENTAL METHODS OF INVESTIGATION

Teaching students to approach the broad and complex issues presented in coastal area management can take many forms. They need to be competent in basic scientific method and data gathering and analysis; have a clear understanding of the social and economic implications and the policy options; and be able to communicate ideas to diverse audiences. They also require some knowledge of technological possibilities and outcomes. As generalists, college graduates will be called upon more to understand the issues, assist and advise decision-makers, and communicate information from and to the public. Some will eventually be trained in more specialized environmental fields.

The course we teach in environmental methods of investigation prepares college students for the generalist roles described above. It also serves as an introduction to technical fields for students who will do graduate study in environmental management. The course has evolved over the past five years to include the following features:

- multi-disciplinary
- teaches technical methods of data collection and analysis
- group learning and team-work
- requires students to synthesize information and develop policy recommendations
- includes public presentation of findings
- involves hands-on learning
- contributes in a real way to coastal area management

The course is designed for advanced students in our environmental studies program. They are expected to take the course after completing a series of discipline-based courses which develop awareness, knowledge, and skills applied to environmental problems. The students in this course are challenged to develop an inter-disciplinary understanding and ability to deal with environmental problems in all their complexity. Educational research has shown that students learn:

10% of what they read
20% of what they hear
30% of what they see
50% of what they see and hear
70% of what they say
90% of what they say when they are doing something

Thus, our goal in this course is to have students progress to the highest level of cognitive abilities in peforming their work for this course. In the culminating presentation and project, they will deliver their conclusions and recommendations regarding the local watershed to the community decision-makers.

The course is taught by a team of faculty who are experts in environmental issues. They each introduce the students to specific environmental research methods in their fields. The course content includes development of information and analysis in the following areas:

- chemistry: water quality, soil quality, toxicity and risk assessment
- geology: watershed mapping, topography, soils, hydrology
- biology: biodiversity, ecological impacts
- political science: governmental units and jurisdictions, planning procedures
- economics: population distribution and growth, economic activity, infrastructure needs and financing, community values and social structure

In each of these areas, students begin by doing background research about the selected watershed in teams. In their initial research, they prepare information about the trends, influences, and patterns of social/environmental/political/economic factors in the watershed based on available primary and secondary documents and interviews. They present this research in background papers and develop conclusions about how these factors are related and what are the dominant influences and issues in the watershed.

In the next stage, students gather new data about the environmental, political, social, and economic features of the watershed. They perform on-site field work and conduct interviews to gather data. The students analyze these data in teams and present their conclusions about current and prospective conditions facing the watershed, particularly as they relate to one another and the major issues identified in their earlier work.

The students are ready to develop recommendations and prepare their work for public presentation.

III. USE OF INDICATORS FOR STUDENT LEARNING AND COMMUNITY POLICY-MAKING

Indicators are being used more frequently in international, national, and local fora for a variety of purposes. They are used to communicate information, to monitor conditions, and to assist in policy development. When indicators are regularly updated, they can tell a community where it has been and where it is going. Indicators are useful for community decision-making regarding environmental issues because they are flexible, can be relatively inexpensive, and can present complex issues in a simple format. While subject to abuse for the same reasons, indicators are now a widely-accepted and understood tool of local and international policy-makers.

For similar reasons, indicators present a good opportunity in educational settings to present and convey information, and facilitate understanding of complex issues. By developing indicators to present their findings, students are afforded the opportunity for hands-on work which allows them to better understand difficulties of data collection and analysis and gives them insight into a range of real-life issues. In so doing, students can use indicators as a means of understanding community values and goals. Therefore, the course requires students to move beyond the standard data collection and analysis steps to use, communicate, and develop recommendations based on their findings.

The students develop their indicator study of the watershed in several steps:

Priority areas of analysis are defined based on the values and objectives identified by the community. The information needed for this step can be obtained from published documents in the community, interviews with community leaders, or ideally, through a scientifically-based process of community value elicitation.

A limited set of indicators is selected based on data availability, significance, clarity, and credibility. Ideally, selected indicators should fit certain criteria. They should be:

- credible
- available in a cheap and timely fashion
- easily interpreted
- significant
- unambiguous

The data needed to represent the selected indicators are obtained for a common time period, and if desired, are formed into a common index. This gives students an opportunity to practice quantitative skills and consider the difficulties of presenting complex information in a form that can be widely understood and communicated.

In developing indicators with the data they collect, students must surmount some of the typical difficulties faced by scientists and researchers. They must figure out how to find and retrieve the data needed for the indicators selected (in the fields described above), reconcile conflicting data and information, analyze data at the appropriate level of detail, and eliminate redundancy. Each of these obstacles is easily overlooked when students are allowed to simply accept published and second-hand data at face value.

If desired, once they are put in a common form, the selected set of indicators can be aggregated into a single index, with or without weighting. These aggregated indexes are commonly portrayed as Community Quality of Life indexes, or Environmental Scorecard indexes, etc. Should they decide to aggregate the indicators they select, the students will again face the important issue of portraying complex information appropriately.

As a final step in the preparation of their work, students develop policy recommendations for the community that reflect the information derived from the indexes, as well as the community values and objectives identified at the outset. Students may consider a wide array of policy proposals in this step, but those that survive must face the scrutiny of the community leaders affected. Students are also called upon to consider the real-world aspects of political feasibility, cost, distributional impacts, and environmental outcomes in their policy recommendations.

The indicator study and resulting recommendations are presented to community leaders and citizens in a public forum as the final step in the study. Students use the indicators to explain the important factors affectng the health of the watershed, and defend and explain their recommendations based on their research and knowledge of the data.

IV. WHAT THE COURSE DOES AND DOESN'T DO

The Environmental Methods of Investigation course described above accomplishes several important objectives of environmental education:

1. Allows students hand-on, integrative, multi-disciplinary learning using real-world conditions with both fieldwork and quantitative analysis
2. Can include a high level of public, stakeholder involvement
3. Presents the community with a meaningful, usable product
4. Can be used sequentially as an evolving, adaptive management tool

The course does not include every necessary aspect of environmental education that is needed by the future decision-makers in coastal regions of the world. It does not:

1. Allow for in-depth technical research in a specific field
2. Include implementation activities (restoration, etc.)
3. Create a thorough understanding of local values and objectives
4. Resolve conflicts among competing resource users and interests

V. APPLICATION TO PACIFIC RIM COASTAL WATERSHEDS

Pacific Rim countries have many examples of innovative and successful coastal management programs. Some involve university-based training and education. Examples are at Silliman University in the Philippines and Prince of Songkla University in Thailand. Other coastal management programs are operated by NGOs and major international organizations in Asia, including COREMAP, a program financed by the Asian Development Bank and the World Bank in Indonesia which aims to protect coral reefs in Bunaken and other national parks.

These and other efforts could benefit from students trained at the university level to understand the inter-related nature of watershed management issues, and effective means of communicating information to decision-makers and to the public. While the course described in this paper was developed at an American university, it may be useful and adaptable to Pacific Rim educators. A few examples of possible applications are suggested.

Coastal areas in Thailand are faced with growing pressures that threaten the ecosystem health of sensitive marine treasures, as well as the livelihood of coastal zone populations. Around Phuket Island, for instance, issues include fast growing tourism and economic development, declining fishery catches, siltation from tin mines and construction activity in-land, and nutrient discharges from agriculture. Specific needs have been identified by government and NGOs as mangrove protection, greater water quality awareness, increased land use management, and reduced tourism pressure on sensitive areas.

Students could develop background information on these pressures and influences, select priority indicators for monitoring and policy development, and provide such information on a frequent basis to the public and officials on Phuket Island and in other coastal areas of Thailand. Among the indicators that would be useful are numbers of tourists, fish catch per level of effort, water quality measures, water flow, and acreage in protected status. Data for each of these indicators is relatively simple for students to develop and collect, yet such an effort could also provide the community with powerful monitors of priority local conditions.

International efforts to protect marine regions of Bunaken National Park in Indonesia have been on-going. Among the issues identified as high priority are endangered species, including the dugong, and the economic viability of artisanal peoples. The protection of biodiversity in the Park and issues surrounding resource use are critical needs. Students could develop such indicators as species counts, land use diversity, and tourist or other human impacts as monitors for environmental conditions. Some of these indicators might then suggest important policy changes to be made in the Park or by the national government.

This paper does not imply that environmental management of coastal areas is a simple matter for students to resolve. The success of the course described in this paper is based on the simple goal of allowing students to use their hands-on experience to develop a broad understanding of complex issues within a community setting. This awareness, combined with a simple set of technical skills and applied experience, can be a first step in effectively responding to the critical issues facing coastal areas in the world today.

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The Regional Sustainable Development and Resource Exploitation in the Changjiang Estuary
— Several large-scale engineering projects to be studied

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Abstract

Changjiang is the largest river in China, and it ranks the third in the world. There are rich natural resources in the Changjiang estuary. Shanghai, the largest city in China, is making a great progress to become one of the international centres of economy, finance and trade. However, the Changjiang delta sometimes is attacked by flood and storm. For the regional sustainable development, it is necessary to bring the advantage of natural resources in the Changjiang Estuary into full play, and to make counter-measures against the natural hazards.

Key Words: Changjiang Estuary, Shanghai, Sustainable Development, Changjiang Delta, Reclamation, Estuarine Reservoir, Deep Harbour, Sluice

The Changjiang River originates in the Qinghai-Tibet Plateau, passes through Sichuan Basin and its mid-lower reach plain, and finally empties into its estuary. Down from Xuliujing is the estuarine region of Changjiang River. It goes into the sea through four water ways by branching three times due to some islands and shoals. From Xuliujing to the mouth, the section of the river has a length of about 150 km with a width of 90 km at the mouth. There are three islands in this area, named: Chongming, Changxing, Hengsha. Besides, there are many submerged shoals and flats scattering in the river channel and on the river mouth bar.

The Changjiang River supplies a great amount of river runoff, sediment and dissolved matters, nutrient salt into the sea, providing beneficial conditions to the Changjiang Estuary to have rich natural resources. The major resources are: land resource, fresh water resource, aquatic resource, water transport resource, and so on.

Shanghai locates closely to the Changjiang Estuary. In order to open the cities along the Changjiang River further, give impetus to the economy in the Changjiang Delta, and have a new economical jump in the Changjiang catchment basin, Shanghai has the historic task to be the dragon head and to be built into one of the international economical, financial and trading centres as soon as possible. So it is necessary to bring the potential energy of Shanghai into full play. Shanghai faces the strict challenge and should coordinate the relationship between resource exploitation and sustainable development of the regional economy.

In order to realize the tasks mentioned above, Shanghai should study systematically the relationship between sustainable development of the regional economy, the exploitation of natural resources and the ecosystem, and should draw out an integral developing plans as soon as possible. For this sake, the authors proposed the following issues to the integral plan:

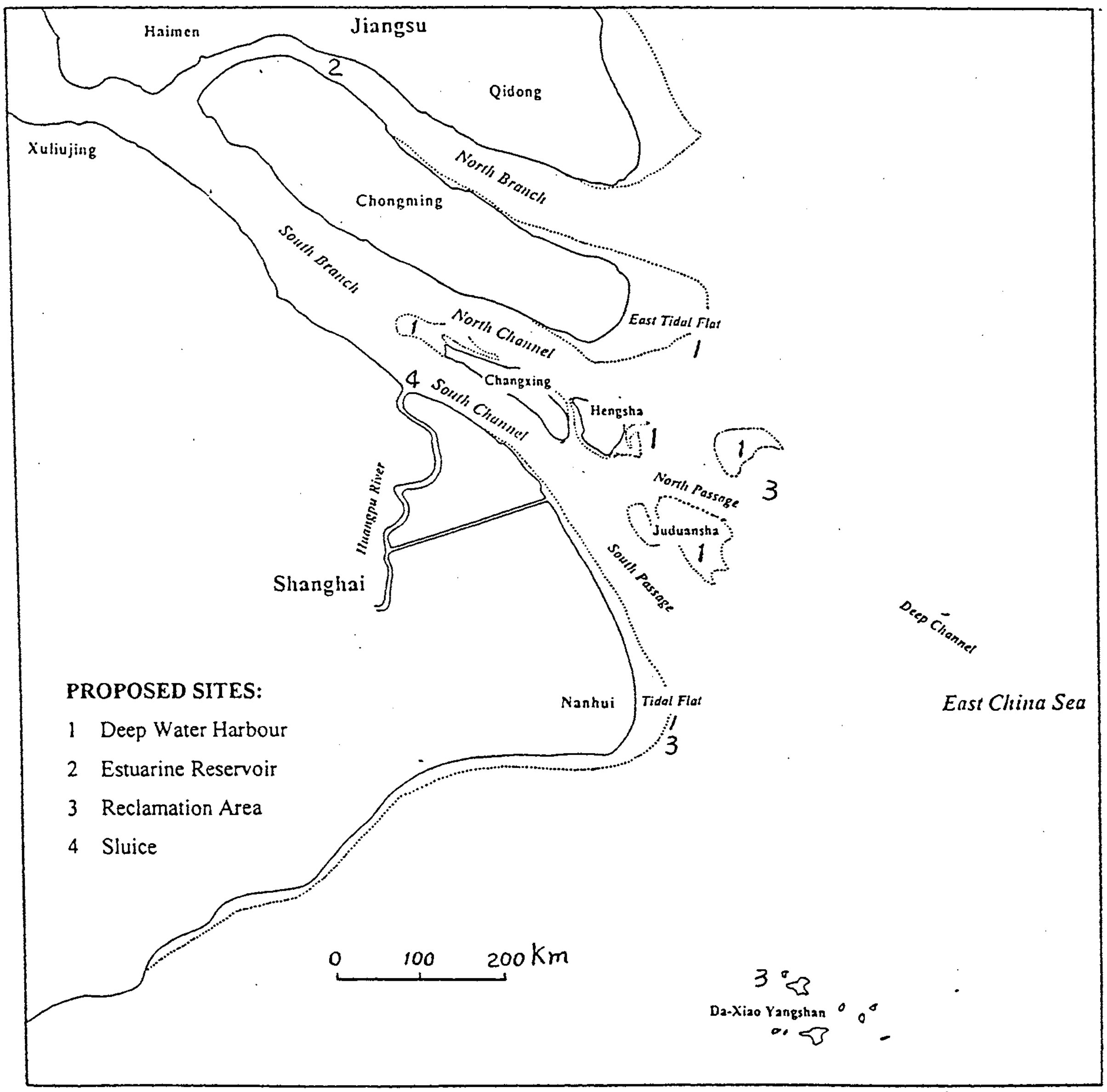

Fig. The Map of the Changjiang Estuary

1) to build a "new Shanghai" over the sea, for relaxing the land leakage in Shanghai.

2) to build a huge estuarine reservoir, for adjusting the changes in the water environment.

3) to build a great deep harbour, for supporting the establishment of the international navigation center of Shanghai.

4) to build a big sluice at the mouth of Huangpu River, for defending the attack of storm surge and guarding against the impact of global rise of sea level on the ecosystem.

The navigation channel problem in the Changjiang River mouth is very important for the economic development of Shanghai, but it is not expounded here, because it has been studied in the program of the South Channel- North Passage.

Build a "New Shanghai" Over the Sea

Shanghai is a municipality directly under the central government, with an area of 6,340 km^2. The shortage of land resources is a big problem in the development of Shanghai society and economy. The urban expansion, road constructions and so on are inevitable to use land. Since the 1950s, the total area of land used is about 1133 km^2, of which 933 km^2 is good cultivable land. At the same period, about 767 km^2 land has been reclaimed in Shanghai. There is still a big gap between the land occupied and the newly reclaimed land. How to increase the area of land for development remains an important problem in Shanghai.

Shanghai has its own advantages in increasing its land duo to a rich supply of sediments from the Changjiang River basin. An extensive tidal flat with 850 km^2 area above the theoretical datum is available for land reclamation. For more than one thousand years, the shoreline has progressively move toward the sea, and increased a great amount of land in Shanghai's coastal area. During the past 40 years or more, the area of the Chongming island has been doubled. There have been as many as 5 embankments being built in the Nanhui spit. Besides, with the progress of technology, the reclamation capability for land reclamation has been improved in recent years. In 1995, the Shanghai Pudong International Airport built a dike at an altitude of 0 m to increase the deposition. Only one year after the dike was built, the sedimentation reached to a maximum 2.7m in the closed tidal flat.

According to the conditions mentioned above, it is possible to reclaim a large scale coastal land in Shanghai. For this sake, the authors proposed a scheme to reclaim about 1,000 km^2 flats in Shanghai, which will increase a land area as much as that of the three districts in Shanghai.

1. To build a "new Nanhui"

Nanhui spit is the product of convergence and divergence of near shore current of The Changjiang Estuary and Hangzhou Bay. Its underwater part extends the Shengsi Island at the depth of -10m. The region less than -8m is an important passage for the sediment from the Changjiang River to the Hangzhou Bay by various ways such as long-shore sediment transport and density current, etc. We proposed a scheme to build two dikes at -2m to increase deposition. They will speed up the deposition of sediment from the Changjiang River ebb current and from the flood current, and will form an area of an artificial peninsula about 330 km^2.

2. To build a "new Baoshan"

Changxing and Hengsha Islands are a part of Baoshan district, Shanghai. At the lower reach of Hengsha island, there is a submerged shoal called the "east flat of Hengsha". At the upper reach of Changxing island, there is a submerged shoal named Zhongyangsha shoal. The area of east flat of Hengsha above -2 m is about 260 km^2, which is a shallow flat between the troughs of the North Channel and the North Passage in the Changjiang Estuary. A large area of this shoal is above the mean tidal level now. The Zhongyangsha shoal is a shallow flat between the troughs of the North Channel and South Channel. At present, its area is about 40 km^2 above 0 m sea level.

Between the troughs of the South Passage and the North passage, there is another shallow shoal called Jiuduansha. Its area is 114 km^2 above 0 m. Some grass has grow on part of the shoal. It is much beneficial to the stability of navigation channel of the South Passage and the North Passage for Jiuduansha to develop into land.

There is 300-400 km^2 land that is expected to be reclaimed on the east flat of Hengsha and Jiuduansha. It will increase an area of land for Baoshan district as much as that of Baoshan at present.

3. To build a "new Chongming"

Chongming is the third greatest island in china, whose area was 602 km^2 in 1949. From 1950 to 1990, there were 446 km^2 reclaimed, and in 1991, 44 km^2 of Dongwangsha shoal were reclaimed. Thus, the area of Chongming Island almost doubled. The tidal flat of Chongming Island is still extending now, the east flat of which is extending with a velocity of about 100m a year. The area of this flat is 346 km^2 above -2m sea level and 275 km^2 above mean sea level. Therefore, it has still great potentiality to reclaim on Chongming, and it is possible to build another "Chongming" (about 300-350 km^2). But, it should be pointed out that the east flat of Chongming is a conservation area of migratory birds. To treat the relationship between the reclamation and nature conservation, a dynamic management strategy may solve the problem.

Build a Large Estuarine Reservoir

Shanghai is a quick developing city. Water expenditure is increasing rapidly with urban area expansion, population growth, and living standard rise. The expenditure of running water has been increased 6-7 times since 50's.

Water quantity may exceed 3 billion tons by the end of this century due to the continuous enlarging of supplied extent and increasing of supplying strength. Shanghai is increasing the water sources area vigorously. For example, building Qingcaosha Reservoir, of which the earlier stage work has been conducted.

Water quality in the Changjiang Estuary is influenced by salt water intrusion. In the dry season especially in January to February, the salt water intrusion will threaten the water supply of Shanghai because of the decrease of the discharge. The salt water in the North Branch will intrude to the South Branch. For instance, in 1979, the salinity at the upper entrance of the North Branch reached 16 ‰. Its influence arrived at more upper of Xuliujing. Besides, there are several factors chiefly affecting the water quantity and quality:

1) The Three Gorge Project will adjust the distribution of water resource in the Changjiang River

in time dimension.
2) The South to North Water Diversion Project will adjust the distribution of water resource in the Changjiang River in space dimension.
3) Huaihe River will discharge to the sea directly.
4) The regulation of deep water navigation channel in the Changjiang Estuary will be increase the water depth on the bar area from 7.0m to 12.5m. Therefore, salt water intrusion will change in the dry season.
5) The global change in climate will cause the sea level to rise. In the middle of next century, the sea level rise at Shanghai will reach 30-50 cm according to some study, which will affect sea water action.

Facing this situation in the utilization of water resource, what measurements can we take? We consider to make use of the water channel of the north Branch. That is to say, to build a dike in the middle of the North Branch to intercept the water from the Changjiang River. This reservoir may have a capacity of several billion cubic meters, which can be transported to the south bank area of the Changjiang Estuary by pipeline and can supply water to Chongming and the northern bank of the Changjiang Estuary. Because this reservoir will be 80-100 km away from the river mouth, it will not be influenced by salt water intrusion. Therefore, it will provide a reliable guarantee of fresh water source for Shanghai, Estuarine islands as well as the frontier of the whole Changjiang River Delta for sustainable development.

Build a Deep Harbour

To reach the aim that Shanghai will built into one of the international economical, financial, and trade centers, the construction of international navigation center is a basic aspect. Both water channel and deep harbour constructions are necessary for developing international navigation.

There are several nature navigation channels with 6 m depth and an artificial channel with 7 m depth in the bar area of the Changjiang Estuary. Nowadays, the second generation container(25,000 tons) can go by taking tide, but such water depth can not suit the demand of economic development. For this reason, the south channel and north passage are decided to be improved as a deep water channel of Changjiang River mouth by more than year's investigation, reconnaissance and design. The planning is that taking ten years and several stages, based on the principle of combing regulation, dredging, and reclaiming together, make the water channel depth reach to 12.5 m. It will make the 50,000 tonnage ship, the third or forth generation container go all day, 100,000 tonnage ship go by taking tide, and the big ships can arrive to Nanjing. Therefore, the 300-400 km river bank along the Changjiang River of Jiangsu province can build harbour complex, industry corridor and city group.

For the aspect of deep harbour construction, the harbour for 100,000 tonnage and the fifth generation container is in the stage of sitting position now. There are three positions being suggested by the department concerned, they are the east tidal flats of

Juduansha and Hengsha, the artificial peninsular of Luchaogang, and the Da-Xiao Jinshan islands.

Build a Big Sluice of Huangpu River

The frontier of Changjiang delta is often attacked by typhoon, that seriously threaten life and properties of human beings. There are more than 800 Km sea dikes and river walls on both banks of Changjiang Estuary, in which 464 Km locates in shanghai. Also the storm surge by Typhoon and river flood from Changjiang River threaten the Changjiang Delta every year owing to that the Huangpu river is a main river of catchment of Taihu lake and pass through the municipality of Shanghai. Nowadays, for protecting the hazards of storm and flood, there is a suggestion that build a big sluice at Wusong of Huangpu river that will not only protect the life and properties of human being, but also improve water environment of Shanghai.

Among the four projects mentioned above, the large reclamation and the reservoir of the north branch are two basic projects, which closely relate to Changjiang Estuarine regulation. These two projects will bring about some changes around the Changing Estuary:

1) North branch will disappear and all discharge of the Changjiang River will go out of the south branch.

2) The tidal prism may be decreased duo to the shoals between the troughs and a part of the tidal flat along the south bank. What effects will happen for these changes?

3) The fresh watêr and salt water meet in the bar area, after the projects carried out, the null point, turbidity maximum and estuarine fronts will be changed. What effects will happen for these changes?

4) Sediment movement and topography of the river bed will be changed also, and What effects will happen?

All changes mentioned above should be deeply study systematically, and we have organized scientists to do this research work.

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RESEARCH AND PRACTICE ON STRUCTURE OF GROIN HEAD PROTECTION IN QIANTANG ESTUARY

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ABSTRACT

More than 600 km long seawalls have been constructed and about 70,000 ha of tidal flats reclaimed since 1960s in the Qiantang Estuary. It is a macrotidal estuary with quite large tidal range and swift currents. Serious collapse often happens in the seawall foundation consisted of silt under the action of the special hydrodynamic conditions particularly the world-known tidal bore in the Qiantang River. The highest bore reached 3m and the recorded maximum velocity is 12m/s. Dumped riprap groins are usually constructed along the seawalls to protect the foundation of the walls from violent bore attack and to shield tidal flats from erosion. The groin, however, especially its head is more damageable for the effect of more complicated hydraulic conditions caused by its projecting position. In order to solve this problem, several structures were used, such as: concrete open caissons casted and sunk in-situ; reinforced concrete floating caissons precasted in land then transported and finally sunk using hydraulic machines; mass concrete caissons and stockade groin head with suspended columns to protect rockfill from washing away, etc., and well results have been obtained. This paper introduces briefly the dynamical conditions of tidal bore, above mentioned various head defense structures as well as their suitability, construction method and engineering effect.

INTRODUCTION

The vast plain of Qiantang Estuary lies below mean tide level about 2-4m. The safety of the people living in both sides of the river is guarded by the seawall. In order to protect the foundation of seawalls from the violent bore erosion, many groins have been built along the seawall (river bank). Since it protrudes from the river bank, the groin, especially its head, becomes more damageable under the frequent attack of the tidal bore. Several measures were employed to protect the groin head and obvious successes have been gotten to some extent.

BACKGROUND AND PROBLEMS

The Qiantang Bore is renowned over the world, the height of the bore ~ the suddenly rising height of the wave front during flood reaches about 3 meters, its propagation rate is generally 6-8 m/s and the maximum recorded velocity is 12 m/s, with a strong dynamic force rarely observed in other micro tidal rivers and thus bringing great destruction to the seawalls along both banks. The land level of the vast plain areas of Hangzhou-Jiaxing-Huzhou in the north and Xiaoshan-Shaoxing in the south lies below mean high tide level by 2-4 m, about an area of million mu (15mu=1ha) and a population of 10 million is protected against flooding by the Qiantang seawall all through the ages. The security of the seawall is of vital importance to the economical development and the safe living in the area.

The ancient seawall still guarding in the front line was initially built in the Ming-Qing dynasties, the broad scale of its construction stands just next to that of the Great-Wall and Grand-Canal in China history. The ancient seawall, being constantly repaired and strengthened, has considerable ability to guard against the tides and waves, however, the wall foundation is higher than desired owing to the limitation of the construction condition then, the wall often endangered by scouring under the attack of the strong bore. Frequent disasters were recorded in history caused by collapsing of the seawall.

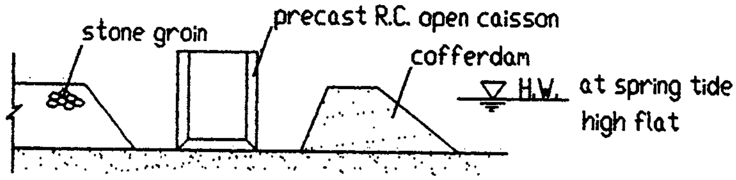
In order to protect the seawall foundation from impact and scouring of the bore, there was long successive experience in groin building in the upper and middle stretches of the estuary. While in the lower stretch, the bore is higher and stronger, the groin, especially its head, encounters frequent ruin by the torrential bore attack. The difficulty lies not in the groin head protection structure itself but that the construction of it encounters many adverse working conditions, i.e., the channel is rather shallow (generally only 2 m below low tide) and working hours is rather short (only 3-4 hr. during lower water level before bore arrives) in each tidal cycle, the construction process could only be carried out in a hurry and with small-size facilities. Since the impacting force is very strong, individual precasted concrete block of 2-3 tons in weight could be thrown away tens of meters from its original location. Concrete casted under water is not feasible under above mentioned situation, heavy construction machine could not be used on boat and can also hardly reach the deep scour pit (where needs to be protected urgently) on top end of the groin because too long arm of a crane is required.

MEASURES OF GROIN HEAD PROTECTION

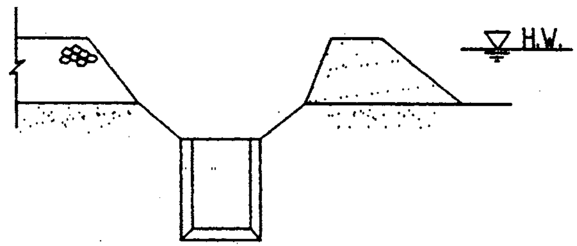
After consistent probing and investigating, the following measures for groin head protection are successful to some extent.

Open Caisson

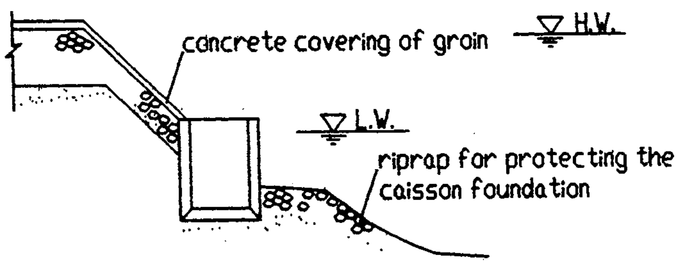
Open caisson of precast concrete or masonry was built at the groin head, with a plan size of 6 × 12m, height of 10-15m. The caisson is sunk to more than 8m below low water by hydraulic suction pump to suck out the mud in the caisson (Figure 1) and riprap be dumped outside the caisson to prevent scouring of the caisson foundation. By this way, a complete protection system is formed that the sea wall foundation is protected by the siltation between groins, the groin head is protected by caisson and the caisson foundation is prevented from undermining by riprap.



(a) Precasting open caisson on high flat



(b) Caisson already sunk to designed depth



(c) High flat being eroded stone dumped outside the caisson

Figure 1. Sinking processes of the open caisson

Practice confirms its good effectiveness, and the caisson has been popularized in new groins built on high tidal flat where caisson can be constructed on dry ground without the interruption of inundation. Where the seawall is by the side of deep main channel, there is no high flat around the groin head, it is very difficult and expensive to build cofferdam, this kind of caisson construction could not be used. A test has been made that a reinforced concrete thin shell open caisson is precasted and floated to site and filled with water then sunk to the river bed, then continued sinking by filling stone as well as by sucking out the mud and silt around the caisson shell to the designed depth. After the first section has been sunk to the designed position and elevation, the second upper section is floated and connected with the lower one (Fig. 2.). This test was carried on with success in technical procedures, however, it is difficult to be popularized due to its complicated technological process, high risk and great expense, especially in reaches under violent bore attack.

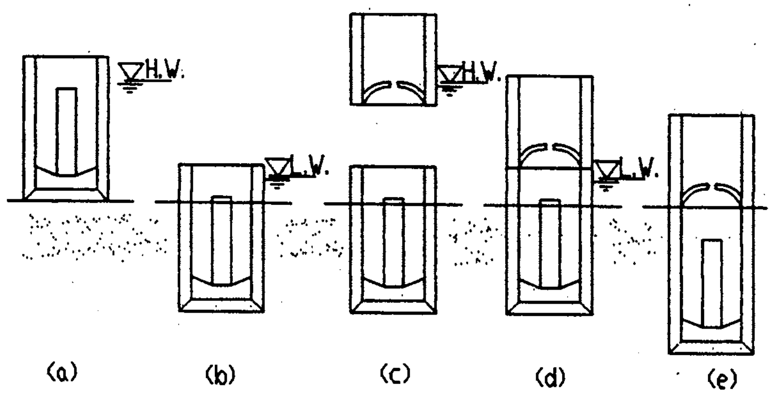


Figure 2. Sinking processes of floating open caisson

(a) First section being sunk on river bed in position

(b) Sinking Suction, the top of the caisson be kept above L.W.

(c) The second section is positioned to connect with the first section

(d) The two sections already connected

(e) The two sections were sunk by suction simultanlously to designed depth

Caisson

A caisson has high self floating ability and need not to use mud suction apparatus in sinking process, the construction procedure is greatly simplified and easy to be carried out. Furthermore, owing to its well structural integration, larger weight and good stability, it's a favorable structure for groin head protection. The crux of this type of structure is the stability of its riprap foundation which should be able to stand against the impact of bore and swift current. According to the dynamic condition in the Qiantang estuary, the top elevation of the riprap foundation should generally be 4-5 m below designed low water where the velocity is not high. Because of large amount of stones already being placed at the groin head and cannot be removed easily, the riprap foundation could hardly be excavated to the required elevation. Besides, if the caisson is too high, it is very inconvenient to float. At present, the caisson height is generally 3-4.5m, part of them are still in good condition, part were ruined due to undermining of their riprap foundation. A schematic view of the longitudinal profile of the caisson and the groin head is shown in Fig. 3.

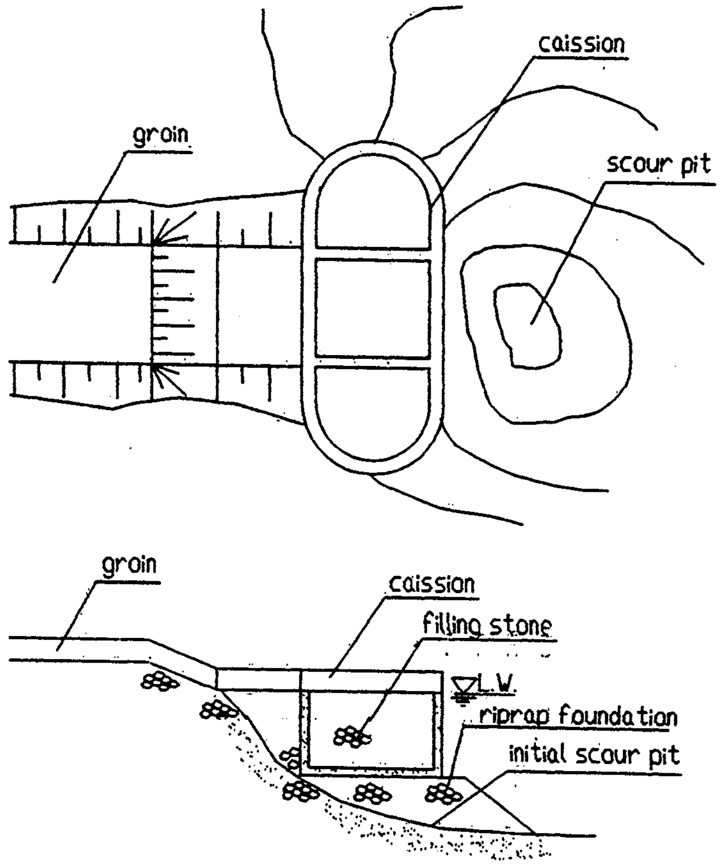


Figure 3. Groin head protection by caisson

Suspended stockade

Theoretical analysis and practice both demonstrate that the stability of underwater stone depends not only on its grain size and specific gravity, but also on the water depth. Because the velocity decreases rapidly near the bottom as the depth increases. Flume test indicates that on the flat bottom, the erosion-resisting velocity for a single block can be stated as:

$$V=\sqrt{2g\frac{r_s-r}{r}d\left(H/d\right)^{1/4}} \qquad (1)$$

In which, d and H are respectively the equivalent spherical diameter of the stone and the water depth. The larger the ratio H/d, the more stable will be the stone. Even though the scour pit at the groin head is quite deep, the stone on the slope near bottom may remain stable. Thus we get the idea that the foundation below certain depth could be protected by riprap, while in the region from this depth up to low water level should be protected by some type of integral structure.

That's why in the past, integral structures such as caisson and open caisson were generally used for groin head protection. Nevertheless, the use of caisson is limited to certain condition, while the region should be protected by integral structure is only within a certain depth below low water, we conceived that some type of suspended railing structures may be used to prevent the inside stones from washing away by violent bore. Based on this idea, a reinforced concrete semi-circular ring beam is built on the riprap foundation at an elevation somewhat higher than lower water and the beam is connected as an integral part with the top of the groin head. A series of holes are arranged along the ring; in each hole, a reinforced concrete column could be inserted in and be suspended on the ring by a key bar. Whatever the stone at the groin head was scoured away to a certain depth, R.C. columns were inserted in the hole to form a ring of railings thus preventing stone from further scouring. The length of the R.C. columns was so designed that the lower end of the suspended column will be a proper distance, generally 4-5m, below low water, since stone below such elevation is stable. In case worse dynamic condition occurs than designed, additional stone should be replenished. The structure scheme is shown in fig. 4, the building procedures are shown in fig. 5.

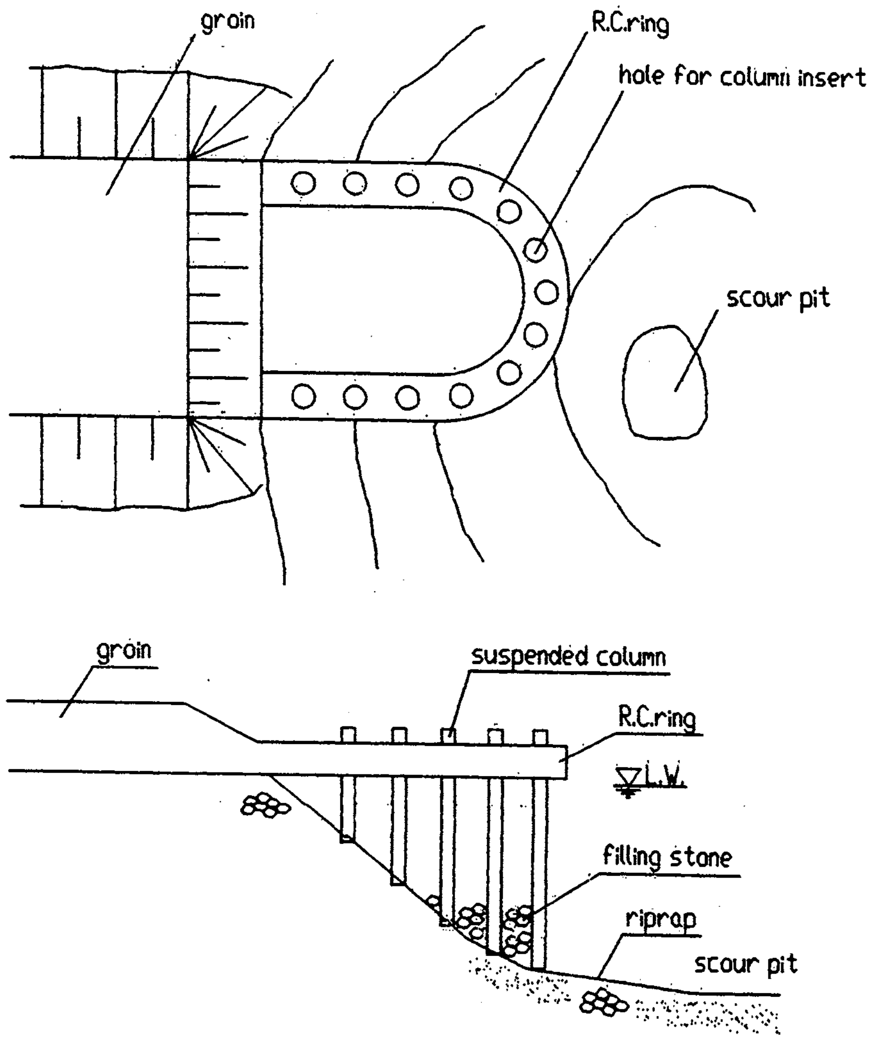


Figure 4. Suspended column for groin head protection

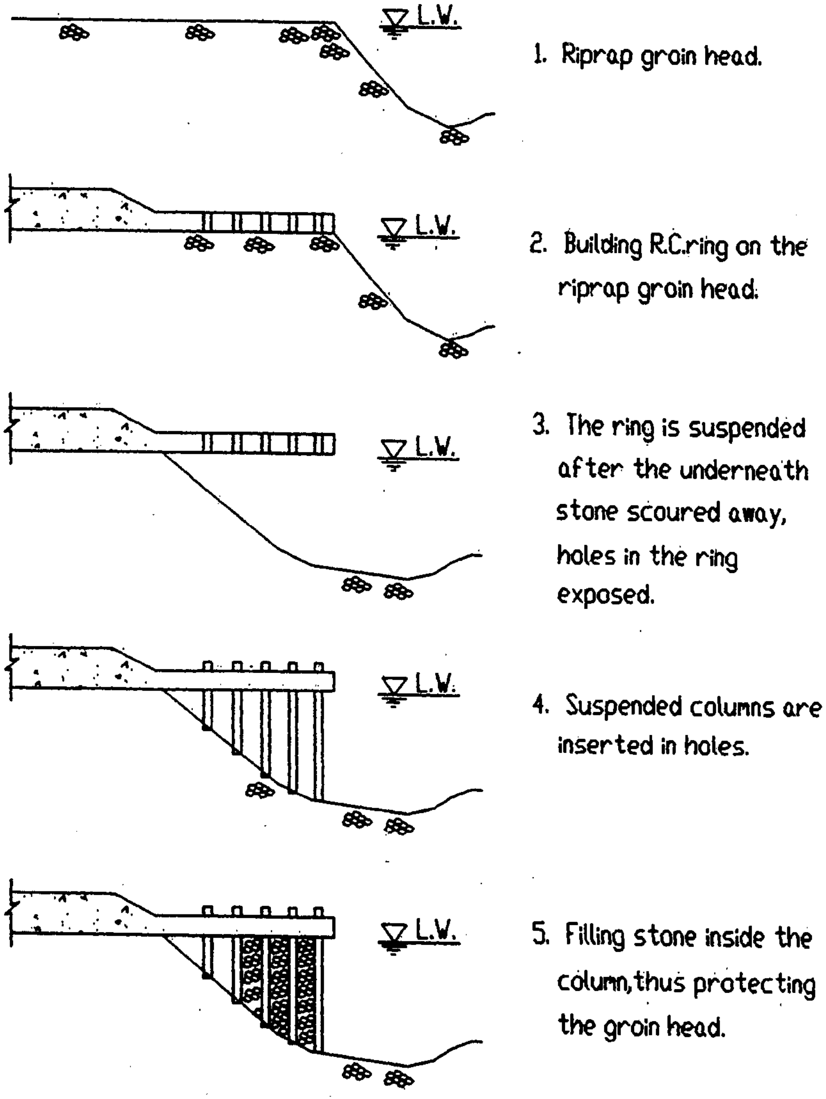


Figure 5. Building procedure of suspended column

The construction process of suspended railings are all carried out above low water, no underwater works needed to be done, and there are no complicate processes as precasting, floating and sinking in caisson construction. Although stone below the end of railings may be scoured away during worse condition than designed, the stone inside of the railing will sink down accordingly, it can be easily found and replenished. Therefore, the construction and maintenance works are quite convenient and favored by engineering organizations. The key point in designing is to determine the reasonable length of the columns.

The usual scouring pit at the groin head in Qiantang Estuary has been observed in situ and recorded by flume test, for a groin of 70m in length with its top elevation of about 1 m above low water, under the impact of 2.5m high bore, the deepest point of the scouring pit is about 4 m below low water. The length of the railing columns then will be 5.5m.

Of course, the depth of scour pit and the slope of the riprap at groin head vary with the bore height in different reached, length and top elevation of the groin; however, the length of the railing columns could be determined by flume test and field observation data with a proper clearance provided for safety.

CONCLUSIONS

Various types of structure for groin head protection are suitable to the different conditions. The open caisson can only be constructed on the high flat; the floating caisson is adaptable to the groin head in deep channel, but its construction is much more complicated and expensive; the mass caisson is simple to be constructed, but it wants a sufficient deep foundation and that could not be satisfied anywhere; the stockade groin head may be used in any case, after a longer period of practice to get more improvement, it will be a reasonable structure for groin head protection in the Qiantang Estuary.

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TIDE CHANGES AFTER RIVER CONTRACTION/RECLAMATION IN QIANTANG ESTUARY

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ABSTRACT

The principles for regulation of Qiantang Estuary have been determined since 1960s, that is, to decrease tidal inflow volume in order to increase the ratio between river flow and tidal discharge and to increase the ebb discharge per unit width. Reclamation combined with river regulation projects (the river course was contracted to 1/2-1/5 of its original width) were carried out by stages and in groups in recent thirty years and the river gradually reaches its regulation alignment. In order to clarify the effects of the river regulation and reclamation works on the variation of the features of river bed, the changes of tidal characteristics, flood water level, water quality (salinity) and navigation conditions, the related field data measured before and after contraction should be analyzed and compared. This paper deals with the changes of tidal characteristics in the estuary after its contraction/reclamation.

Statistical analyses and comparison were made systematically for the main tide characteristics such as high/low tidal levels, tidal ranges, duration of flood tide, tidal volume etc. by using the field data before and after regulation/reclamation. Field data show that after regulation/reclamation, the tidal wave deforms more severely, i.e., the high tidal level rises and the duration of flood tide is shortened. The reason of above changes was explained qualitatively and quantitatively with the aid of numerical modeling of tidal wave equations coupled with 1-D and 2-D. The calculated values merged well with the field data. These results may provide some references for other estuaries.

INTRODUCTION

The Qiantang Estuary is quite wide and shallow, its main channel wanders frequently and rapidly. The regulation of the river calls for the contraction of the width in a large scale and a large area of tidal flat was then impoldered and reclaimed. Up to the year of 1994, the river width in the reach of 64 km in length from Hangzhou to Shibao of Haining County has been contracted from 2-16 km to 1-4 km and the channel becomes fixed, 60,000 ha. of tidal flat have been impoldered in Qiantang Estuary (Figure 1).

It is quite interested for civil engineers to analyze systematically the effect of river contraction on the variation of the river regime, tidal characteristics, river flood behavior, salt water intrusion and the navigation conditions, thus valuable experience and concepts might be obtained. This paper analyzed systematically the tide data before and after regulation/contraction and several comparisons were made, besides, 1-D and 2-D coupling mathematical simulations were used to explain the reasons of tidal variation. Other articles, such as the channel meandering, the longitudinal and vertical erosion and siltation, were studied by Han and Lou earlier in 1995.

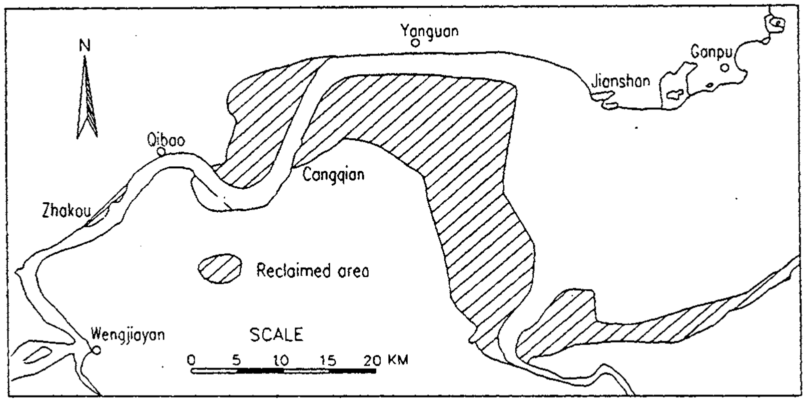

Figure 1. Regulation/reclamation scheme of Qiantang Estuary

GENERAL DESCRIPTION ABOUT TIDE VARIATIONS

Tide characteristics include high/low water levels, tidal range, tidal prism (tidal volume), duration of flood tide and flood/ebb velocities. Tidal water levels are recorded in field systematically, while the measurement of tidal volume as well as tidal velocities are quite difficult and expensive, in most cases, they are calculated from tide water levels, so that the variation of levels is most important and particular attention is paid to analyze it in this paper.

Tide characteristics in Qiantang estuary depend upon the elevation of the riverbed, the curvature degree and the rate of contraction of the river. The period selected to analyze the effect of river contraction on tides must be quite representative and comparative. The variation of the main tide indexes is stated as follows.

Variation of the characteristic water levels in mean tides

In Qiantang estuary, the depth below LW is very small. The effect of bed variation on the LW level is quite large and the erosion/siltation of the river bed depends on the elevation of the initial river bed in the earlier stage and the amount of runoff of the year. Therefore, the tide data selected to be used for comparison were recorded in the years with nearly equivalent average discharges including wet, normal and dry series before and after the river being contracted. After careful analyses, the average tide levels of 1955-1957 were used to represent that of the Jianshan reach in generally relatively straight configuration before contraction, while similar average tide data of 1988-1991 were used to represent the related conditions after contraction. The average tidal data of 1983-1985 represent that of the Jianshan reach in relatively winding configuration after contraction. Table 1. shows the average values of characteristic tide levels for Jianshan reach in relatively straight configuration before and after river contraction.

Table 1. Variation of Characteristic Values of Average Tide before and after Contraction

	Mean high tide			Mean low tide			Tidal range		
	A	B	C	A	B	C	A	B	C
Zhakou	5.91	6.31	0.40	5.22	5.52	0.30	0.69	0.79	0.10
Qibao	5.87	6.31	0.44	4.88	5.23	0.35	0.99	1.08	0.09
Cangqian	5.70	6.08	0.38	3.58	4.20	0.62	2.12	1.88	0.24
Yanguan	5.51	5.76	0.25	1.40	2.07	0.67	4.11	3.69	0.42
Ganpu	4.69	5.01	0.32	-0.67	-0.67	0.00	5.36	5.68	0.32
Zhapu	4.23	4.44	0.21	-0.28	-0.27	0.01	4.51	4.71	0.20

Notes: A and B indicate before and after contraction respectively, C =B-A.

It is shown in Table 1 that after contraction, mean HW lifted 0.21-0.44m. At Qibao, it reached the most and at Zhapu, it was the least; mean LW raised respectively 0.67m, 0.62m, 0.35m and 0.30m at Yanguan, Cangqian, Qibao and Zhakou, while at Ganpu or Zhapu, it remained generally the same. At Yanguan and Cangqian, tidal range decreased respectively 0.42m and 0.24m, while at other gauges, it increased 0.09m-0.32m.

Variation of the characteristic water levels in spring tides

The intensity of the tidal bore or the salt water intrusion in Qiantang estuary depends highly upon the magnitude of the tidal range. Tidal bore is the most violent force to threaten the safety of the sea dikes and groins. Therefore, spring tide is more important. In Figure 2, fifteen highest HW water levels occurred in September of above mentioned three sequences of years have been plotted which shows the comparison of the arranged HW levels in three different periods for Zhakou, Qibao, Cangqian, Yanguan and Ganpu. It is obvious that during the Jianshan reach being in the relatively straight configuration, the increments of HW after river contraction are as follows: 0.65m-0.40m, averaging 0.53m at Ganpu; 0.89m-0.64m, averaging 0.73m at Yanguan; 0.75m-0.34m, averaging 0.56m at Cangqian; 1.02m-0.74m, averaging 0.87m at Qibao; and 0.83m-0.59m, averaging 0.71m at Zhakou. It is shown that the raise of HW levels in spring tides is much more (nearly 2-3 times) than that in mean tide as mentioned before. It is one of the reasons that tide in Qiantang river becomes stronger and salt water intrusion is more serious now, it is a problem needing high attention. It can also be seen in Figure 2 that the increment of HW will decrease by about one half during the Jianshan reach became relatively winding. Consequently, in order to weaken the tide in its upstream reaches, it is advantageous that the curvature of the Jianshan reach should be made larger in the future regulation.

Similarly, fifteen largest tidal ranges were selected and arranged in order of its magnitude. It showed that the variations of tidal range after river contraction are: increased 0.49m-0.10m, averaging 0.30m at Ganpu; decreased 0.81m-0.44m, averaging 0.65m at Yanguan; generally remained the same at Cangqian; increased 0.78m-0.62m, averaging 0.63m at Qibao, and increased 0.47m-0.19m, averaging 0.32m at Zhakou. Tidal range decreased at Yanguan resulted from that the increase of LW was more than the increase of HW; while at Cangqian, tidal range generally did not change due to the effect that variations of HW and LW on tidal range were counteracted. Owing to the increase of HW far exceeded the increase of LW, tidal range at Qibao and Zhakou increased essentially. At the river reach from Qibao to Zhakou, the tidal volume (tidal prism) increased obviously for the increase of HW and tidal range at these two gauges while the river configuration generally remained the same as before contraction. This is the reason that in this river reach, the problem of salt water intrusion near Hangzhou becomes more serious.

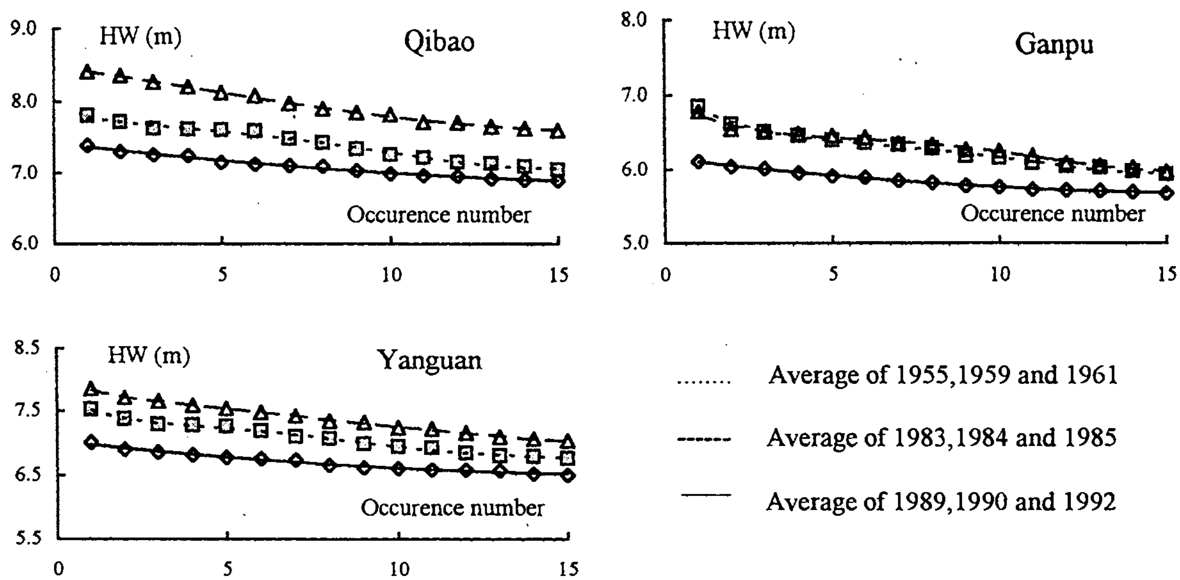

Figure 2. Variation of HW

Variation of tidal prism

Tidal prism (tidal volume, tidal influx) is a very important factor of tide which relates to salt water intrusion, the bore intensity, flow velocity, sediment concentration, sediment discharge etc., field measuring of tidal volume, however, is rather difficult and expensive. Besides a few field measurements of tidal influx, tidal volumes could be calculated based on the HW/LW records at different stations and the corresponding cross sectional areas by using following equation:

$$\overline{V} = \eta \sum_{i=1}^{n} (F_{h_i} - F_{l_i}) \Delta L_i$$

in which F_{h_i} and F_{l_i} denote sectional areas under HW and LW of section i respectively, ΔL_i indicates the distance between section i and section i+1, η is a coefficient nearly being 0.90 to correct the condition that at sections i and i+1, HW or LW does not occur simultaneously. Figure 3 shows the relationship of tidal prism vs. range at three different periods. Table 2 shows the tidal volumes in September for spring tide (p=20%) and mean tide (p=50%) respectively. It is shown in Table 2 that:

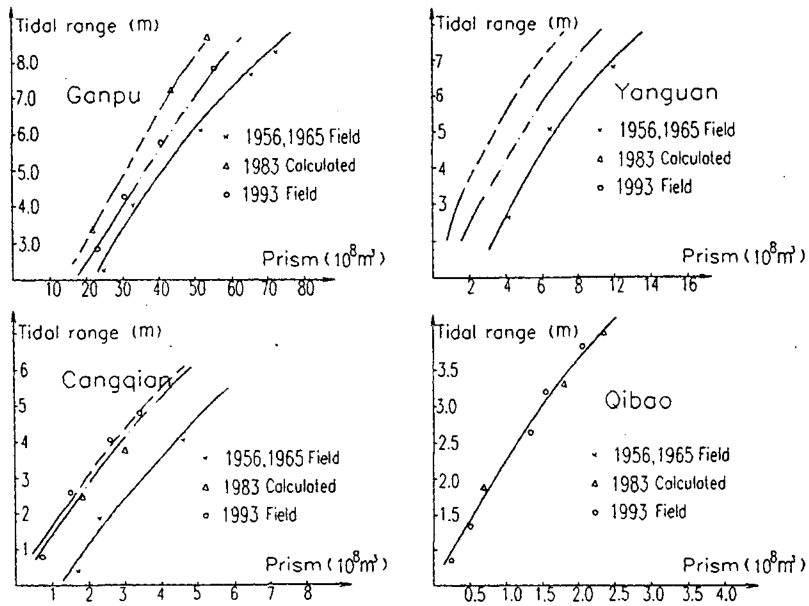

Figure 3. Tidal range vs. prism

Table 2. Tidal Volume for Several Sections before and after Contraction

Unit: 10^8 m^3

		Ganpu		Yanguan		Cangqian		Qibao	
	Tide	Range	Prism	Range	Prism	Range	Prism	Range	Prism
Before, straight	Spring	7.14	51	5.47	7.5	3.39	3.5	1.98	0.9
	Mean	5.39	35	5.10	6.9	2.60	2.8	1.60	0.6
After, straight	Spring	7.37	45	4.70	5.1	3.34	2.2	2.63	1.3
	Mean	5.67	32	4.25	4.2	2.55	1.4	2.10	0.9
After, winding	Spring	7.47	39	3.71	2.6	2.40	1.3	1.80	0.7
	Mean	5.70	28	2.15	1.7	1.70	0.8	0.30	0.4

Notes: In the first column of Table 2, before or after indicates before or after river contraction; straight or winding means that the river configuration was relatively straight or relatively winding.

- As a result of river contraction, the tidal prism in spring tide at Ganpu, Yanguan and Cangqian decreased by about $6\times10^8m^3$, $2.4\times10^8m^3$ and $1.3\times10^8m^3$ respectively, i.e., tidal prism decreased relatively by about 12%, 34% and 33% of their original quantity respectively at these three sections;

- There was no essential contraction works in the river reach upstream of Qibao, tidal prism would increase because the increment of HW was more than that of LW. Consequently, tidal prism at Qibao in spring tide would increase by $0.4\times10^8m^3$, 44% of its original value; that in mean tide would increase by $0.3\times10^8m^3$, 50% of its original value;

• When the Jianshan reach is relatively winding, tidal prism at Ganpu and Yanguan would decrease by $6\times10^8m^3$ and $2.5*10^8m^3$ respectively as compared with that while the same reach is in the relatively straight configuration, it accounted for about 13% and 44% respectively of their original quantity. For this reason, if the Jianshan reach would be regulated to a bend of larger curvature, tidal prism at Yanguan would be cut down nearly one half or so.

Variation of flood tide duration

In the reach from Jianshan to Shibao, owing to the contraction rate of the river width is very large, tide wave deformed more sharply after contraction, thus rendering the bore more intensive and the max./mean flood velocity increased. The flood tide duration at several stations before and after river contraction is shown in table 3.

Table 3. Variation of Flood Tide Duration

Unit: hour: minute

	Ganpu	Yanguan	Cangqian	Qibao
Before contraction	5:35	3:03	2:22	1:52
After contraction	5:25	1:59	1:40	1:03
Difference	0:10	1:04	0:42	0:49

NUMERICAL SIMULATIONS FOR TIDE VARIATION

Governing equations of the mathematical model

In order to reflect correctly the effect of river regulation/contraction on the tide phenomena along the river, the upper and lower boundaries of the mathematical model should be selected at the locations far away from the effect of regulation. For this reason, the lower boundary of the model was fixed at the connecting line (section) along Luchaogang-Zhenhai of the Hangzhou Bay, while the upper boundary was set at the Fuchunjiang Hydro-Electric Station. The rivers reach covered by the model is about 300 km in length (Figure 4). The computation domain includes 1-D and 2-D sub-areas and they will be coupled with each other. The governing equations are:

1-D model:

$$\frac{\partial Z}{\partial t} + \frac{1}{B}\frac{\partial Q}{\partial x} = 0 \tag{1}$$

$$\frac{\partial Q}{\partial t} + 2u\frac{\partial Q}{\partial x} + Fg\frac{\partial Z}{\partial x} = u^2\frac{\partial F}{\partial x} - bg\frac{u|u|}{C^2} \tag{2}$$

2-D model:

$$\frac{\partial Z}{\partial t} + \frac{\partial(uH)}{\partial x} + \frac{\partial(vH)}{\partial y} = 0 \tag{3}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial Z}{\partial x} - fv + gu\frac{\sqrt{u^2+v^2}}{C_z^2 H} = \frac{\partial}{\partial x}(\varepsilon_x\frac{\partial u}{\partial x}) + \frac{\partial}{\partial y}(\varepsilon_y\frac{\partial u}{\partial y}) \tag{4}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial Z}{\partial y} + fu + gv\frac{\sqrt{u^2+v^2}}{C_z^2 H} = \frac{\partial}{\partial x}(\varepsilon_x\frac{\partial v}{\partial x}) + \frac{\partial}{\partial y}(\varepsilon_y\frac{\partial v}{\partial y}) \tag{5}$$

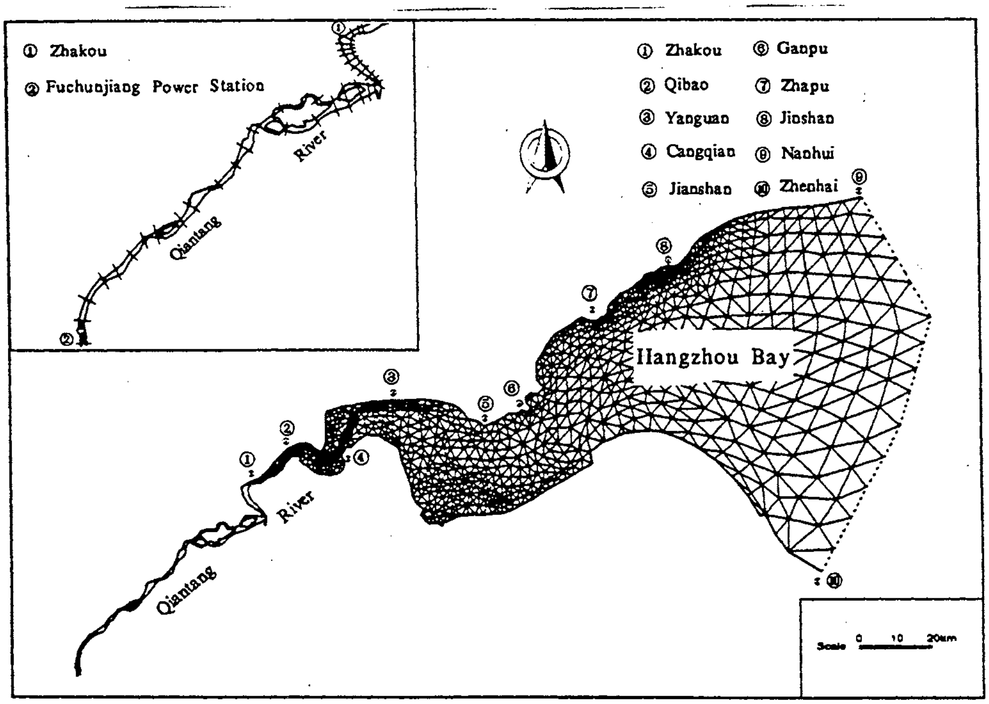

Figure 4. 1-D~2-D computation domain and grids

In above equations, the meaning of notations used are the same as usual tide wave equations for shallow water, e.g., see Han (1988). 1-D equations and 2-D equations can be solved with characteristic oriented difference method and finite element method respectively. Ni (1996) used the coupling method for the solving of the joined area. The Equation sets can also be solved simultaneously.

Verification of the model

The reliability of a mathematical model depends mainly on the precision, number of times and representativeness of its verification. There are several dozen tide gauges along the bank and 8-9 verticals of current measurements in the Qiantangjian River and Hangzhou Bay. Zhejaing Provincial Institute of Estuarine and Coastal Engineering Research has made a great number of mathematical models for those waters, verifications were carried out for large, medium and small (local) areas respectively. Normally, in the verification, the error of water levels is 0.1m, the maximum error is 0.2m; the error of velocity is less than 20% for about 80% verticals. Figure 5 shows the verification results of magnitude and direction of tidal velocities in several representative points arbitrarily selected.

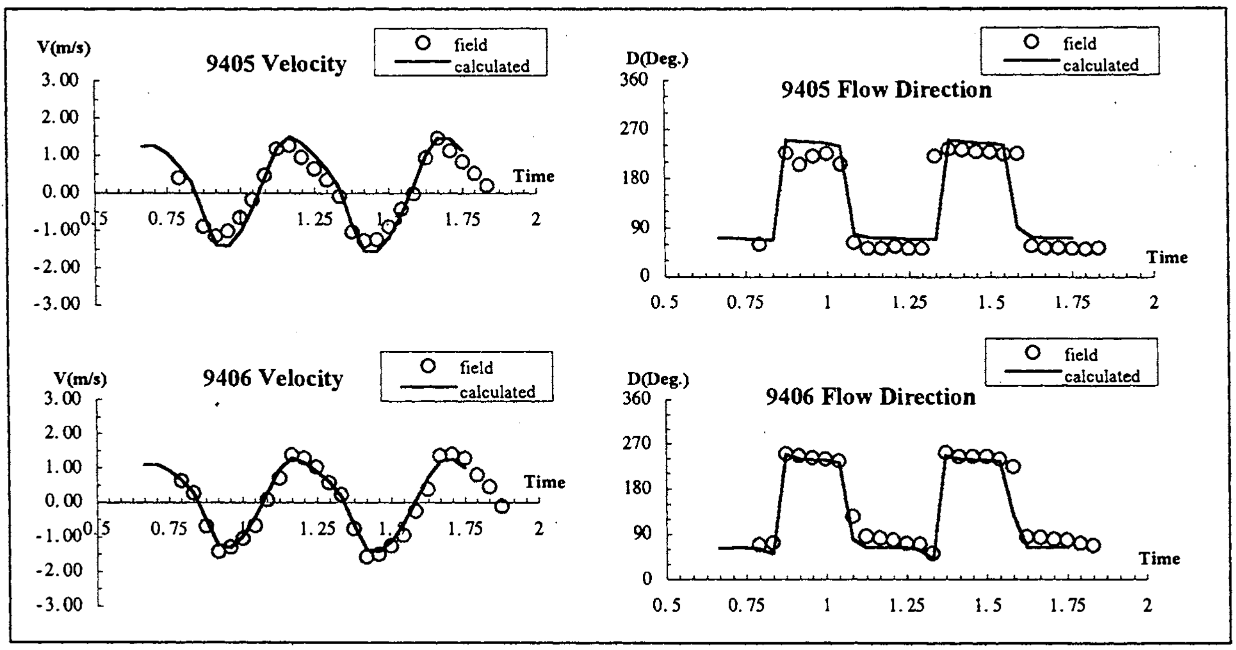

Figure 5. Verifiecation of tidal current for field data in 1994

Results of numerical simulations of tides before and after contraction

Two different cases were considered in order to separate the effect of river contraction in plane and bed erosion/siltation on HW, LW and the duration of flood tide.

Case 1.

Tide levels (HW/LW) were firstly calculated using the strand line and configuration (cross-sectional data) surveyed in 1955, then the levels were calculated again using the strand line of 1995 and the original cross-sections (1955), the difference of above two sets of levels reflects the effect of plane contraction of the river;

Case 2.

On the basis of case 1, using the cross-sections of 1995 instead of that of 1955 used in case 1. Except in the reach near Hangzhou, there finally were aggradation all over the estuary in the period between above two years. The calculated tidal levels reflect the effect of both plane contraction and bed erosion/siltation. Table 4 shows some results calculated and related field data for comparison.

Table 4. Tide variation after river contraction

	Raise of HW					Duration* hr.:min.	
	Ganpu	Yanguan	Cangqian	Qibao	Zhakou	Ganpu	Yanguan
Case 1	0.73	0.94	1.33	1.18	1.03	0:17	0:29
Case 2	0.53	0.73	1.01	0.80	0.57	0:17	0:33
Field	0.53	0.73	0.58	0.87	0.35	0:10	1:04

Notes: * Duration means the shortening of flood tide duration.

It is shown in Table 4 that:

- The calculated results of case 2 could be compared with field data because they synthesized the effect of variations of boundaries and cross-sections. The raise of HW in spring tide (p=10%) calculated and field data was quite close at Ganpu, Yanguan, Qibao and Zhakou, only at Cangqian, it was an exception. It explained qualitatively and quantitatively that the raise of HW mainly resulted from the change of boundary after river contraction. The kinetic energy of water flow can be transformed into potential energy, the current in Qiantang Estuary is quite swift, especially in spring tide, the change of boundary made the HW higher.

- Comparison of the results of case 1 and case 2 showed that the raise of HW was due mainly to the contraction of river boundary. The silting up of the river bed offers the resistance to flow and would decrease the HW level. The analyses and comparison of LW and tidal range involved issues of detailed and shifty factors of topography, more verification is required. The simulation of the duration of flood tide showed a tendency of accordance with real conditions and it also needed to be improved.

CONCLUSIONS

Statistics were made concerning tidal characteristic indexes before and after river regulation/contraction using representative hydrological years and taking plane configuration of the river into account. Following conclusions were obtained:

• The HW along the river increased in different degree, the raise of HW in spring tide was more than that in the ordinary tides, it increased in the river reaches where the contraction works was mainly implemented;

• The duration of flood tide shortened after contraction, tidal prism decreased normally. In the reach upstream of Qibao, tidal prism increased resulted from the increase of tidal range while the above reach was not contracted obviously;

• Above mentioned phenomena, such as the raise of HW, shortening of the duration of flood tide and increase of tidal range, could be simulated with 1-D and 2-D mathematical models. The increase of HW as well as tidal range mainly resulted from the sharp contraction of river boundary and the further deformation of tidal wave, the raise of river bed would counteract these effects.

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ALGAL BLOOMS BY *Cochlodinium* IN THE SOUTHERN COASTAL WATERS OF KOREA

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ABSTRACT

The numbers of red-tide outbreak have continuously increased since the first scientific report in 1961. A dinoflagellate *Cochlodinium polykrikoides* is one of the 30 toxic species reported in Korea. An algal bloom by *Cochlodinium* was first reported in September of 1982 in the southern coastal waters of Korea. Since then, it has frequently occurred especially from July to October, when the water temperature ranges from about 18 to 23℃. A *Cochlodinium* bloom occurred in the southern coastal waters from October to early November of 1993, and cell density ranged from 5,000 to 10,000 cells/ml. About US $750,000 of monetary losses in aquaculture industry were estimated in 1993. The *Cochlodinium* bloom was found again at the same waters in August of 1994. The 1995 bloom was the largest one in terms of scale and damage, covering entire southern and southeastern coastal waters of Korea in September and October. The bloom has resulted in the monetary losses of more than 50 million U.S. dollars in mariculture industry and fisheries. The causes of the bloom suspected were eutrophic condition due to nutrient input from the land and resuspended sediment by storm, optimal temperature condition and use of too much dispersants after oil spill accidents. The bloom by *Cochlodinium* happened again in the same waters in September and October of 1996. In this paper, history of algal blooms in Korea, blooms of *Cochlodinium* in many countries, biological and ecological aspects of *Cochlodinium*, and cause and impacts of the blooms were reviewed.

INTRODUCTION

Rapid growth of phytoplankton colored the water red, green or brown depending on the pigments of the algae and caused detrimental effects on fisheries and mariculture. They also caused public health problem and environmental disaster. Since the first scientific report of the red tides in the Korean coastal waters in 1961, the number of outbreak have continuously increased and bloom area expanded. The 1995 bloom by *Cochlodinium* has been the worst one until now in terms of economic losses and bloom area. In this paper, previous studies on the history of red tides, ecology and biology of *Cochlodinium*, causes and impact of bloom were reviewed.

HISTORY OF RED TIDES AND RECENT *Cochlodinium* BLOOMS IN KOREA

The historical record of red tides was found in an old book, written in the 15th century, saying that seawater color changed into yellow, black and red in Chinhae Bay located in the southern sea of Korea, in 1403, 1412, 1423 and 1428 (Chang *et al.*, 1995). At that time, fishes were found dead and floating on the surface. Not being the scientific record, it could be the evidence that red tide occurred in the long time ago back to the 15th century in Korea.

Table 1. History of red tides in the southern coastal waters of Korea

· Historical record of red tide in the 15th century
· First scientific report of red tide in 1961
· A total of 104 outbreaks during the 1970's
· No harmful red tide by 1977
· Massive red tide by *Prorocentrum minimum* in 1978
· Massive red tide by *Gymnodinium nagasakiensis* in 1981
· First report of *Cochlodinium* bloom in September of 1982
· First PSP case by *Alexandrium tamarense* in 1986
· Bloom by *Cochlodinium polykrikoides* in 1993
· The worst bloom by *Cochlodinium polykrikoides* in 1995

Since the first scientific report of red tides in the southern coastal waters in 1961, a total of 104 outbreaks had been reported during the 1970's. However, no harmful red tides had been reported by 1977 (NFRDA, 1987). Red tides were mainly caused by non-toxic diatoms from 1962 to the mid-1970's, and their occurrences were limited to the southern embayments. Red-tide causative diatoms have been replaced by dinoflagellates since mid-70's, and harmful algal blooms by the dinoflagellates are common nowadays. Massive dinoflagellate blooms destructed aquaculture industry and led to tremendous monetary losses of fishermen in 1978 and 1981 (Table 1).

Algal bloom by *Cochlodinium* was first reported in September of 1982 in the southern coastal waters of Korea. Since then, it has frequently caused blooms especially from July to October. A bloom by *Cochlodinium polykrikoides* occurred in the southern coastal water from October 3rd to November 7th of 1993. The bloom was first found in Namhae Island, and generally spreaded eastward according to current and wind direction. Cell density ranged between 5,000 and 10,000 cells/ml during the bloom period. The density of the blooming alga began to decrease in early November as water temperature decreased, and *C. polykrikoides* disappeared on the 7th of November by sinking to the bottom. About 6 billion won (equivalent to U.S. $750,000) of monetary losses in aquaculture industry were estimated. During the blooming period, temperature ranged between 18 and 22℃, and salinity ranged between 32 and 33‰. A bloom by *C. polykrikoides* occurred in the eastern part of the southern coastal waters near Tongyong, Geoje, and Pusan in August of 1994. The worst algal bloom happened by the same dinoflagellate, *Cochlodinium,* from September to October of 1995. It was the largest blooms in scale historically, covering whole southern and southeastern coastal waters of Korea. It has resulted in the monetary losses of more than 40 billion won (it is equivalent to 51.3 million US dollars.) in mariculture industry and fisheries. In 1995, *Cochlodinium* was first found in the offshore water and spreaded to the coast. Zooplankton abundance was very low where *Cochlodinium* was abundant, however, it was relatively high where *Cochlodinium* was found with other phytoplankton such as *Ceratium* and *Noctiluca.* This observation drew a suggestion that toxic algae possibly excluded zooplankton. The bloom by *Cochlodinium* happened again in the same waters in September and October of 1996.

The causes of the 1995 bloom by *Cochlodinium* suspected were use of too much dispersants after oil spill accident, eutrophic condition by nutrient input from the land and resuspended sediment by storm, and optimal temperature condition. The experimental results on the mortality of zooplankton due to the dispersants showed that mortality of them significantly increased when they were exposed to dispersants (Kim et al., in press). This result suggests that decreased zooplankton grazing pressure on phytoplankton due to high mortality may be one of the trigger of the red tide.

BIOLOGY AND ECOLOGY OF *Cochlodinium polykrikoides*

Dinoflagellates are the most important causative organisms of red tides, but diatoms, ciliates, and euglenoids can also cause red tides. In the southern coastal waters of Korea, 16 species of dinoflagellates, 13 diatoms, and 1 species of ciliate have been reported as red-tide causative organisms. There are about 30 species of phytoplankton reported to be toxic in Korea, and *Cochlodinium* is known as one of the toxic algae (Table 2). *Cochlodinium polykrikoides* (= *C. heterolobatum*) isolated from the eastern Seto Inland Sea were reported to be toxic to the juvenile fish in laboratory tests (Yuki and Yoshimatsu, 1989). This species is widely distributed in the coastal waters of Korea and Japan. Three toxins (neurotoxic, hemolytic and hemagglutinative) separated from *Cochlodinium* type '78 Yatsushiro occurring along the coast of Kagoshima, Japan, were used for ichthyotoxicity test by Onoue and Nozawa (1989). The test fish died within 4~10 minutes after exposures to the neurotoxin fractions (0.01-0.02%). On exposures to the hemolysin and hemagglutinin fractions (0.02%), fish also died with a marked mucous release on their gill filaments.

Table 2. Toxic flagellates reported in the southern coastal waters of Korea from 1984 to 1991 (from Lee *et al.*, 1993).

PSP causative algae	DSP causative algae	Other toxic algae
Alexandrium catenella	*Dinophysis acuminata*	*Cochlodinium polykrikoides*
Alexandrium tamarense	*Dinophysis fortii*	*Gymnodinium breve*
	Dinophysis rotundata	*Gymnodinium mikimotoi*
		Chattonella antiqua
		Chattonella marina

Solitary cell of *Cochlodinium* is ellipsoid and slightly flattened dorso-ventrally, 30~40μm long and 20μm wide. It forms short chain consisting of less than 8 cells. This species produces a resting cyst, which sinks to the bottom, lying latent in the sediments until external triggers cause its germination to the plankton. This species are usually found in the southern coastal waters of Korea in

September and October, when the water temperature is about 18~23℃.

Cochlodinium blooms were reported in many countries such as the United States, China, Japan, Costa Rica and Panama. The followings are the summaries of the *Cochlodinium* bloom reported by now. *Cochlodinium heterolobatum* occurred in bloom concentrations mixing with *Ceratium furca*, *Gymnodinium splendens* (*G. nelsonii*), *Noctiluca scintillans*, and *Gyrodinium aureolum* in the lower Chesapeake Bay, USA, from early July to mid-September 1992 (Soucek and Marshall, 1993). *Cochlodinium heterolobatum* had an extended bloom at concentrations of 10^5 to 10^6 cells/l along the western margin of the Bay from mid-August to mid-September. However, no fish kills were associated with the bloom. An unusual red tide by the toxic dinoflagellate *Cochlodinium* sp. "type 90" occurred in the coastal area from Weitou Bay to Quanzhou Bay, China, during mid-June 1990 (Qi *et al.*, 1993). Although mass mortality of fin fishes and shellfish was observed, no cases of human poisoning was reported. Meteorological conditions of cloudy days for more than one and a half months before the bloom and nutrient supply by the floods of rains were suggested as causes of the red tide. *Cochlodinium* blooms were also reported in the tropical waters. Red tides by *Cochlodinium catenatum* occurred in Costa Rica. The maximum concentration of cells was 8×10^4/ml. Four-celled colonies dominated in natural samples, while in culture, unicells and pairs were more common. Environmental conditions controlling initiation and termination of blooms were unknown. The red tide was apparently non-toxic (Hargraves and Viquez, 1981). In the second half of 1985, mass mortality of reef fishes and invertebrates, especially reef corals, occurred during blooms of the dinoflagellates *C. catenatum* and *Gonyaulax monilata* in the coral reefs in Costa Rica and Panama (Guzman *et al.*, 1990).

IMPACTS OF PHYTOPLANKTON BLOOMS

Phytoplankton blooms can cause mass mortality of marine organisms by depletion of dissolved oxygen as a result of bacterial activity on organic materials, and by asphyxiation through a blocking the fish gills with a mass of phytoplankton. Mass mortalities of marine animals due to bloom-related anoxia and hypoxia have been frequently reported around the world. As mentioned above, the bloom by *Cochlodinium* caused mass mortality of marine living resources especially in aquaculture ground. Even though mass mortality of fishes was found during the 1995 bloom by *Cochlodinium*, no shellfish poisoning was reported. *Cochlodinium* *polykrikoides* is known to be toxic, however, water soluble and chloroform soluble fractions extracted with methanol from it did not show any ichthyotoxicity at the concentration of 5mg/ml. Also paralytic shellfish toxins or diarrheic shellfish poisoning toxins in these fractions were not found on the fluorometric HPLC chromatograms (Lee, 1996). Toxicity of *Cochlodinium* has not been actively studied yet. Considering popularity of eating raw seafood in Korea, intensive studies on various shellfish toxins will be necessary in the future.

FUTURE RESEARCH PLAN

The 1995 bloom was a great shock to not only fishermen but also politicians, and it bacame a trigger for the government to understand necessity of red-tide research. Finally the government began to set up the research plan and budget for the research. The Ministry of Maritime Affairs and Fisheries, the Ministry of Environment, and the Ministry of Science and Technology asked research institutes and universities to prepare research proposals concerned with red tides and harmful algal blooms. Korea Ocean Research and Development Institute(KORDI) prepared a research proposal for red-tide studies, which includes development of red-tide forecasting and monitoring system using satellites and other remote sensing devices, development of biomanipulation techniques using parasites or grazers to reduce harmful algal cells, and development of new materials to prohibit the growth of harmful algae. Biomanipulation techniques using grazers may be valuable to manage algal blooms, because grazing pressure is one of the important factors to control phytoplankton population. Although dinoflagellates are subject to grazing pressure from various grazers, some toxic dinoflagellates seem to discourage them, especially copepods which are the most important grazers. Thus it will be important to find alternate grazers which are not affected by the dinoflagellate toxins. Tintinnids and polychaete larvae are believed to be the efficient grazers on toxic dinoflagellates (Kim and Chang, 1992). If we have sufficient knowledge on the bloom dynamics and trophic interactions between blooming algae and their grazer, it will be possible to develop a biological method to control harmful algal blooms through food webs.

As monitoring of phytoplankton has been carried out over 10 years, there is significant knowledge on the red tides and harmful algal blooms. South Sea Fisheries Research Institute of the National Fisheries Research and Development Agency(NFRDA) is conducting algal bloom monitoring in the southern coastal waters.

NFRDA is also supported by the Ministry of Maritime Affairs and Fisheries to run the Red-tide Research Center for the continuous monitoring. Taxonomy and ecology of causative organisms are relatively well known, and toxicological studies of some dinoflagellates are being performed. However, knowledge on the dynamics of phytoplankton blooms and prediction of their occurrence is still very limited. Thus what we have to do in the future is to make a prediction model of red tide and to develop a new biological method for the control of algal blooming dynamics.

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Recent Ocean Environmental Improvement Technology in Japan

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Abstract

The disappearance of shoals and beaches, vital as the habitats of marine organisms, disrupts the ecosystems in those areas. To ameliorate the situation, an urgent task is to improve the environments of marine habitats as well as coastal physical environment in general.
In this paper, "New port and harbor environment policy" which was established by the Ministry of Transport is mentioned. Then recent technology for environmental creation which was developed in Japan are introduced.

1. Introduction and back-ground

Japan is a small island country surrounded by the sea. It has a land area of 370,000 square Kilometers and the length of its coastal line is 34,000 Kilometers. The population is currently about 120,000,000 and nearly 70 of this total lives in coastal areas. Since old times, the seas have been widely used for the fishing industry and transport utilizing ships. Particularly since the conclusion of World War II, land reclamation and the construction of offshore man-made islands has proceeded in the ocean space including coastal areas and these have been used as sites for factory production, distribution using ports and other facilities, the marine products industry, electric power and energy bases, and also as recreational sites. On the other hand, this use of this coastal area has had an extremely large negative impact on the marine environment. Generally, the sea areas for which use was simple were inlets or inland seas in which the water depth was shallow and the waves calm.
However, these inlets and inland seas are also extremely important sites for the loving organisms of the sea. Therefore, this reclamation and high density use of the sea areas has taken away the habitat of these living organisms to the point in which they even endangered the lives of humans. It is understood that use of the sea has entered a new stage in recent years in correlation with the increasing awareness concerning global environmental problems and also the issuing of the United Nation's Convention on the Law of the Sea.
The Law of the Sea is the first document to clearly state that the seas are the possession of humanity, and it also indicates the duty of humanity to preserve the marine environment.
In other words, not only should environmental preservation be pursued when using the sea but coastal countries are also interpreted to possess the duty to manage sea areas used by them in place of humanity.
As mentioned above, Japan has caused a variety of environmental problems in correlation with its use of coastal areas.
Under these circumstances, Japanese government recently established a new port and harbor environment policy. In this paper, first of all, this new policy is introduced and then ocean environmental technology which was developed in Japan is explained.

2. A new port and harbor environment policy

Japanese government established new environmental policy in 1994(1994, Ministry of Transport). In this paper, port and harbor environmental policy was introduced as follows.

1) Basic concept of the policy

(1) Conserving the rich port environment for future generations:

Reducing the load on the environment caused by the development and utilization of ports and harbors. While making efforts to conserve and create coastal environment, the goal will be to build a user friendly, attractive port that also facilitates product distribution, industry and provides a livable environment. Improving amenities and handing down a rich port environment to our future generations.

(2) Coexisting with living creatures, the ecosystem and the natural environment:

The coastal areas are important because of three reasons; the first, they support and are the breeding ground for marine life and birds; the second, they are a place where people can feel close to nature; the third, beaches and tidelands clean sea water. While conserving and restoring the invaluable nature environment of the coastal regions, we will develop ports that can coexist with living creatures and the ecosystem.

(3) Creating a port environment which is rich in amenities:

In order to realize a high quality of life befitting a mature society, promoting the development of an amenity rich port environment which will pat a central role on the waterfront. Also, fully recognizing the assets of port areas, developing a unique character and attractiveness which will be appreciated well into the future.

2) Goal - The future of a port which coexists with the environment

(1) Creating a port which blends in with the surrounding natural environment and takes living creatures into full consideration.

- Conserving the rich natural environment of the shoals and tidelands.
- Designing the shapes and structure of port facilities so that their impact on the sea currents and water quality will be minimized.
- Taking due consideration of living creatures and the ecosystem, and implementing measures to reduce any adverse effects.

(2) When constructing a port, aggressively implementing measures to create a high quality natural environment.

- Cleaning the water quality and bottom sediments by dredging sludge, covering with sand, and with catalytic oxidation using gravel (gravel contact aeration).
- Utilizing the naturally growing plants, planting greenery in public facilities, and creating green spaces by planting greenery
- Constructing beaches, tidelands and shoals, creating habitats for living creatures.

(3) A port which offers high quality amenities, a resting place where people can enjoy themselves.

• Developing a waterfront which facilitates appreciation of water, and networking.
• Developing a scenic landscape, and utilizing the historical port facilities.
• Developing facilities with due consideration given to the needs of the disabled and senior citizens.

(4) Creating a port with little impact on the environment, a ports where the environment is fully managed.

• Reducing the load that will be placed on the environment when ports are constructed and utilized.
• Facilitating energy and resource conservation, recycling.
• Having a full understanding of the environment, and its appropriate management.

3) Basic measures for attaining the goal:

(1) Formulating the port environment master plan
The port authorities will be responsible for overseeing activities to identify the current status and challenges, for formulating basic policies aimed at developing the Eco-Port, and for planning, designing, constructing and utilizing measures for conserving and creating the environment.
(2) Thorough environmental assessment:

Accumulating environmental data, promoting the improvement of forecasting and evaluation technology, with particular emphasis on improving technology for forecasting and evaluating living creatures and their habitat.

(3) Redevelopment of the port environment:
Technology for conserving and creating the environment, developing port facilities, improving the environment throughout the area, contributing to preserving the global environment.

(4) Promoting environmental management:
The port authorities must be responsible for adequately managing the environment, based on the port environment master plan, with the cooperation of related organizations. Efforts must be made to reduce the load on the environment while constructing and utilizing ports.

(5) Strengthen measures to support the plan:
Efforts will be directed towards promoting research and development activities pertinent to the environment. Responsibilities will be clearly allocated and defined, the budget and resources for the initiatives will be secured, and cooperation between the local community and public administrators will be promoted.

3. Recent technology for environmental creation

It is necessary and important to prevent/preserve the environment and many environmental preservation techniques have been developed and applied to the concerned area where was necessary to improve. Generally, it is difficult to recover their environments once they have been destroyed. On the other hand, technology for environmental creation has also been developed. The differences between preservation and creation is that, former means to improve the environment(restoration) and later means to newly produce/birth a preferable environment (creation).

Table 1 shows the matrix for environmental creation theme and creation technology and several environmental creation technology was briefly described

3-1 Gravel contact purification method:

As can be shown in Photo 1, the gravel contact purification method is a system that, when sea water passes through spaces between gravels, the film of microbes living on the surface of gravels decomposes organic pollution substances, contained in the sea water. In other words, water purification function of a natural seashore is artificially enhanced. At present, experimental facilities are constructed in the port of Amagasaki and related study has been operated(Port and harbor Bureau 1994).

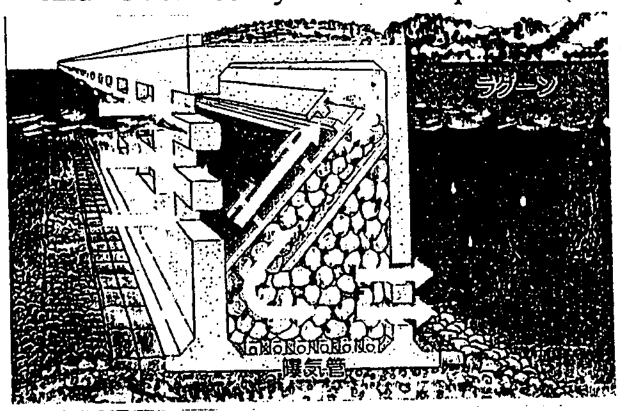

Photo 1. Breakwater by gravel contact purification method

Photo 2. Concrete block using ferrous sulfate for algae community

3-2 Ocean creatures plantation technology:

Port and harbor structures are required to have environmental functions as well as wave protection functions. Therefore, shore protection constructions and waterbreaks that allow seaweeds to adhere on. In other words, fishery-harmonized type constructions are being developed. Development sites include Okinawa and other area.

3-3 Water quality control and algae adhesion concrete structure:

In coastal areas, concrete has been used as a structural materials for breakwaters, revetments and many other offshore structures
However, once concrete structure are submerged in the water, they liquate out a strong alkaline composition into the sea water for a long time, occasionally converting the surround water area into a strong alkaline region with pH value 10 to 11 for seawater and 13 for fresh water. Figure 2 shows a concrete block which was transformed its surface with ferrous sulfate. Ferrous sulfate is using to prevent lease out of carbon hydroxide from concrete as well as an essential element for algae growing.

3-4 Wave-power extracting caisson breakwater

Up and down motion of waves is converted to the flow of oil in an air chamber equipped in a caisson, and a turbine is rotated to convert wave energy to electric energy, in the breakwater. A system of this type is constructed in the port of Sakata and is shown in Figure 3.

3-5 Dual cylinder caisson:

Table 1. Matrix for environmental creationtior

Environmental creation theme(objective and methord) \ Environmental creation technology			Beach	Tideland	Algae ground	Taide pool	Reef	Lagoon	Offshore discharge	Living filter	Dredging/covering	Channel/sakurei	Sand by-pass	Gravel contact bulkhead	Aeration bulkhead	Break water	Gentle slope revetment	Low rise step revetment	Head land/ jetty	Offshore revetment Submarged break water	Wave permeable break water	Ocean creature plantation structure	Amenity break water	Beach park/walking road	Brackish area
Creation of Marine Environment	Growth environment of living creature	Growth area	●	●	●	●	●	●	●	●				●			●				●	●			●
	Sea area purification: Depollution of sources	Cutback of inflow load																							
		Forced diffusion							●																
	Sea area purification: Sea water prrification	Removal of SS	●																						
		Precipitation/filteration	●																						
		Aeration				●									●	●									
		Dilution										●													
		Sea water installation/exchange										●													
		Bio attack/absorption	●	●		●		●		●				●			●					●			
		Supply oxygen/photosynthesis			●	●	●			●															
	Sea area purification: Bottom purification	Removal/displacement/cover									●	●													
		Purification by bentos	●	●		●		●		●	●	●													
	Sea area purification: Beach cleaning	Clean rubbish																							
		Predation by animals	●	●		●				●															
	Erosion prevention	Wave control				●			●							●			●	●	●	●			
		Control bottom sediment				●			●										●	●	●				
		Supply of bottom sediment											●												
	Calmed sea area	Wave control					●	●								●			●	●	●	●			
	Amenity	Improvement of amenity	●	●		●		●		●							●	●	●				●	●	●
		Improvement of view	●	●	●	●	●	●		●							●	●	●				●	●	●

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Using a cylindrical structure, the breakwater allows incident waves to crush with each other in the cylinder to dissipate wave energy(see figure 4). This type of breakwater is most suitable for a seaside of large depth or high tide. After completion of a demonstration test in the port of Sakaiminato, a breakwater of this type was also introduced in the port of Shibayama, Hyogo Prefecture.

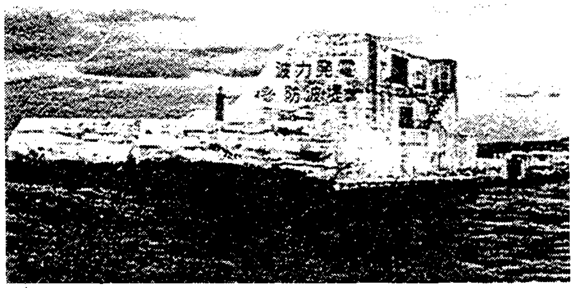

Photo 3. Wave-power extracting caisson breakwater

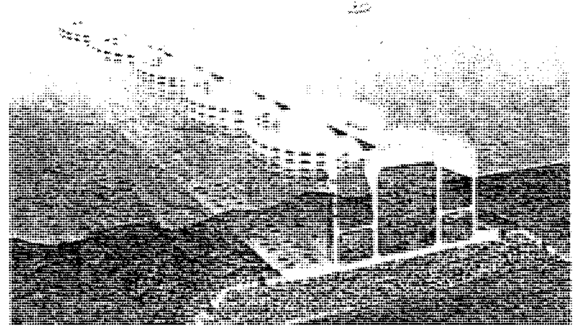

Photo 4. Dual cylinder caisson type of breakwater

3-6 Semicircular caisson:

With this breakwater, wave force acts vertically and downwardly by making the shape of a caisson semi-circular, thereby a sliding resistance of the caisson is increased for anti-wave stability. As can be shown in Figure 5, this type of caisson is most suitable for an area with a high tide or a soft ground base. A caisson of this type is being tested for demonstration, presently in Miyazaki port.

3-7 Long caisson breakwater:

Making a caisson long and large can smoothen acting wave force, and thus the section of the caisson can be reduced. Other advantages of this type of caisson include shorter construction period and lower construction cost. This type of caisson is used in the port of Kochi(see Figure 6)

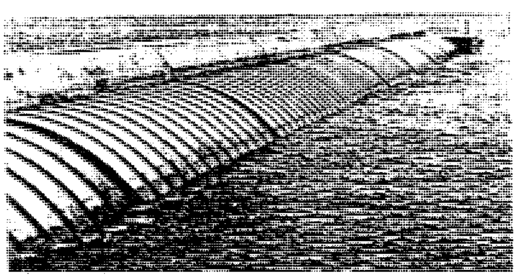

Photo 5. Semicircular caisson type of breakwater

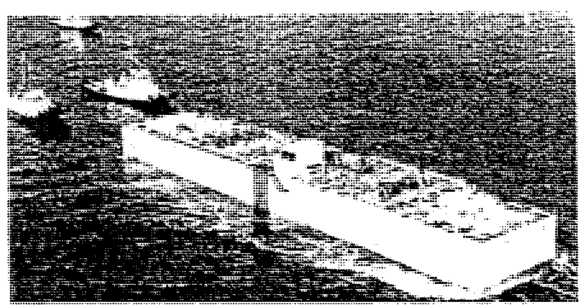

Photo 6. Long caisson type of breakwater

3-8 Promenade breakwater:

People can take a stroll on the pier, while enjoying a beautiful view to the sea, like a walkway at the seaside(see Figure 7). Similar piers were already constructed in Wakayama Marina City . Admission of the handicapped and safety of users are assured with particular precautions, and computer graphics was fully used in designing the pier, to construct a beautiful sight.

3-9 Zone coastal protecting complex technology:

Zone coastal protecting complex systems combine an offshore waterbreak, a sandy beach, a gentle slope of revetment(see Figure 8). Using systems , even a low-profile pier can ensure satisfactory safety and a beautiful view and seaside.

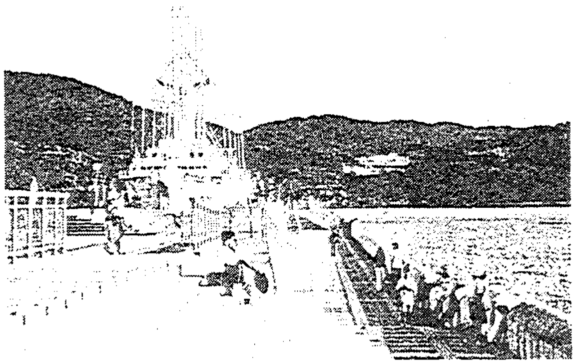

Photo 7. Promenade breakwater

Photo 8. Wave breaking system using underwater barrier

3-10 Jetty and head-land:

As can be seen in Figure 9, jetty is a structure sticking out toward offshore for sand stability and a jetty having an anchor shape of head at the end is call Head-land. Head-land construction is a useful method, not only preserving coast but also forming a sand beach at the inside of Head-land (Hioshi Nishiumi 1995).

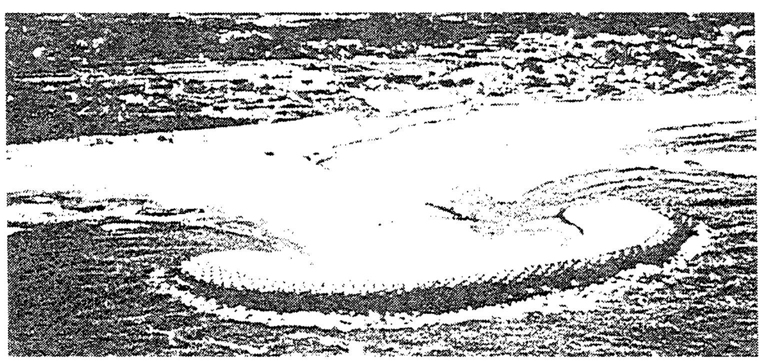

Photo 9. Head land

4. Conclusion

At present, research and technology development on mitigation is very active in Japan and preliminary study on mitigation and its future direction as well as its implementation has been studied by the government. There is no doubt that technology for environmental creation is a useful measure of the mitigation.
In this paper, recent technology on the environmental creation was briefly introduced. However, these technology are not all-mighty, of course, and depending on the condition of concerned area these technologies might not to solve the problems including economic feasibility. Therefore, consideration on its effects and selection of appropriate technology will be necessary.

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RESEARCH ON DRAINAGE PROBLEMS IN JAPAN'S FISHING PORTS AND VILLAGES AND ITS EFFECT UPON DEVELOPMENT

(CASE STUDY FOR KOIZU FISHING PORT, SHIMANE PREFECTURE)

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ABSTRACT

The fishing ports are, in general, located in the comparatively tranquil water areas such as inner bay, creek and inland sea and even the ports facing the ocean have the layout so surrounded by a variety of the protective facilities like breakwater. The sea water in such ports, therefore, tends to stand, and this is deemed to be one factor of demerits against water quality conservation. Since 1978, the drainage facility development has been promoted under the synthetic fishing village environmental improvement plans in order to cope with the increasing needs for prevention of water pollution in mooring basin and sea area to be caused by both discharge relating to fisheries and domestic wastewater from the hinterland.

In 1996, the number of the district where the wastewater treatment facilities in the fishing village have been implemented amounted to 268 districts (inclusive of the planning stage districts). Such districts are forecasted to be more and more increased in future.

It is noted that a quantitative analysis on water quality in mooring basin and water area has never been pratically performed. This reserch aims at making investigation and evaluation on water quality before and after the use of such treatment facility so as to realize the extent of water pollution prevention in the ports from a viewpoint of quantitative analysis.

INTRODUCTION

1.Basis of site selection :

To select the most preferable site for this reseach, the following conditions were taken into consideration ;

①The waste water treatment facility in the fishing village is on a conventional and standard level in the capacity.

②Drainage system to the fishing port and sea area is not so complicated.

③Items of discharge load to the fishing port and sea area are not so many.

④Items of factors influential to water quality are a few.

⑤Change in population is not so intensive.

⑥Any development plan of the protective facilities of the fishing port is not mapped out during the research period.

⑦Any large-scale development plan is not mapped out in the ambient area during the research period.

⑧Analysis of test samples can be carried out whenever necessary at any local facility.

2.Selected site :

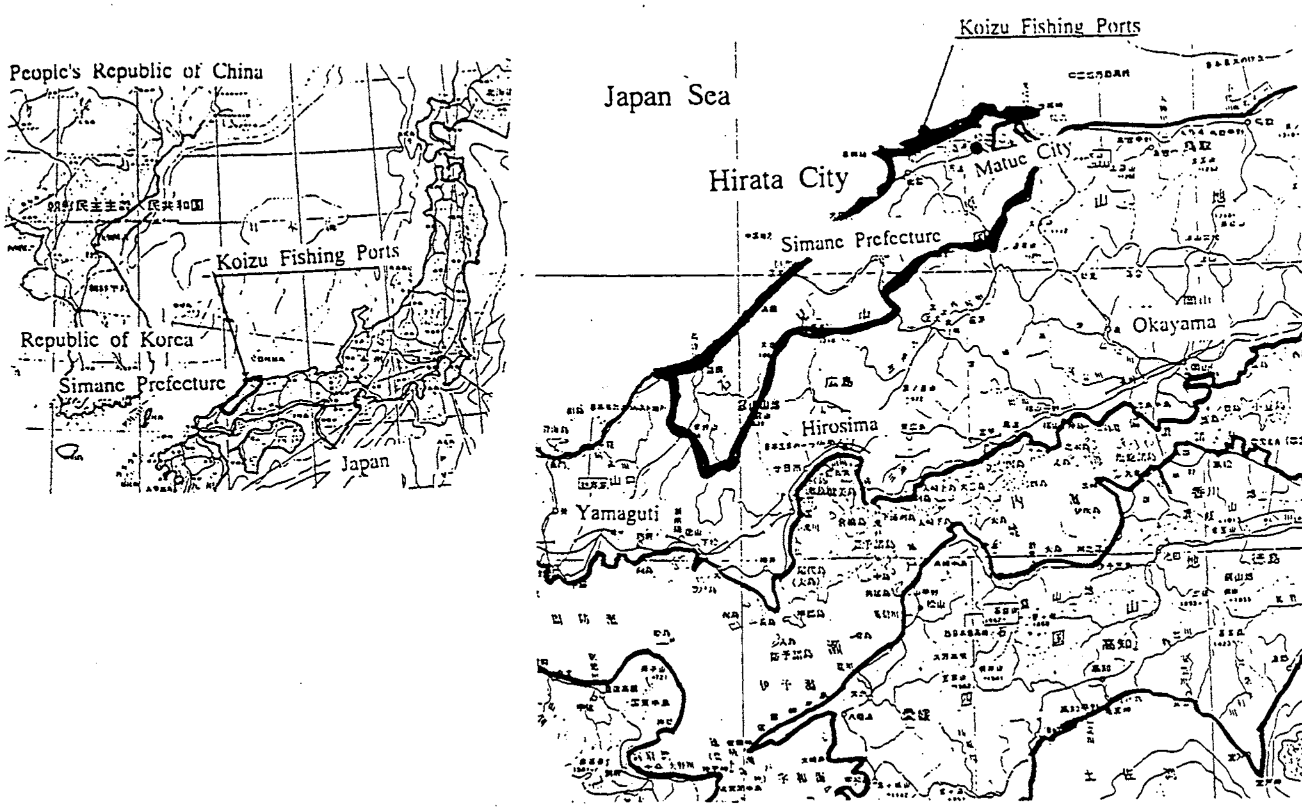
The waste water treatment facilities in the fishing villages were investigated throughout Japan, in accordance with above-mentioned site selection basis. As a result, the following site was selected.

Koizu(Miura)district, Hirata City, Shimane Prefecture.

(1)Location

Hirata City located in the eastern part of Shimane Prefecture, adjoining Matsue City in east, Taisya-Mati in west, Izumo City in south, and facing the Sea of Japan in north. Miura district is the northern part of Hirata City, 8Km off or accessible in about 15 minutes by car from the town center.

Fig-1 : Location Map



(2) Villages :

Miura, district consists of 4 villages viz Mitsu, Nishitani, Nakamura and Sugasawa. (Fig-2)

(3) Drainage system :

The wast from Nishitani and Nakamura villages is discharged into the Mitsu river, and then after passing along Mitsu village to the fishing port. The waste from Sugasawa is discharged into the Ohtani river, and to the fishing port after running into the Mitsu river. (Fig-2)

(4)Population • Household :

	Year	1980	1990
Hirata City	Population	31067	31352
	Household	7343	7486
Miura District	Population	942	917
	Houschold	241	246

(5) Present situation of drainage :

① Domestic drainage :

Gray water : This is discharged to the street gutter together with rain water , and to the fishing port after running into the Mitsu river.

Night soil : This is collected and disposed by the vacuum car once a month , which is, however, insufficient in services due to narrow structure of the village.

② Fishery drainage :

Discharge water from fishery processing field :

Ita-Wakame, a famous processed good, is produced during February to June, through drying after rinse. In rinse process, waste water runs out, but concentration is so low. That is domestic fishery gray water.

Waste from auction shed :

Local fisheries are long-line fisheries to catch cuttlefish. Yellowtail, Gill net fisheries to catch yellowtail and flying fish, collection of seaweeds, shells and Wakame culturing, as the coastal fisheries with the fishing boats of less than 3 gross tonnage on an average. Without auction the catch is dirtrbuted after metering to the Matsue markets by the fishery Cooperative organization. Little blood-stained water runs due to flesh fish and case-delivery basis.

③ Agriculture drainage :

Waterfield rice cultivation is carried on a small scale in the terraced field along the basin of the river, with the area of about 2 ha.

④ Others

Discharge load to the fishing port is small due to narrow basin area, but on the occasion of heavy rain the fishing port becomes muddy to some extent by the discharge mixed with earth and soil from the farms · waste land.

RESEARCH

1. Scheme:

(1) Measuring method :

water quality and quantity are, in principle, to be measurred on a progress of utilization rate at the measuring stations set up in the fishing port. Measuring is planned to be conducted at there levels ;nil, 50% and 100% utilization rates on the treatment facility. Measurement is for the purpose of checking the pratical effect of the drainage system improvement works.

(2) Measuring stations :

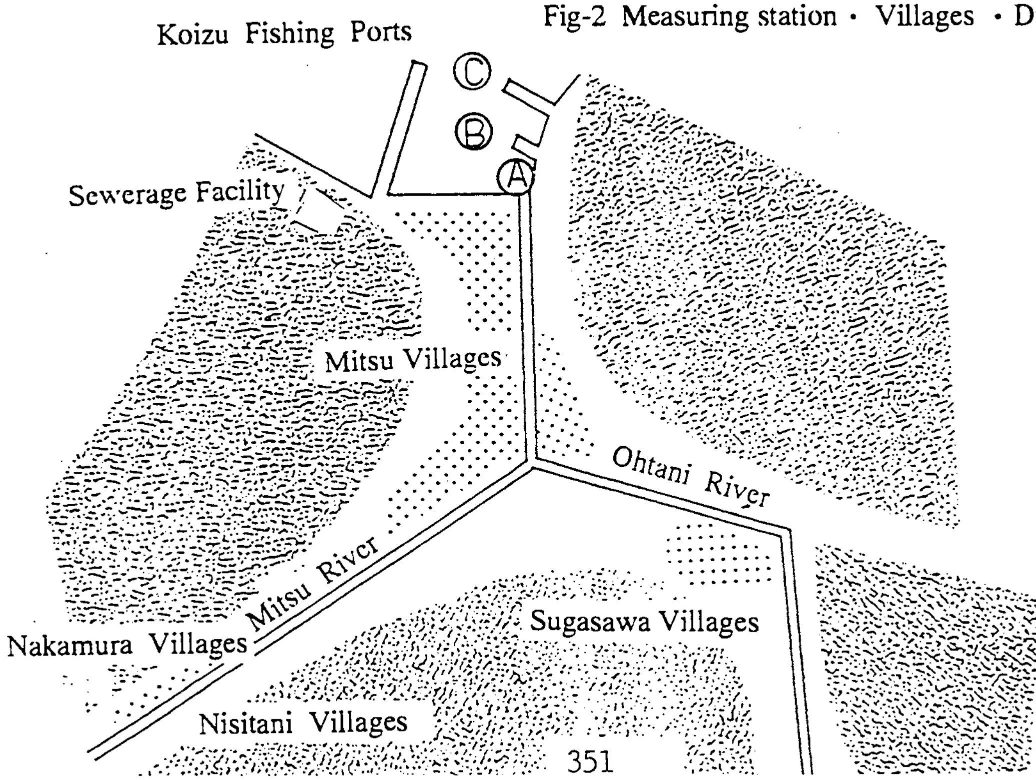
The following 3 points were set up as the measuring station ;

① A point near river-mouth of the river flowing into fishing port · · · · A Station

② A point on border line between the fishing port basin and ocean · · · · C Station

③ A point at middle between ① and ② · · · · · B Station

Fig-2 Measuring station · Villages · Drainage system



(3) Measurement Time Schedule :

1st.Measurement	17Feb.1994	At nil utilization rate
2st.Measurement	28Feb.1996	At 50% utilization rate
3st.Measurement	Pending	At 100% utilization rate

(4) Measuring Time

8:00、10:00、12:00、14:00、16:00、18:00、20:00

2. Water quality survey

(1) Measured Items

COD	(Chemical Oxygen Demand)	mg/ ℓ
DO	(Dissolved Oxygen)	mg/ ℓ
SS	(Suspended Solid)	mg/ ℓ
T-N	(Total Nitrogen)	mg/ ℓ
T-P	(Total Phosphorus)	mg/ ℓ
pH		
Transparency		c m
Water Temperature		℃

(2) Sampling Method

Direct sampling by water-bottle.

3. Water quantity survey ;

(1) Measuring station :

A station near river -mouth of the river flowing into the fishing port.

(2) Measuring Method :

As the current meter cannot be used due to shallow waterdepth at the site, the section 10m lpng along the river stream was set up, and the velocity was calculated by measuring drifting time of the float.

(3) Number of sampling:

Same as for water quality survey at A Station.

MEASUREMENT RESULTS AND CONSIDERATIONS

1st. Measurement Results (1994)

Measuring time		8:00	10:00	12:00	14:00	16:00	18:00	20:00	Average
A station	Water Quantity	4.16	4.43	4.32	4.33	4.28	4.46	4.07	4.29
	Temperature	6.4	6.7	7.8	8.4	7.6	6.6	6.0	7.1
	Transparency	86	72	80	84	92	81	91	84
	DO	10.1	8.5	9.6	11.2	11.9	11.7	10.16	10.5
	pH	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
	COD	3.0	4.9	5.1	4.7	3.7	3.1	3.0	3.9
	SS	5.1	7.5	5.7	5.1	5.8	6.8	6.1	6.0
	T-N	0.61	0.75	0.55	0.57	0.62	0.73	0.67	0.64
	T-P	0.066	0.079	0.069	0.071	0.057	0.049	0.046	0.062
B station	Temperature	11.0	11.0	11.5	11.7	11.8	11.8	11.8	11.5
	Transparency	83	81	78	83	91	98	>100	88
	DO	11.3	11.3	11.6	11.9	11.8	11.1	11.2	11.5
	pH	8.1	8.2	8.1	8.1	8.2	8.1	8.2	8.1
	COD	2.7	3.1	3.5	3.5	3.4	3.6	2.8	3.2
	SS	3.8	3.1	3.6	3.7	3.3	3.5	3.6	3.5
	T-N	0.41	0.45	0.46	0.44	0.49	0.55	0.51	0.47
	T-P	0.027	0.029	0.031	0.038	0.041	0.055	0.045	0.038
C station	Temperature	11.3	11.4	11.5	11.6	11.8	11.5	11.3	11.5
	Transparency	>100	99	98	95	>100	>100	>100	99
	DO	11.2	11.5	12.5	11.4	12.7	12.5	11.6	11.9
	pH	8.1	8.1	8.1	8.2	8.1	8.1	8.1	8.1
	COD	2.2	2.2	2.1	2.1	2.1	2.2	2.1	2.1
	SS	3.8	3.7	3.4	3.2	3.1	3.4	3.0	3.4
	T-N	0.32	0.31	0.31	0.32	0.29	0.29	0.25	0.30
	T-P	0.045	0.041	0.045	0.044	0.045	0.048	0.05	0.045

Unit : Water Quantity : m^3/min. Temperature : ℃ Transparency : c m
DO・COD・SS・T-N・T-P : mg/ℓ

The change by time of water quantity at AStation shows the peak at 10:00 and 18:00. This is deemed to be caused by domestic waste water. The rate of water pollution corresponds to the change of water quantity, and this demonstrates that the cause of such pollution is domestic waste water.

Trial calculation of COD loading amount

(1)Domestic drainage

Assumption:

Population is, 920 for permanent and 30 for temporary water demand

Water demand is 150 ℓ × 920+200 ℓ × 30=144 m^3/day

COD concentration is , 150mg/ℓ

Loading amount is , 144 × 150 × 1/1000 = 21.6Kg/day

(2)Agriculture drainage

Assuming that the paddy field area is about 2ha and COD concentration is 5mg/ℓ, loading amount is, $200 \times 5 \times 1/1000 = 1$Kg/day

(3)Natural drainage

The basin is narrow , and there is no specific conditions (Golf Course.Dumping area,etc.) to be taken into consideration. So loading amount is estimated to be 1.0Kg/day.

To sum up the above-mentioned (1)(2)and(3),21.6+1.0+1.0=23.6Kg/day

Besides average flow rate is 4.29m³/min,therefore, assumed water quality is,

$23.6/4.29 \times 60 \times 24 \times 1000 = 3.8$mg/ℓ

This value is nearly equal to the measured average COD of 3.9mg/ℓ and indicates the reasonable estimated loading amount.

2st. Measurement Results (1996)

Measuring time		8:00	10:00	12:00	14:00	16:00	18:00	20:00	Average
A station	Water Quantity	4.63	5.13	4.78	4.95	5.55	5.01	5.16	5.03
	Temperature	5.3	6.6	8.2	9.0	9.3	8.0	7.0	7.6
	Transparency	>100	>100	94	93	85	80	>100	93
	DO	11.2	11.4	11.8	11.79	10.72	9.98	10.16	11.0
	pH	7.8	7.9	7.9	7.9	7.8	7.6	7.8	7.8
	COD	2.4	2.6	2.5	2.5	2.5	2.8	2.3	2.5
	SS	4	4.2	4.1	4.3	3.8	4.4	3.9	4.1
	T-N	0.35	0.39	0.4	0.37	0.35	0.28	0.25	0.34
	T-P	0.026	0.033	0.034	0.028	0.024	0.028	0.021	0.028
B station	Temperature	10.2	10.4	10.4	10.6	10.5	10.5	10.4	10.4
	Transparency	97	94	98	>100	98	97	>100	98
	DO	11.5	11.6	11.8	12.5	12.3	11.8	11.9	11.9
	pH	8.1	8.2	8.2	8.2	8.1	8.2	8.2	8.2
	COD	2.2	2.1	1.9	2.1	1.9	2.1	2.3	2.1
	SS	2.8	2.9	3.3	3.2	3.1	2.6	2.2	2.9
	T-N	0.27	0.29	0.27	0.26	0.22	0.22	0.21	0.25
	T-P	0.033	0.035	0.037	0.036	0.034	0.034	0.033	0.035
C station	Temperature	9.8	9.9	10.2	10.2	10.1	10.1	10.1	10.1
	Transparency	>100	>100	>100	>100	>100	>100	>100	100
	DO	11.8	11.8	11.9	11.8	12.1	12.4	12.1	12.0
	pH	8.2	8.2	8.2	8.2	8.1	8.1	8.2	8.2
	COD	2.1	2.1	2.2	2.2	2.1	2.1	2.0	2.1
	SS	2.4	2.5	2.5	2.6	2.7	2.4	2.5	2.5
	T-N	0.19	0.15	0.22	0.19	0.18	0.21	0.25	0.20
	T-P	0.019	0.018	0.018	0.017	0.015	0.019	0.015	0.017

Unit : Water Quantity : m³/min. Temperature : ℃ Transparency : c m
DO・COD・SS・T-N・T-P : mg/ℓ

Comparison analysis

1) A Station

The change by time of water quantity in 2nd. Measurement shows same peak as in 1st. Measurement, and this demonstrates the effect by domestic waste water.

Transparency · DO have been improved, but the effect by domestic waste water are observed from a viewpoint of correlation with water quantity.

COD loading amount is estimated as follows,

Domestic drainage is , 21.6/2=10.8Kg/day

Other loads are constant,viz 2Kg/day Total 12.8Kg/day

Average flow rate is , 5.03 m^3/min therefore, assumed water quality is ,

$$12.8/(5.03 \times 60 \times 24 - 144/2) \times 1000 = 1.78 \mathrm{mg}/\ell$$

The difference between the above and the measured average value of 2.5mg/ℓ is 0.72mg/ℓ , while having improved by 1.4mg/ℓ as compared with 1st.Measurement results(3.9mg/ℓ), and this verifys the effect by waste water treatment facility. Other measured Items also indicate the improvement as compared with 1st. Measurement results, which demonstrates the effect by the treatment facility.

2) B Station

In the fishing port basin, transparency · T-N have been improved and other Items have been also slightly improved. This depends on the effect of utilizing the treatment facility.

3) C Station

2nd. measurement results show a little improvement as compared with 1st. Measurement, but the effect by ocean is strong and the characteristics of water quality in sea area come out.

At Owashi Beach Resort ; pH 8.1～8.3, DO 7.1～9.7, COD 0.9～2.2

Summary

Water quality improvement was verified by 2nd. Measurement at 50% utilization rate on the waste water treatment facility. Since this sort of measurement is liable to be affected by natural environmental conditions like change of water quantity, it was difficult to carry out the measurement under the same condition at the same time. Actually the measurement was accomplished at last after spending several days on stand-by. At the time of 2nd. Mesurement, it was more windy than at 1st.Mesurement and rather stormy in ocean , but such did not affect much the actual measurement. Future Mesurement at 100% utilization rate should be conducted under the same condition at the same time .

For that purpose, the detailed meteorological investigation must be done to enable the measurement to be carried out on the dates when no error on the measurment results is possibly foreseen.

In addition, there are several points to be taken into consideration such as increase or decrease of water quantity ・quality in natural drainage・agriculture drainage・fishery drainage・auction shed drainage as well as the natural environmental change over the wider local area.

The de-contamination in the fishing port is observed in a steady progress way,but it is further necessary to check the property and its effect of the sediments and also the effect of ocean.

It will take one year or two to achieve 100% utilization on the treatment facility, but pollution load (COD) at that time is estimated as follows ;

Pollution loading amour is, natural plus agriculture one =2Kg/day

Assumed water quality is,

$2/(5.03 \times 60 \times 24-144) \times 1000=0.28$ mg/ℓ

Therefore, the fishing port basin is forecasted to be de-contaminated in a great measure.

At C Station, the water quality might not be improved due to the effect of ocean, but it will not cause any further environmental deterioration .

The operation condition of the waste water treatment facility are as follows ;

Average amount of water treated

Year	1995	1997
m³/日	80.8	120

Average COD of water discharged

Year	1995	1997
mg/ℓ	21.1	28.5

This demonstrates that 81～86% of COD on influent have been eliminated.

As discharge points are in ocean outside of the fishing port, the fishing port basin suffers no influence.

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LAND USE AT THE COASTAL ZONE IN METROPOLITAN AREA

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ABSTRACT

This research employs a multi-dimensional spatial and historical approach to identify and analyze past, current and emerging trends in land utilization patterns along the northern coast of Tokyo Bay. The target area includes a strip of coastline several kilometers in width, and stretching from Urayasu in the west to Ichihara in the east. Quantitative data for six variables, Regional Planning, Existing Land Use, Population Density, Landfill History, Transportation Access and Distance from Waterline, were obtained and mapped on 100m X 100m grids. Correlation among the variables were also investigated.

The results show that industrial zoning and industrial uses dominate in areas near the waterfront, and that residential uses and population density increase as one moves inland. Problems identified included a lack of integration and coordination, especially in directions perpendicular to the coastline; difficulty of access to open space resources; and insufficient public coastal access. These problems were due to the history of landfill, during which industrial and residential areas were clearly separated; as well as poorly laid-out transportation networks, which strongly tend to function only in a direction parallel to the coast. Suggestions for improvements included increase in public access to the coast, more flexible restrictions on land use, and transportation systems which allow residents better access to open space and waterfront facilities.

INTRODUCTION

Most of the Tokyo Bay landfill development was implemented for industrial facilities during Japan's postwar period of high economic growth. Following the oil shocks of the early 1970s, however, patterns of trade, economy and industry changed rapidly. Transport of goods by air also increased. These changes have exerted a powerful effect on environment and land use patterns in the coastal zone. In recent years, waterfront redevelopment and coastal access, as well as provision of integrated urban functions within the existing landfill, have become important trends in coastal zone land use.

A single-dimensional study would be insufficient to understand and analyze these trends in coastal zone usage. This research thus employs a multi-dimensional spatial and historical approach, analyzing how formal zoning, actual land use and population relate to one another and to factors such as landfill history, transportation access and distance from the waterfront. The purpose is to understand past, current and emerging trends in Tokyo Bay coastal zone land use patterns, and to use this analysis to help identify points for future planning.

RESEARCH AREA

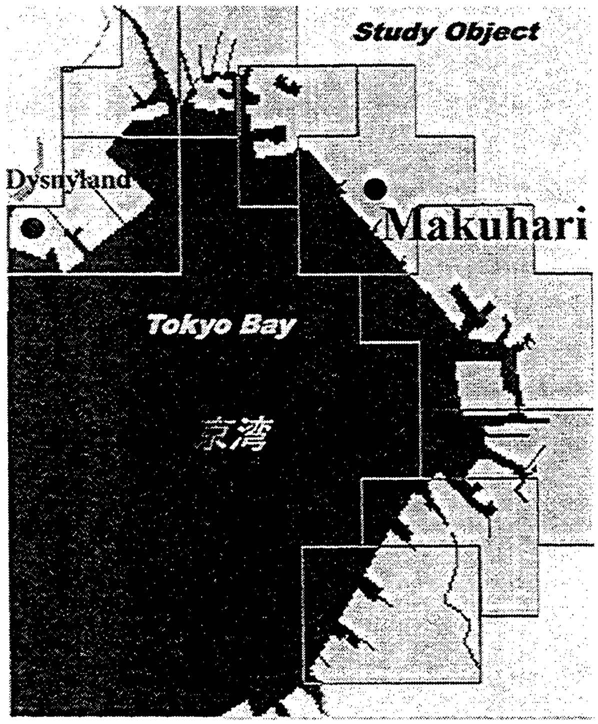

Figure 1. Research area

The area targeted by this research included the Chiba Prefecture coast of northern Tokyo Bay, a strip of coastline 2-3 km wide and stretching from Urayasu in the west to Ichihara in the east. This coast is mostly contained in the Keiyo Port Complex, with tranasportation, storage and heavy industrial facilities, but includes residential areas and facilities such as Tokyo Disneyland and Makuhari Convention Center.

RESEARCH METHODOLOGY

Quantitative data for six variables, Regional Planning, Land Use, Population Density, Landfill History, Transportation Access and Distance from Waterline, were researched and analyzed using 100m X 100m grids on 1/10000 scale maps. The data was mapped onto graphing software (Microsoft Visual Basic) worksheets, with each cell representing a 100m X 100m grid. A total of about 18,000 grids were obtained for each variable. Primary analysis mapped each variable by itself, and secondary analysis focused on correlations among variables.

PRIMARY RESULTS

Regional Planning (Land Use Zoning)

Data was based on urban zoning maps provided by the various municipalities. The zoning categories identified were:

Category 1 exclusive low-rise residential (Residential 1)
Category 2 exclusive low-rise residential (Residential 2)
Category 1 exclusive mid-to-high-rise residential (Residential 3)
Category 2 exclusive mid-to-high-rise residential (Residential 4)
Category 1 exclusive residential (Residential 5)
Category 2 exclusive residential (Residential 6)
Light residential (Residential 7)
Neighborhood commercial
Commercial
Light industrial
Industrial
Exclusive industrial use
Urbanization control area
Others

Industrial zones account for 23% of the target area and Light industrial 13%. In Urayasu City Light industrial is especially prevalent, accounting for 45% of the area.

Existing Land Use

Data was based on actual maps, and distinguishes industrial, commercial, residential, agricultural, open space and public use. Industrial use is dominant, except in the Makuhari and Urayasu areas, where residential and public space uses are widespread. Much of the landfill in these areas was developed as residential. Open space is present in industrial areas, but is still insufficient in residential and commercial areas. Furthermore, the parks and green belts in the industrial areas are cut off from the other areas by poor access, and are thus difficult for residents to use. In the future, better integration of open space and public space with industrial, commercial and residential uses is required. Currently, such an integrated pattern can be seen emerging in the Makuhari and Urayasu districts, which have a good mixture of uses and enjoy a favorable public image. Problems with public access, however, still prevent the facilities in these two areas from being efficiently utilized by people in the neighboring municipalities.

Population Density

Categories are measured as residents/grid, and set at 0-50, 50-100, 100-150, 150-200, 200-250, 250-300 and above 300. Chiba Prefecture is located adjacent to Tokyo, and many parts of the prefecture have developed as commuter towns. Along the coast, however, with the exception of the Urayasu and Makuhari areas, population density is quite low. Population tends to be concentrated in neighboring municipalities just inland of the coastal areas.

Landfill History

This variable indicates when an area was landfilled; before 1925, 1926-1945, 1946-1965, 1966-1975 or after 1976. Most of the Chiba Prefecture coastal landfill is of postwar origin, especially from 1966 to 1975, during which 52% of the total area was landfilled.

Distance from Waterline

This variable was mapped at 100 m intervals up to a distance of 1 km. The Urayasu area is contained within the 1km line, but still has problems with access to the waterfront, water quality and full utilization of parks and greenbelts.

Transportation Access

Distance from the nearest railway station is graphed in 100 meter intervals up to a distance of 500 meters. Much of the coastal landfill is beyond the 500 meter line. Even Funabashi, which had the most area within the line, only scored 30%. This problem makes it difficult for people to reach the coastline. The JR Keiyo Line runs through the coastal landfill, but the JR Sobu Line is the main line used by commuters. Several major highways service the Chiba coastal area, but surface roads are poorly developed and suffer from chronic traffic jams.

CORRELATED ANALYSIS

All 6 variables were correlated against each other, and several relationships involving the effect of landfill history, distance from the waterline and transportation access on the other variables were identified for further analysis.

Landfill History

The effect of landfill history on population density, regional planning and land use were analyzed. As can be seen in Table 1, residential population density is higher in the areas that have been landfilled more recently. This trend is especially evident after 1966.

	0-50	50-100	100-150	150-200	200-250	250-300	300-
-1925	167	10	0	0	0	0	0
1926-1945	163	13	0	0	0	0	0
1946-1965	1240	50	0	0	0	0	0
1966-1975	3012	274	221	107	116	84	37
1976-	1923	30	48	0	5	0	7

Table 1. Landfill History and Population Density

The relationship between Landfill history and land use is shown in Figure 2. Industrial use is prominent in areas landfilled before 1965, but the extent of total area devoted to industrial use begins decreasing dramatically following the oil shocks of the late 60s and early 70S, while open space increases. Previously developed inland areas are crowded and congested, and the new coastal landfill areas were designed with more open space. Difficulty of access, however, prevents full utilization of these open space areas. In addition, parts of the new landfill were developed as corporate locations, but some of the these districts have yet to find a buyer, and currently there are many empty, unused lots.

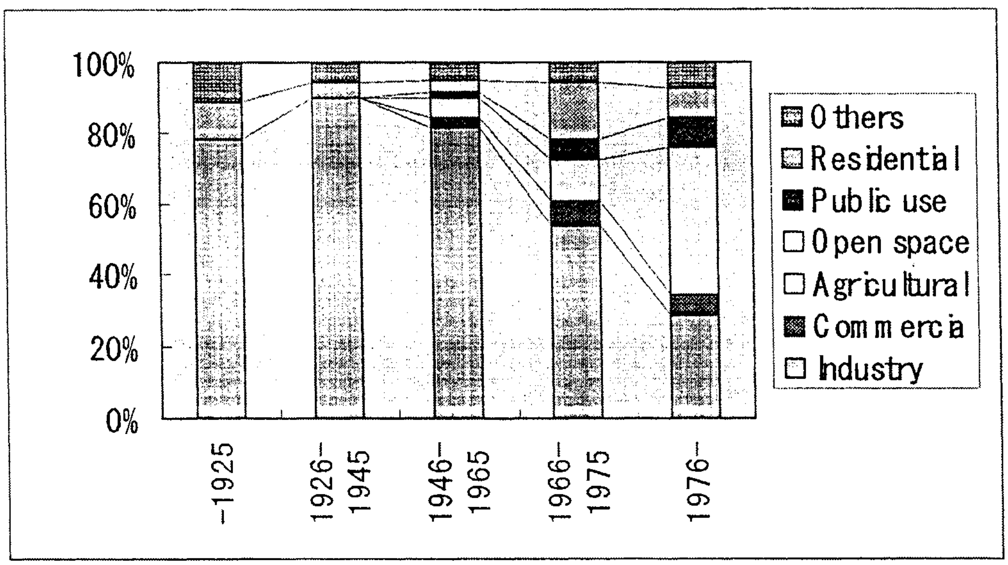

Figure 2. Landfill History and Existing Land Use

Landfill history and regional planning are correlated in Figure 3. Area designated as industrial decreases after the oil shocks, while light industrial designations, which allow for more flexible usage, increase. Light industrial designations are especially extensive in the Makuhari and Urayasu areas.

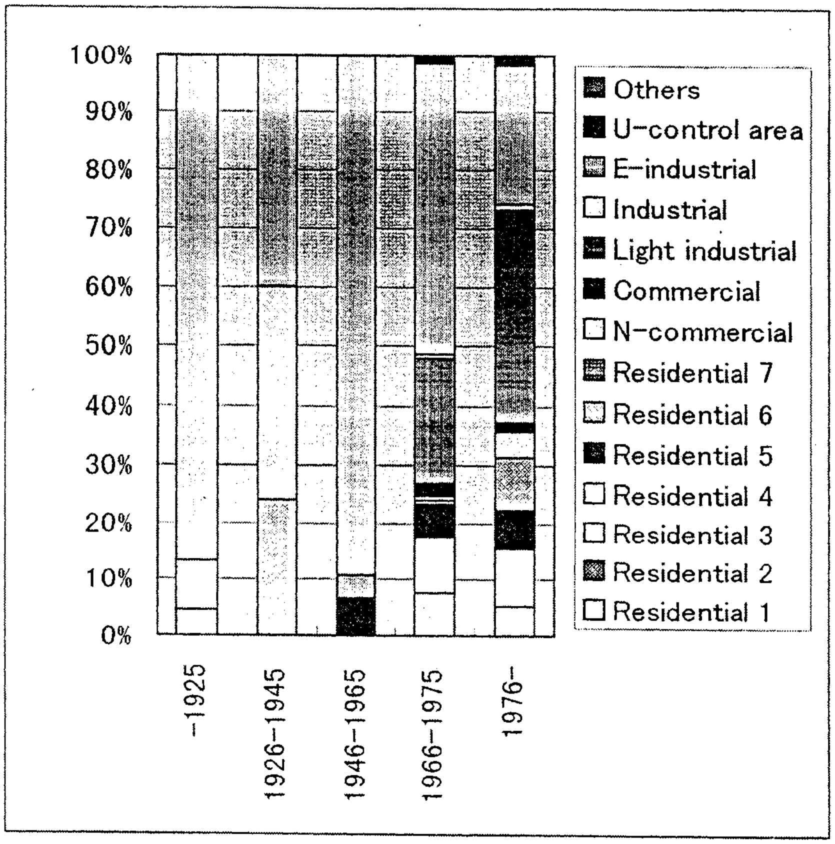

Figure 3. Landfill History and Regional Planning

Distance From Waterline

The effect of distance from waterline on population density, regional planning and land use were analyzed. Figure 4 shows the relationship between distance and regional planning. As can be seen, industrial designations are dominant near the water, but decrease and are gradually replaced by residential to a distance of 1 km. Further than that, industrial designations disappear.

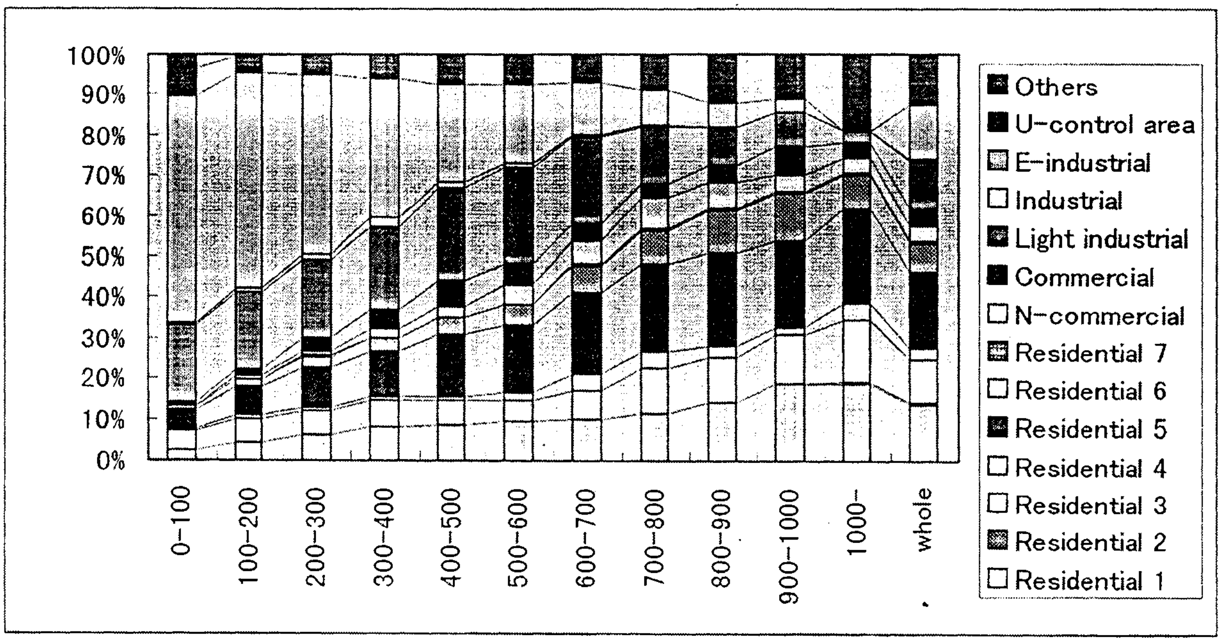

Figure 4. Distance from Waterline(m) and regional planning

Figure 5. shows the correlation between distance from waterline and existing land use. Actual land use shows the same pattern as regional planning, with industrial uses decreasing and residential use increasing as one moves away from the coast. This indicates that the formal designations clearly determine actual use patterns. In the future, restrictions should be softened so that areas near the coast are more open to residential uses.

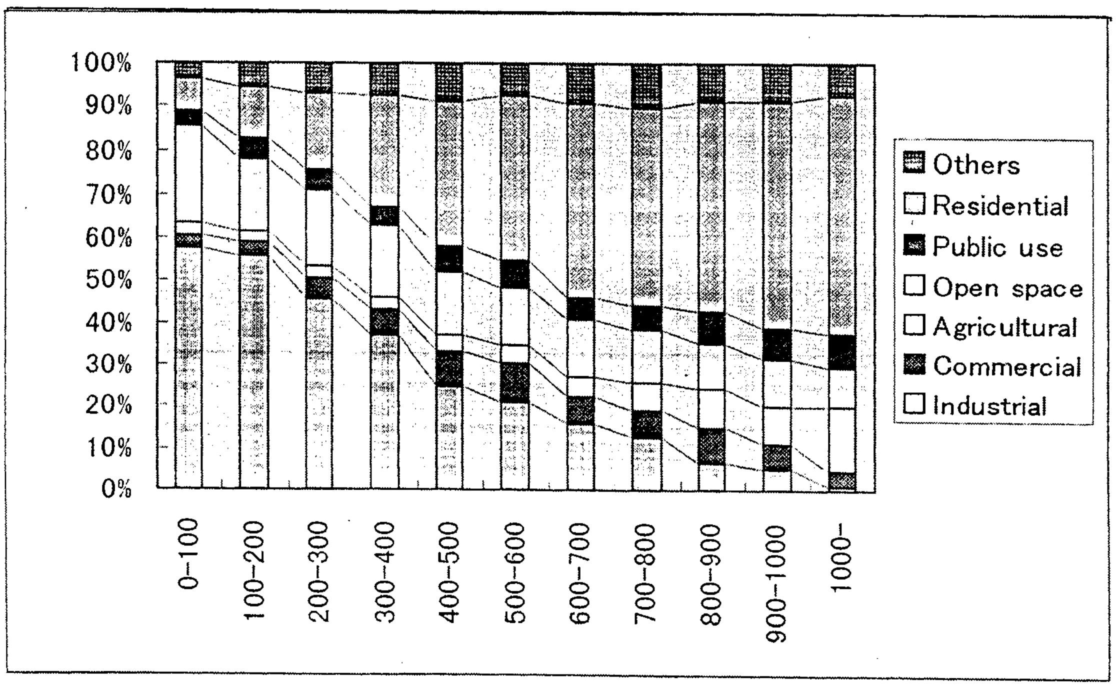

Figure 5. Distance from Waterline(m) and Existing Land Use

The relationship between distance from shoreline and population density is shown in Figure 6. As might be expected from the previous results, population density also increases with distance from the shoreline. The areas closest to the shore contain substantial open space areas within the industrial zones, but poor transportation access makes these areas difficult for the residents to utilize.

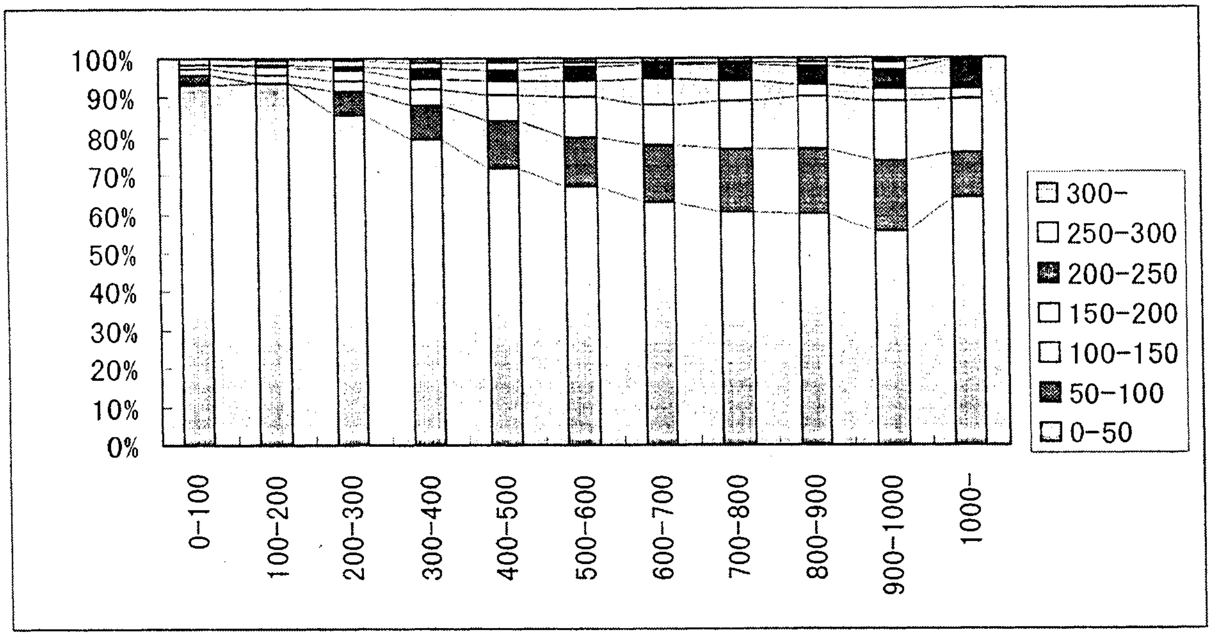

Figure 6. Distance from Waterline(m) and Population Density (man/mesh)

Transportation Access

Transportation access, in terms of walking distance to the nearest train station, was correlated with the other variables. Table 4 shows the percentages accounted for by various land use categories for the areas within 500 m of the nearest station. Commercial uses are low, due to the fact that the areas are primarily commuter communities and the recent growth in large retail shopping facilities located on the outskirts and accessed mainly by automobile. In addition, open space accounts for only 6% of the land within the 500m zone, indicating that open space for daily use is poor. Taken as a whole, the target area has considerable open space, but most of this is poorly integrated and difficult to access, and the residents must put up with a scarcity of open space in their immediate living environment. Many of the residential districts are located a considerable distance from the nearest train station, but high rise apartments and corresponding high density populations are found in the immediate vicinity of the stations. As might be expected, industrial designations show a clear distribution outside the 500m zone, with very little inside.

	Industrial	Commercial	Agricultural	Open space	Public use	Residential	Others
0-500(m)	63	248	19	162	115	1032	268
The whole area	4427	920	1430	2539	1128	6416	1295
Frequency(/whole)	1%	27%	1%	6%	10%	16%	21%

Table 2. Transportation Access and Existing Land Use

CONCLUSIONS

The target area, often called the Keiyo Coastal Industrial Zone, was developed during Japan's postwar decades of high growth. Industrial and residential areas were clearly separated during this first stage of development. As a result, industrial and open space facilities are concentrated near the shoreline, with residential areas further inland. Following the oil shocks, however, the Japanese economy began moving away from a concentration on heavy industry, and landfill utilization changed accordingly. In the newer landfill areas, a variety of functions are mixed together, but due to access and other obstacles the overall integration and coordination of facilities in the target area coastal zone leave much to be desired. In addition, much of the actual coastline is isolated from the surrounding areas.

Many of the original air and water quality problems associated with the coastal industrial strip have been alleviated. Scrubbing and other waste treatment technology has improved greatly, and many industrial facilities have converted from factory to lower-polluting storage and distribution functions. Given this situation, clear separation of industrial and residential areas is no longer necessary.

Given the history of the landfill process, integration of facilities tends to run in a linear pattern parallel to the coast. Transportation corridors also run in a similar pattern. This makes overall integration and access to the coastline difficult. The major problems identified in the target area can be summarized as follows:

1- The newly landfilled areas near the coast tend to be cut off from the older areas, making access to the coastline difficult

2- Few people live in the landfill areas near the coast

3- Residential infrastructure development is insufficient

4- The demand for industrial development in the coastal zone is weakening

5- Open space is scarce, and often difficult for local residents to effectively utilize

6- The current system of land use is not flexible enough to respond to changlng socio-economic needs.

7- The semi-industrial designations in the most recent landfill areas enjoy more flexible land use regulations, and thus are not completely dominated by industrial facilities but show a more varied pattern of utilization. These areas are thus more able to respond to changing socio-economic needs than the industrial zones in the older landfill.

In the future, new changes in the socio-economic order, such additional decreases in the amount of time spent working, aging of society and subsequent increase in welfare and tax burdens, widening gaps in income, etc.., will require corresponding adjustments in utilization of the coastal zone. With this in mind, the following recommendations can be made:

1- widespread opening of the waterfront to public access

2- promotion of more varied utilization patterns, while maintaining environmental standards

3- increase in low-cost facilities that can can be readily utilized by people of younger age and lower-income

4- provision of transportation and integration that runs in a direction perpendicular to the coast

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TAKE THE SUSTAINABLE USE OF MARINE ENVIRONMENT AND RESOURCES AS THE NATIONAL STRATEGY OF CHINA

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ABSTRACT

Sustainable utilization of marine environment and resources is concern of global environment and society development. China government pay a great attention to oceans, and the China Ocean Agenda 21 which is the polices guideline for marine development of China in future, was publicized by China government. The major principle of China Ocean Agenda 21 is keep on the sustainable utilization for marine environment and resources. In fact, oceans is and must be taken the more and more great role for China's society and economy development. There are a lot of resources and riches in ocean, We must put resources to rational use and protect marine environment in our best power for keeping ocean's sustainability. This paper will discuss and study the benefits of ocean for China, the marine development strategy of China, including the strategic objectives, strategic principles and basic policies.

INTRODUCTION

UNCED Agenda 21 points out that the marine environment -- including the oceans and all seas and adjacent coastal areas -- forms an integrated whole that is an essential component of the global life-support system and a positive asset that presents opportunities for sustainable development.

The Chinese Government has formulated China's Agenda 21--White Paper on China's Population, Environment, and Development in the 21st Century and determined to implement the sustainable development strategy for its future development. China is a continental country as well as a marine country. In China, the social and economic development will depend more and more on the sea. As a result, China's Agenda 21 makes the conservation and sustainable development of ocean resources one of its major programme areas. In 1996, the Master of PRC for the National Economy and Social Development in the Ninth Five-year Plan and the Perspective in 2010 has determined that China will Approach the sustainable development strategy in future so as to realize whole development on both the national economy and social development, It is determined that the policy of enhancing the investigation of marine resources, developing the ocean industries and protecting the marine environment as one of the important issues to wards comprehensive development. In the Master Plan, deciding seven economic developmental areas of transboundary regions, there are 5 relative with marine development directly. Chinese government is paying an attention to ocean greatly.

China has over 18,000 kilometers of continental coastline. According to the regime of 200 nautical miles of exclusive economic zone (EEZ) and the regime of continental shelf as provided in the United Nations Convention on the Law of the Sea, China has under its jurisdiction about 3 million square kilometers of sea waters. China has more than 6,500 islands and islets along its coast and a population of more than 400 million people living in the coastal area. The gross industrial and agricultural output value from the coastal cities and counties accounts for about 60 percent of the national industrial and agricultural gross output value. China's coastal and offshore waters and oceanic waters under its jurisdiction are rich in marine resources such as living resources, oil and gas resources, solid mineral resources, sea water resource, ocean energy and marine tourism resources, etc. The development of various marine resources has resulted in the formation of various marine industries, of which the traditional ocean industries includes ocean fishing, ocean shipping and salt making from seawater and the new marine industries includes mariculture and enhancement, offshore oil and gas industry, coastal tourism industry, seawater direct use industry, marine pharmaceuticals industry and seafood industry, etc. At the same time, some additional marine industries such as ocean energy utilization, deep-sea mining, ocean information industry and seawater integrated utilization industry are still in the stage of technical brewing. In conclusion, marine industry has become an important component of the coastal economy and has taken shape with the development in the past years. According to incomplete statistics, the gross output value from ocean economy in China has reached 287.7 billion Yuan (RMB). Moreover, the ocean exercises effects on the climatic changes, the distribution of precipitation and the outburst of natural disasters, thus possibly affecting directly or indirectly the economic and social development in the coastal area or even the inland areas. Therefore, the development and conservation of the ocean has been an important and inseparable part of China's environment and development.

Theoretic Frame of Sustainable Use of Ocean and the Major Content of China Ocean Agenda 21

In order to implement better in the marine fields the China's Agenda 21 and promote the sustainable development and utilization of the oceans, China Ocean Agenda 21 is formulated, which is an integral part of China's Agenda 21 and is the policy guideline for the sustainable development and utilization of the seas and oceans.

China Ocean Agenda 21 sets forth the basic strategies, strategic objectives and fundamental countermeasures for the sustainable development of the oceans, and major programme areas. Each chapter is composed of an introduction and programme areas. The introduction describes the core contents, major bases, present state and issues, development tendency and prospects, etc. Each programme area consists of three parts: basis for action which illustrates the international and domestic legislative basis for the programme areas, the major problems to be solved and the temporal and spatial feasibility for the settlement of the problems, objectives which refer to the objectives and goals which will be reached by various actions taken in the programme areas, and activities which refer to various measures and actions to be taken for the realization of the objectives.

China Ocean Agenda 21 includes 11 Chapters and 43 programme areas. Each chapter contains two parts, introduction and programme areas. The introduction describes the main content, basis and premise, status and problems, as well as prospects of tendency, etc. The programme areas is composed of three parts such as basis for action(explanation of the international and domestic legal basis, the major problems which need to be solved and the possibility in time and space, etc.), objectives(explanation of the goal for taking various action) and activities(explanation of the countermeasures and action to be taken for realizing the goal).

1. The Guiding Principles and Basic Idea

It is clear the that concrete objectives of sustainable use of the ocean are the marine environment and resources. Ocean is the component of the important life support system and the property which guarantees the sustainable development. Therefore, the sustainable development of mankind and various kind of ocean concerned causes must depend upon the sustainable utilization of the marine environment and resources. China takes the sustainable utilization of the marine environment and resources to the her total objectives and the basic guideline on development of the ocean in the 21st century. So-called the content of sustainable utilization of the ocean are:

1.1 to fairly share the ocean related benefits among nations all over the world including delimiting boundaries of territorial sea, continental shelf, EEZ between and/or among states in accordance with equitable principle, the management being carried out be the international community for some kinds of living marine resources and the international seabed mineral resources;

1.2 to fairly configure the coastline, tidal flat, sea area and the natural resources within for all professions concerned like aquaculture, transportation, seasalt industry, tourism and city construction, etc.;

1.3 to guarantee the marine resources and environment be sustainable utilization and the benefits be fairly share by both our generation and the coming generations; and

1.4 to fairly and/or commonly share the duties and obligations by all states of the world towards protection of the ocean and prevention of the marine environment from pollution damage, and avoiding the degradation of marine resources;

2. The Strategic Principle for Sustainable Use of the Ocean

In order to ensure the sustainable use of the ocean, there must be a series of strategic principles concerned in ocean related activities.

2.1 The principle of taking the development of ocean economy as the core task. The ocean related activities include scientific research and investigation, development of natural resources, forecasting service, management and conservation, etc., and the ocean economy to be formed based on use of marine resources is the core task, and all other ocean related activities should carried out to contribute to the development of ocean economy.

2.2 The principle of controlling the development at a moderately fast speed. China is a developing nation. The development of the ocean cause is still a not high level, and there will be rather large potentialities. The speed of the development, therefore, might be faster. Since 1980, the increase ratio of the total output value of ocean economy goes quite fast. The predicted ratio of 11 percent - 13 percent which was made by the Master Plan of National Marine Development, but the figure is lower than that of the actual situation. It is foreseen that the average annual increase ratio of the total output value of ocean economy in China will no less than 15 percent by 2000, and we believe that is in line with the situation of China's ocean cause development. The increase ratio in 15 percent will hopefully be maintained for a period of time.

2.3 The principle of unified model in both the land and the ocean development. This principle was raised before, but the situation is that there has not been research in detail and practical application so far. In the near future, the efforts to be made in following three aspects should be strengthened: Firstly, enhancement of the research on the relationship between the economic development in the land area in coastal region and the marine resource and the marine environment, including the research of the supporting capabilities of marine environment and resources as well as the requirement to the ocean for promotion of economic development of coastal region, etc., so as to provide the basis for the sustainable development of the region; Secondly, formulation of the well coordinated development plan for both the land and the ocean, specially for coordination of the development in coastline, tidal flat and shallow water area with that in coastal land area; Lastly, formulation of uniformed policies, laws and regulations as well as the coordination and management system in order to enhance the coordination between the marine environmental and resource conservation and the environmental protection in land area.

2.4 The principle of development of ocean by relying on science and technique. The concept of DORST is to promote the rapid development of ocean economy by means of development of marine science and technique, that is the development of ocean economy should depend upon the support from modern science and technology. In general speaking, exploitation of offshore oil and gas and marine transportation are the high technology contented industries, whereas there are large technical different among local public jointed mariculture and comprehensive utilization of seawater and marine tourism. Therefore, the urgent task of DORST is to solve the problems regarding utilization and protection of the ocean by means of application of advanced scientific and technical methods in coastal region. In addition, the promotion of DORST should also be accord with the principle of sustainable development. That is to say the scientific and technological community should follow the way of providing the services such as knowledge, technologies and methodologies to ocean economy in accordance with the principle of sustainable development and facilitating the sustainable development of ocean economy. To this end, it must be to (a) detect the new and possibly developed resources by means of advanced approaches; (b) develop the high-effective methods and techniques for promotion of the development; and (c) develop pure production techniques which are beneficial to protect the resources and environment so as to gradually increase the kinds of marine resource development and enlarge the industrial group and finally go on the way of sustainable development.

2.5 The principle of coordinated development. It is clear that the insurance of sustainable development should rely on the coordinated development of a number of marine causes concerned, and all activities relating to the ocean should pay great attention to this issue. Firstly, the marine scientific and technical community should pay more attention to the cooperation of multi-sciences. both the National Comprehensive Survey of Resources in Coastal Zone and Tidal Flat and the National Survey of Marine Islands are the successful examples. In addition, there are a few important area which need multi-sciences cooperation such as the comprehensive survey and assessment of China's 200 nautical mile EEZ and the continental shelf as well as the study concerning supporting capabilities of resources and environment in coastal zone and related sustainable development. Secondly, all marine industries should bear in mind the concept of coordinated development, and there should be comprehensive development plan so as to guarantee the practical coordinated development of different industries especially in case of there have been industrial conflicts in some coastline and coastal water area. Thirdly, the coordinated development should make sense into the practical actions of development and protection.

3. The Target System of Sustainable Use of the Ocean

The goal of sustainable utilization of the ocean is composed of following three aspects, and could form a target system.

3.1 Prevention of the marine environment from pollution damages. This is the requirement set by UNCED for the global marine environmental protection. The detailed objectives of that are (a) to promote the renovation of the coastal waters polluted gradually; and (b) to prevent the unpolluted area nowadays from pollution.

3.2 Establishment of the well circled marine ecosystem. There are three kinds of work should be done in terms of (a) efficient conservation of marine biological diversity; (b) gradual enhancement of the establishment of marine natural reserves and formulation of the network of natural reserves such as mangroves, coral reef, sea grass bed and wet land, etc.; and (c) establishment of the development pattern for utilization of living marine resources being accord with the principle of sustainable utilization and recovery of the fishery resources which was seriously destroyed before so as to ensure the sustainable development of marine fishery resources.

3.3 Formulation of the continuously enhanced marine industrial group. A continuously enhanced marine industrial group might be funded for there are a lots of kinds of resources in the ocean and it will be possible that the extension of the marine resources could be enlarged more and more. In 1950s, the major marine industries were fisheries and marine transportation, and seasalt industry appeared in a few counties only. Since 1960s, offshore oil industry and marine tourism became the important marine industries. At present, a number of new emerged marine industries like marine energy generation, comprehensive utilization of seawater and ocean orientated medicine, etc. have been growing rapidly. In the coming century, it can be foreseen that there will be the industry of utilization of elements which can make nuclear fusion in deep ocean.

4. The Key Task Areas of Sustainable Use of the Ocean

The phenomena that people willing to go to the sea is the general tendency of immigration all over the world at present and in a quite long time period. Since the reform and open to outside world, it is more and more outstanding that the Chinese people settle in coastal region, and the inner power of this rapid new emerged immigration is the imbalance between eastern and western China in terns of the natural geographic circumstance and socioeconomic development. The key issue of executing the sustainable development strategy is to study the capability of supporting ability of the ocean and of public participating and insurance of the sustainable utilization of the ocean, this kind of study must take man itself as the most important issue. Under strengthening public participation, China Ocean Agenda 21 mainly sets the following projects and programme:

4.1 Protection of the marine environment. The main task of this is to prevent the marine environment from pollution damage caused by land based sources, and in the meantime, prevent the marine environment from the pollution by various marine development activities, oil spill accident and ocean dumping, etc.

4.2 Protection of living marine resources. The main task of this is to control the intensity of catching, and enhance the resources of artificial multiplication and innovate the environment of fishing grounds, and protect marine biological diversity and establish network of various kinds of marine natural reserves.

4.3 Construction and protection of islands at a fast speed. It will be done step by step to construct the modernized facilities on people settled islands and protect the non-people islands.

4.4 Natural marine disasters prevention and mitigation. It is to strengthen the establishment of ocean observing, forecasting and warning system and the disaster rescue system.

4.5 Promotion of the sustainable development of marine industries. It includes enlargement of marine industrial group, development of pure production techniques, and formulation of the ocean development pattern which is accord with the principle of sustainable development.

5. Basic Policies and Countermeasures for Sustainable Development of the Ocean

5.1 Establishment of the integrated coastal management regime. It is the common trend internationally and also a new task in front of China's marine cause. The UNCED Agenda 21 calls for developing the integrated coastal zone management of the(ICZM) ability in all coastal states, and executing ICZM and over break the impacts derived from the climate change. The declaration of the World Coastal Conference'93 pointed out that ICZM is an important means towards realizing the sustainable development in coastal states. One thirds of the states who participated the conference have carried out or promised to undertake ICZM. It is reasonable that China actively promotes the execution of ICZM and establishes ICZM system as soon as possible. In order to do so, It seems to be (a) to formulate comprehensive laws and regulations; (b) to establish high level programme coordinating and decision making mechanism; (c) to establish marine management organizations at different level; (d) to form the system which provides the possibility of public participation of the marine conservation; and (e) to form the system of scientific and technical support for the comprehensive management.

5.2 Formulation of the development pattern which is accord with the principle of sustainable development. The damage to the marine environment and resources mainly derives from irrational development pattern. For instance, the over fishing causes for exhaustion of marine fishery resources and discharge of large quantity of pollutants causes for marine environmental pollution. However, what scientific way of the development pattern is, which is still less theoretical recognition and experience of practice.

5.3 Enhancement of the scientific and technological supporting system. The scientific and technological forces all around the country should be organized by both the national science and technology competent agency and the marine affairs competent organization aiming at supporting the execution of China Ocean Agenda 21.

How can the Ocean do in Contribution to Riches and Challenge for Chines Sustainable Development

The ocean is a life space for the development of Chinese nationality. The jurisdiction sea area of China is near 3 million square kilometers in terms of territorial sea and internal waters from 370,000 to 380,000 square kilometers, and in addition the executive economy zone and continental shelf. There is 150,000 square kilometers of mining district with multi-metal nuclei which have been gained by China, and it is the "over seas property" of China. The mud and sand originated from western plateau of Chinese mainland constructs deposited coastal land continually, and the velocity of deposited coast increasing is from 27,000 to 33,000 hectares annually and new land, therefore, is silted up naturally with annual average increasing rate of 667,000 hectares, which is a valuable land resource.

The ocean could contribute greatly to reduce the press of population and environment. Since coastal area is suitable for both economic development and existence of people, there has been an increasing tendency that people emigrate towards ocean along with rapid economic development. According to statistic of UN Agenda 21, already more than 60 percent of the world's population lives within 60 km of the coast, and the ratio of that will go up to three forth in 2020. The population of China's coastal provinces is 479,670,000 which accounts for 40 percent of the country. It is estimated that there might be 700 to 800 million people living in coastal area when China goes up to middle developed country, and coastal area then could contribute to reduction of population press in inner part of China.

Ocean becomes a valuable resource for dealing with abandoned wastes since powerful capacity of self-purification is there in the ocean. At present, there is near 10 billion tons of sewage that is discharged into ocean, and increasing ratio of which is 5% to 8%. China is now being at initiative stage of economic taking off. In accordance with the experience of other countries, an important symbol of economic taking off is that the ocean closed industrial zone are established in coastal area. The ocean closed industrial zone is being established in china, and heavy chemical industry, electricity industry and new developing industries concerned are being planned in a lots of coastal area. The quantity of industrial wastes and domestic rubbish's, therefore, will obviously increase in a large scale, and total amount of sewage, which is discharged into the sea, might go up to 20 billion annually in coming 10 to 15 years. The ocean provides a rubbish treatment site for economic taking off, as well as the task of marine environmental protection is put in front of us.

The ocean will hopefully be a energy basis of the coming century. The yield of marine petroleum has attained 6.4 million tons per year, which accounts for 4% of Chinese total out put(the total out put of petroleum was 147,000,000 tons in 1994). There is some 1.2 million square kilometers continental shelf with the depth less than 200 mile in China, where seven large oil and gas deposit basin have been discovered, and also 30 oil and gas fields with over 0.8 billion ton of oil and 130 billion cubic meters of gas(resource quantity) have been evaluated and confirmed in over 60 oil and gas deposit structures. According to status of construction of offshore oil and gas fields, the out put of marine petroleum and gas will be over 10 million ton per year at the end of the century, and the ratio of which is over 7% of the national total.

The ocean is a huge resource basis of high quality food production. In the China Sea, the pure productivity of living organism is 2.8 billion tons a year, and average productivity is 3.02 tone per square kilometers in offshore area. At present, the annual yield of marine fisheries around 11 million tons, but the ratio of utilization of living marine resource is quite low. The area of offshore fishing ground is 2.81 million square kilometers in China, and the tidal flat is 21,700 square kilometers as well as 157,000 square kilometers of shallow water with depth between 0 to 20 mile. Regarding to the resources in shallow water and tidal flat, the total area, which is suitable for developing aquaculture, is 6,700 square kilometers, according to relevant surveys, and the ratio of utility is around 20 percent only. In 2020, the area of aquaculture will be enlarged up to 66.6 thousand square kilometers, and total out put of marine fisheries is 15.4 million tons annually and the consume level per capital of marine originated food is 20 kilogram then.

The sea water resource is a way in resolving lack of water resource. China is poor country with regard to water resource, nowadays, the series fresh water crisis out breaks in developed coastal region, and the major large or middle cities are facing the problem of lacking water seriously in different degree. The unique way of solving the problem is to make use of sea water. The development of sea water direct use and marine pharmaceuticals industry is an important way in over coming the difficulty.

Conclusion

Opportunity and challenge are being faced by Chinese marine cause, and the Chines government has been paying great attention to development and protection of the ocean in order to realize sustainable use of marine resource and environment which is the macrocostmic objectives of marine efforts after wards. The ocean can contribute to the Chinese sustainble development, and while the sustainable development of China must depend on oceans, also the reality alternative of marine development suit be listed into the national developing strategy in order to face the opportunity and chellagy.

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COASTAL MANAGEMENT PROBLEMS IN HONG KONG AND TOWARDS SUSTAINABLE DEVELOPMENT

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ABSTRACT

About 10% of the present land area of Hong Kong has been created by coastal land reclamations over the last quarter millennium. This has resulted in major changes in the coastal configuration creating management problems including a declining seawater quality, flooding, waste disposal, failure of engineering structures during storms, offshore sand exploitation, mariculture, coastal fisheries and recreation. Based mainly on an understanding of the natural sedimentological characteristics of the coastal waters and past experience, a policy towards sustainable coastal development is outlined. The territorial waters of Hong Kong is divided into an eastern, central and western zone to permit all existing types of utilization to continue in at least one zone while the natural characteristics of each zone is preserved. In the naturally 'clean' eastern zone, offshore sand exploitation and marine waste disposal should be banned in order to preserve the natural attributes of the zone for recreation, coastal fisheries and limited mariculture. In the densely populated central zone where land demand is the greatest, a cost-effective strategy is to allow regulated effluents from storm drains and sewage outfalls to be contained within typhoon shelters in order to minimise their environmental impact. Such typhoon shelters may be reclaimed every twenty to thirty years as part of a long term plan to provide new development land. In the western zone, where the waters are high in turbidity due to the influence of the Pearl River, regulated waste disposal and offshore sand exploitation should be permitted.

INTRODUCTION

The coastal zone is one of the most important of the world's finite resources (Apsimon et al., 1990). It is the area where much of the world's population lives and obtains its food. Currently it is under the threat of the combined effects of population growth, urban development, industrial expansion and recreational pressures; the disposal of wastes; the exploitation of groundwater, minerals, fisheries and other resources; the destruction of habitats such as mangrove swamps; coastal erosion, and, the possible effects of a rising sea level. This threat will grow as the population in the coastal zone increases. It is therefore essential for the Hong Kong Government to adopt a future development policy to ensure that the utilization of the coastal zone is as sustainable as possible.

Rapidly developing cities by the sea are expected to have the greatest environmental impact on the coastal zone. Hong Kong, currently the busiest container port in the world, with a population of about 6.5 million is one such example. As a major city, Hong Kong has a surprisingly short history; much of its expansion took place after the end of the Second World War when there was a population boom largely related to immigration from mainland China. Since there is a shortage of naturally low-lying land and the steep hillslopes are prone to disastrous landslides (Lumb, 1972), land needed for development has been created episodically through coastal land reclamations. In the present study, based mainly on experience gained from coastal management problems in Hong Kong, a policy towards sustainable coastal development is outlined. This is a follow-up to an earlier study of Yim (1995).

ENVIRONMENTAL SETTING OF HONG KONG

Hong Kong is located just south of the Tropic of Cancer on the northern coast of the South China Sea, near the mouth of the Pearl River (Figure 1). It has a subtropical climate with hot and wet summers and cool and dry winters, associated with the southwest monsoon and northeast monsoon respectively. Out of its total land area of approximately 1100 sq. km, about 10% has been reclaimed from the sea (Peart and Yim, 1992). The coastline of some 870 km in length (So, 1985) is highly indented with numerous headlands, bays and offshore islands. Due to the irregular coastal configuration, there are a number of relatively large sheltered water bodies including Tolo Harbour and Victoria Harbour (Figure 2).

Hong Kong is a highland area without major rivers formed largely of volcanic and intrusive igneous rocks. The rugged terrain does not appear to have undergone any major changes since the late Mesozoic. Evidence obtained from offshore sediments indicate at least five high and low stands of sea level related to interglacial and glacial periods during the Quaternary period (Yim, 1994). The present day sea level was attained between 6,000 and 7,000 years ago as a consequence of the termination of the last ice age (Yim, 1986). Analysis of tide gauge records (Yim, 1991a) failed to indicate a rising sea-level trend but at least some of the coastal land reclamations are known to have subsided as a result of ground settlement.

Morton (1985) divided the present day coastal waters of Hong Kong into three hydrographic zones - eastern, central and western (Figure 1). The waters of the eastern zone are under the strongest oceanic influence with salinity marginally below normal seawater. They are relatively clean because of the low concentration of suspended particulates and are uncontaminated because of the lack of anthropogenic effluents discharged into them. In contrast, the western waters are estuarine with low salinity and high turbidity due to the discharges of the Pearl River. In the central zone, Victoria Harbour and Tolo Harbour show sharply contrasting tidal flushing characteristics. The former is regularly flushed by strong tidal currents entering through a number of narrow channels while the latter, having only one narrow entrance out to sea, is poorly flushed. It is in the densely populated central zone, where the pollution effects have been the most obvious (Morton, 1985 and 1989; Wu, 1988).

COASTAL MANAGEMENT PROBLEMS

The true effectiveness of a coastal management policy can only be determined a long time after the policy has come into effect. In this section, coastal management problems in Hong Kong are examined.

Coastal flooding

Coastal flooding is attributable to a combination of factors:

1. The creation of large areas of low-lying reclaimed land from the sea which are susceptible to rainstorm and coastal flooding.
2. Long term ground settlement of coastal land reclamations. A long term rate averaging about 5 mm/year was found at the North Point tide gauge site (Yim, 1991b). Similar rates can be expected in other coastal land reclamations although monitoring has not been carried out. The oldest reclamations create a 'trough-effect' between the inland areas and the new reclamations (Peart and Yim, 1992). This is a problem in Victoria Harbour where the new reclamations seaward of the old reclamations have been constructed to a higher elevation to allow for a possible future sea-level rise.
3. Intense rainfall. The record for 1-hour and 24-hour rainfall at the Royal Observatory station

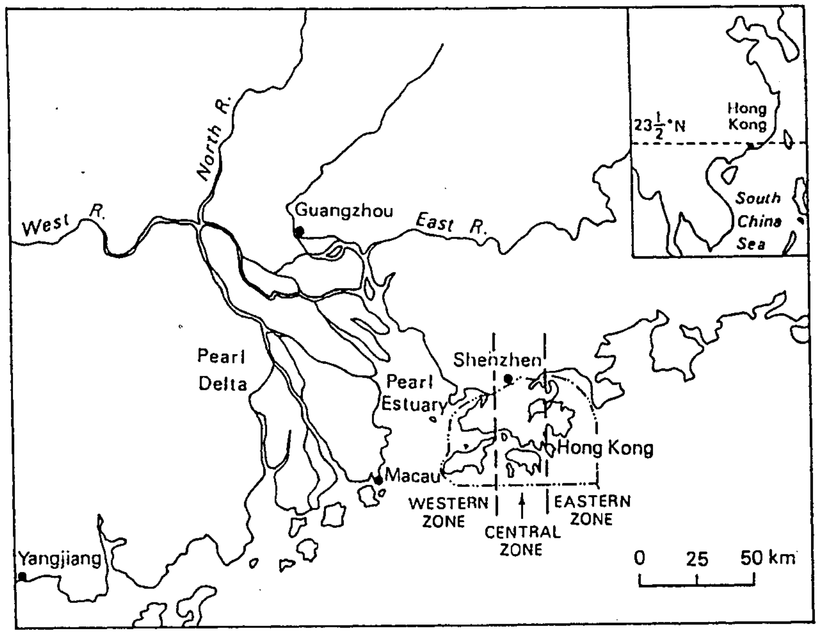

Figure 1. Location map showing Hong Kong, the three hydrographic zones, the Pearl Delta and the Pearl Estuary

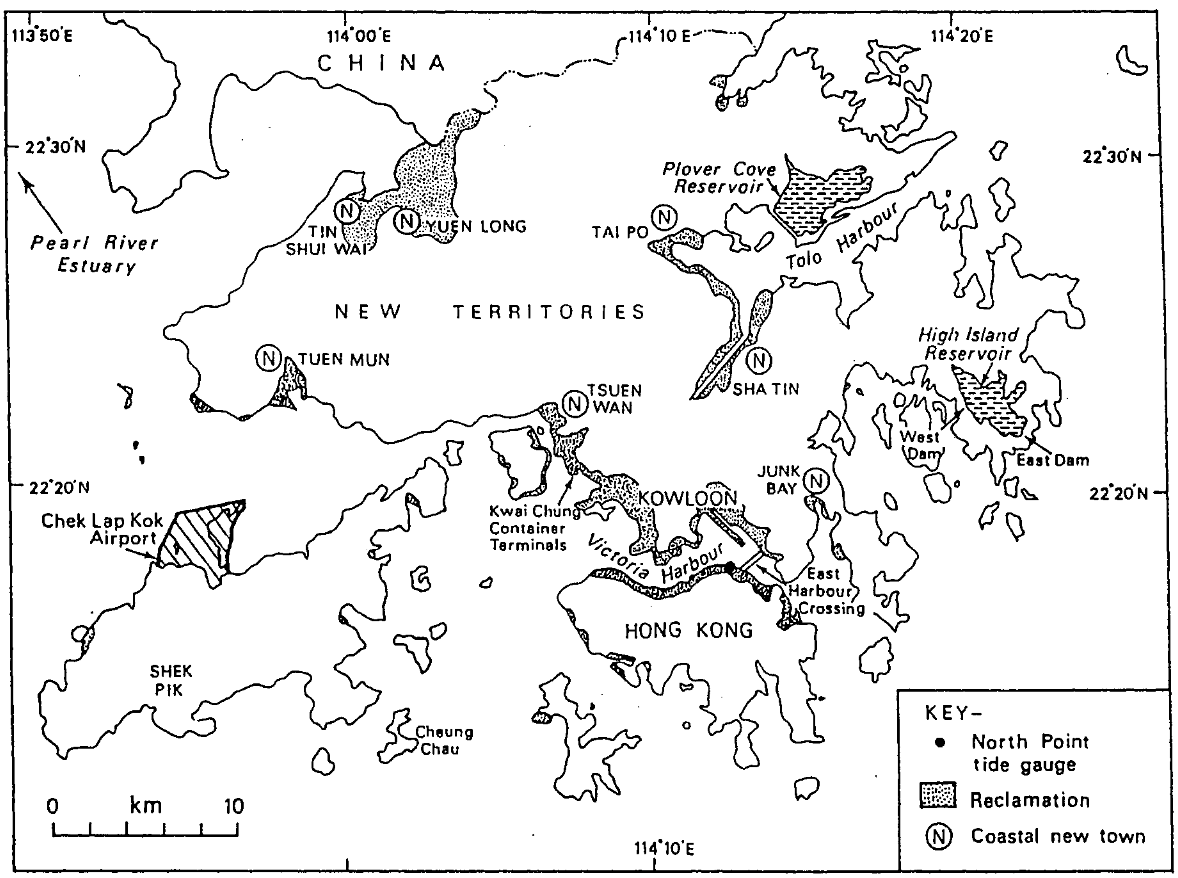

Figure 2. Map of Hong Kong showing coastal land reclamations, coastal new towns, coastal reservoirs and other selected coastal features

located in Kowloon is 108.2 mm and 697.1 mm respectively (Yim, 1996). In concreted urban areas, the bulk of this rainfall will form surface runoff because of minimal infiltration.

4. Storm surge associated with the passage of a typhoon. The height of the maximum sea level attained during a storm surge is largely determined by the coastal configuration and the typhoon track (Yim, 1993). In Tolo Harbour, the highest maximum sea levels is found because of the unusual coastal configuration namely its dimension and the narrow eastern exit into the open sea (Figure 2).
5. Inadequate drainage systems in the coastal land reclamations. Because of the low gradient, it is difficult to design adequate storm-water drains to cope with the surface runoff generated by heavy rainfall and/or storm surge.

From the above, it can be seen that the coastal land reclamations are under the greatest threat to flooding. However, in addition to the urbanized areas, coastal land reclaimed for agricultural use are also affected. For example, in Deep Bay on 21st May, 1989, a large area of agricultural land for redevelopment comprising mainly of fish ponds was severely flooded as the result of heavy rainfall associated with typhoon Brenda. It is necessary to monitor the rates of long term ground settlement in the coastal land reclamations for flood mitigation.

Coastal disposal of wastes

Four main types of wastes are currently disposed of either into the coastal waters or into the coastal landfill at Junk Bay (Figure 2):

1. Screened sewage and wastewater from treatment plants discharged via submarine outfalls.
2. Constructional wastes including uncontaminated dredged spoils where the content of heavy metals are below the preset limit shown in Table 1. These wastes are disposed of at designated marine dumping grounds shown in Figure 3.
3. Contaminated dredged spoils with contents of heavy metals exceeding the limit shown in Table 1. These wastes are disposed of either at the pre-dredged trench near Sha Chau or at the Junk Bay landfill.
4. Domestic and other categories of wastes which are disposed of in the Junk Bay landfill.

In addition to the above categories of wastes, domestic, industrial and agricultural effluents may also find their way into the coastal waters via streams and storm-water drains.

In Victoria Harbour prior to 1970, screened sewage was discharged into the coastal waters via seawall outfalls. During the 1970s, most seawall outfalls were converted into submarine outfalls aimed at more effective dispersion within the water column. However, whether the submarine outfalls are better than seawall outfalls for dispersing an organic waste like sewage is uncertain. Figure 4 shows the main differences between the seawall and submarine types of sewage outfalls. The levels of dissolved oxygen in Victoria Harbour waters from 1976 to 1992 was found to have declined (Environmental Protection Department, 1993). The trend suggests that the conversion to submarine outfalls accelerated eutrophication for four reasons. First, the effluents entering typhoon shelters via seawall outfalls and storm-water drains is poorly dispersed due to the weak tidal circulation. Because the astronomical tidal range is only 2.7 m, typhoon shelters such as Kowloon Bay adjacent to the Kai Tak International Airport runway act as a trap for the land-derived effluents, effectively preventing their spread into other parts of the harbour. Second, seawall outfalls allow organic wastes to be broken down by natural means. The surface water is better aerated, mixed by wind-generated waves, has greater sunlight penetration, and, the development of a thermocline during the wet summer season. Therefore conditions are more conducive to the breakdown of organic matter by light-dependent micro-organisms. Third, since submarine outfalls release wastes into deeper waters, the conditions are more anoxic making it difficult for breakdown by natural means. Furthermore, progressive reclamation means not only the destruction of natural coastal habitats such as mangroves but also the

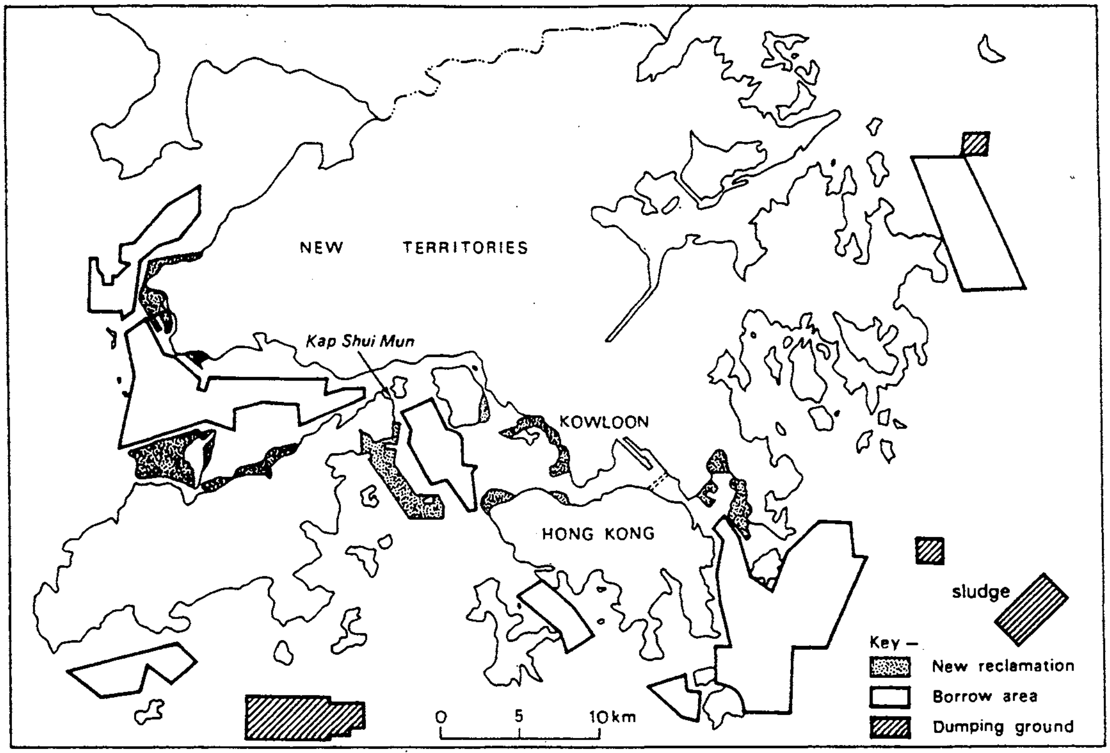

Figure 3. Location map of the Port and Airport Development Strategy reclamations, offshore burrow areas and dumping grounds in Hong Kong. After Brand (1992) with modifications

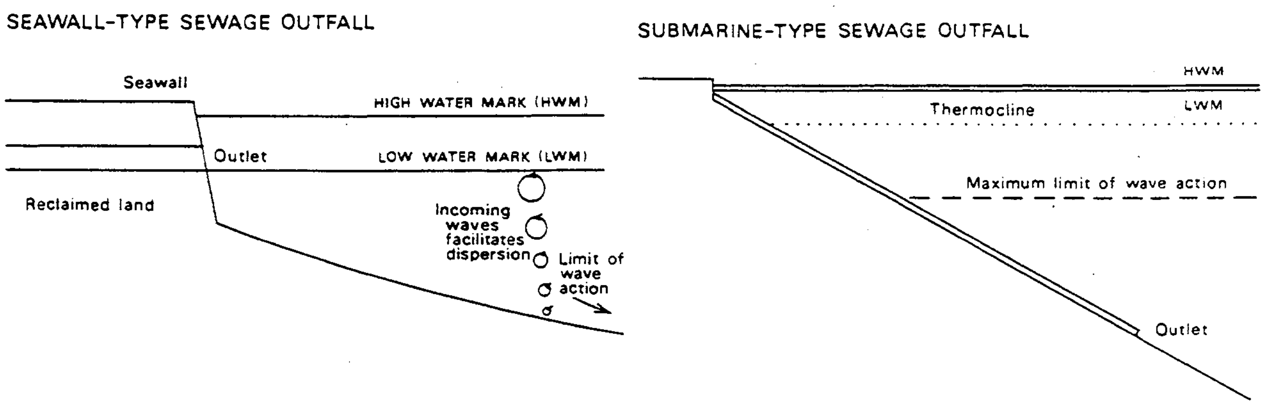

Figure 4. Simplified diagrams showing the main differences between the seawall-type and submarine type of sewage outfalls

creation of seawalls fringed by relatively deep waters. Both are conducive to eutrophication.

Constructional wastes are produced in large quantities in Hong Kong mainly through infrastructural development and urban renewal. In 1991, a peak of 16,374 tonnes/day of constructional wastes categorised into roadwork material, excavated material, demolition waste, site clearance and renovation waste were received at landfill sites (Environmental Protection Department, 1993). The shortage of landfill sites onshore is the main reason for dumping these wastes into the sea. At the Cheung Chau Marine Spoil Ground, continuous dumping have resulted in major changes of sea-floor topography (Nash and Yip, 1988) making the site hazardous to shipping as well as impacting

Class	Category	Heavy metal content (mg/kg dry weight)						
		Cd	Cr	Cu	Hg	Ni	Pb	Zn
A	uncontaminated	< 0.9	< 49	< 54	< 0.7	< 34	< 64	< 140
B	moderately contaminated	1-1.4	50-79	55-64	0.8-0.9	35-39	65-74	150-190
C	seriously contaminated	1.5 or more	80 or more	65 or more	1 or more	40 or more	75 or more	200 or more

Table 1. Classification of uncontaminated and contaminated dredged sediments in Hong Kong according to heavy metal content, after Reed (1992)

marine life. At the Sha Chau pit used for the disposal of contaminated dredged spoils, plans are made to cap the pit with uncontaminated marine muds to isolate the spoils.

The only coastal landfill site in use at present is located in Junk Bay. However, the impact of leachate from the landfill on coastal waters is not well understood at present.

Stability of coastal structures during storms

Coastal land reclamations have shifted the original coastline seaward with beaches and headlands replaced by seawalls. The changes in coastal configurations and sea bed profiles inevitably lead to changes in the wave regimen which modifies the coastal processes (So, 1984) including the current flow pattern (So, 1986a and 1986b). During the passage of typhoons, seawalls have failed because their design did not fully take into consideration the change in wave run up characteristics. Two examples of seawall failure have been documented. In 1960, the seawall of the Royal Hong Kong Yacht Club was destroyed during typhoon Mary. In 1983, part of the Kwai Chung Road was destroyed by huge waves approaching from a southwesterly direction during typhoon Ellen.

Offshore sand exploitation

A location map of offshore borrow areas is shown in Figure 3. Over the past ten years, there has been a dramatic increase in the exploitation of offshore sand needed for coastal land reclamations. Major recent coastal land reclaimed using marine sands includes the West Kowloon Reclamation (330 ha) and the Chek Lap Kok Airport (1200 ha).

Offshore sand exploitation is preferable to flattening the hillsides to provide constructional fill mainly because of land shortage and the problem of land rights. The exploitation of offshore sands has given rise to a number of coastal management problems (Bowler, 1985). To date there has not been any co-ordinated effort to address the long term impact on the marine environment in spite of objections by the fishing industry and green groups such as the Marine Conservation Society. From Figure 3, it can be seen that the sand borrow areas are distributed in all three hydrographic zones of Hong Kong. The environmental impact on each zone is expected to vary considerably because each zone possesses different characteristics. In the eastern zone, coral reefs are sensitive to the increase in turbidity caused by the release of suspended solids during dredging. Since the annual mean sea water temperature in Hong Kong and the fresh water discharge of the Pearl River already makes conditions marginal for coral growth, under increased environmental stress, their chances of survival would be reduced. In the western zone, oyster cultivation has been carried out for at least fifty years in Deep Bay. Although it is difficult to predict the long term impact of dredging, there is likely to be a decrease in nutrient availability. If the rate of sedimentation is increased through dredging, oysters will have a slower growth rate while the oyster beds may become buried. Dredging will also destroy the spawning ground of benthonic organisms with disastrous consequences to coastal fisheries.

Mariculture and coastal fisheries

The territorial waters support a traditional inshore fishing industry based on trawling of the sea floor. Because of the increase in demand for fish, many inlets and bays have been developed for fish culture using floating cages over the past twenty years. Based on data from the 1987 Hong Kong Year Book, Wu (1988) estimated some 270 tonnes of fish were lost by the mariculture industry through pollution. Out of this total, a lost of 12 tonnes was attributed to coastal development including reclamation and silting. However, it was after 1986 that the scale of dredging in Hong Kong intensified.

Red tides caused by pollution are harmful for two reasons (Environmental Protection Department, 1993). First, they deplete oxygen levels in the water causing marine life to perish. Second, they may produce toxins that enter food chain, contaminating shellfish which are then dangerous to eat. In April 1992, one of the largest bloom on record occurred covering nearly the whole of Hong Kong's eastern waters resulting in mass mortality of fish (Environmental Protection Department, 1993). Such events are linked to the increase in nutrient load discharged into the coastal waters through sewage outfalls and agricultural effluents.

Coastal recreation

As a coastal city, Hong Kong has its share of coastal recreational activities including sea bathing, yachting and other water sports. Due to the popularity of sea bathing in the summer, the government places a high priority on maintaining the water quality of the most popular bathing beaches. A system of beach grading based on the indicator bacteria *Escherichia coli* is enforced to provide health-risk warning.

An increase in turbidity through dredging is clearly undesirable for bathing and other watersports such as scuba diving. Out of the three hydrographic zones in Hong Kong, the eastern zone has traditionally been the best for clean water, because of the oceanic influence. Additionally, coral reefs which are associated with a diversity in marine life are attractive. The decline in visibility in these waters is related to offshore sand exploitation, offshore dumping of constructional wastes, offshore disposal of sewage sludge, and, increase in shipping activity. Major quarries located near Mirs Bay also releases dust into the coastal waters.

A POLICY TOWARDS SUSTAINABLE COASTAL DEVELOPMENT

Based on the coastal management problems, it can be seen that in every case, problems have arisen through coastal utilization by humans. In order to develop a policy towards sustainable coastal development, it is necessary to accommodate the different types of utilization in naturally favourable areas to reduce their environmental impact.

Since typhoon shelters are excellent traps for land-derived effluents, they may be used effectively to prevent the spread of effluents to reduce their environmental impact over a wide area. For sustainable and cost-effective coastal development, the long term coastal management plan should be divided into stages of reclamation on a smaller scale than the West Kowloon Reclamation at about twenty or thirty-year intervals. Each stage is to be accompanied by urban renewal and reclamation of typhoon shelters. In this plan, effluents should be treated whenever possible at the source while typhoon shelters are used to prevent their spread. This is a different approach to the Hong Kong Government's sewage strategy involving the construction of a territory wide sewage collection network, primary treatment plants and a long sewage outfall. This sewage strategy is considered to be short sighted because it is aimed at tackling only one aspect of concern to coastal management, namely sewage disposal. Furthermore, the effectiveness of ocean disposal is in doubt and there is also opposition from the People's Republic of China because the waste will also have an impact on their waters.

In view of the conflicting demands on the utilization of coastal waters, it makes sense to use the three hydrographic zones in Hong Kong so that the most desirable natural characteristics can be conserved. The recommended utilization in each of the three zones is summarised in Table 2. Waste disposal and offshore sand exploitation should be banned in the eastern zone because of the naturally

Western zone	Central zone	Eastern zone
Land reclamation for development Container terminals Sand and gravel dredging Sewage disposal Disposal of uncontaminated and contaminated wastes Coastal landfills Tyhpoon shelters	Land reclamation for development Container terminals Limited sand and gravel dredging Typhoon shelters	Recreation including bathing beaches Marine parks Wetland nature reserve Watersports e.g. scuba diving, yachting, etc. Coastal fisheries Limited mariculture

Table 2. Recommended utilization of the three hydrographic zones in Hong Kong shown in Figure 1

clean environment. It should be kept for limited mariculture, coastal fisheries, and, recreation including marine parks to protect coral reefs and wetland nature reserves. The central zone can continue to be used for coastal land reclamations including container terminals, typhoon shelters, and, limited amounts of sand and gravel dredging. On the other hand, since the western zone is already influenced by the estuarine conditions of the Pearl River mouth, offshore sand exploitation, the disposal of uncontaminated and contaminated wastes, and the disposal of sewage sludge may be carried out. The scheme of utilization of coastal waters proposed is favoured by the net westerly drift of sediment along the south China coast.

Much information obtained on the marine environment in Hong Kong is now available to suggest that the policy towards sustainable coastal development outlined is correct. These include the distribution of metals in sea-floor sediments (Yim and Fung, 1981; Yim, 1984), sedimentological characteristics (Yim and Leung, 1987), sedimentation rate (Yim et al., 1996) and the hydrology of the coastal waters (Watts, 1973; Morton and Wu, 1975; Ridley Thomas, 1985). The policy is based on sound earth science principles which permitted the better prediction of human impacts. It should be possible to refine this policy as part of a long term coastal management plan based on using the natural characteristics of the coastal environment to the best advantage.

CONCLUSIONS

The policy of coastal development for Hong Kong outlined is sustainable because it attempts to work in harmony with nature. Through being able to cater for many types of coastal utilization and the ability to conserve the most desirable characteristics of the coastal environment, it is cost-effective. Further advantages include nature is used to the best advantage and that it is based on known earth science principles. The relocation of some of the current utilization is however necessary while a continuous effort is needed to reduce wastes.

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SPECIAL COMPENSATION FOR SUBORDINATE SALVAGE OF MARINE ENVIRONMENT

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ABSTRACT

With the advent of the coming into force of the International Convention of Salvage 1989 in July 1996, the salvage service rendered to prevent or reduce marine pollution has now been recognised as rewardable to varied degrees in law internationally even if the salvage is unsuccessful. This proves to be an exception to the general principle of salvage law - "No Cure No Pay". After reviewing the greening process of the marine salvage law and commenting upon the landmark English case on the new salvage convention: The Nagasaki Spirit, this article will reveal, among other things, that the essence of the word "Pay" in the "No Cure No Pay" maxim in fact refer to the "pay" of the salvage expenses or costs because in respect of the salvage of marine pollution the new maxim "No Cure No Pay of the Profits" is applied instead.

Besides, the issues as to the salvors'pollution liability and the possibility of its limitation in law will receive discussion as well as the P&I club's salvage retainer concept.

INTRODUCTION

Along with the green movements, increasing penalty and obligations have been imposed in the form of international conventions about pollution on potential polluters. Among them, there are the following conventions all aiming one way or another at preventing or reducing marine pollution: International Convention relating to Intervention on the High Seas in Cases of Oil Pollution Casualties 1969 and Protocol Relating to Intervention on the High seas in Cases of Marine Pollution by Substances other than Oil 1973, Protocol to amend the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage 1971, International Convention for the Prevention of Pollution from Ships 1973 (MARPOL) or its 1978 protocol, The Dumping of Waste Convention 1972, 1978 and 1988, Convention on Civil Liability for Oil Pollution Damage 1969 and its recent version in 1992, Protocol to amend the International Convention on Civil Liability for Oil Pollution Damage 1969 (C.L.C.), Convention on the Establishment of an International Fund for compensation for Oil Pollution Damage 1971 or its recent version 1992 Protocol to Amend the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage 1971 (The Fund Convention). To be added to them, is another convention about marine salvage which has been amended from its predecessor in 1910 taking into account the commercial or political need to counter the marine pollution. That is, to use the salvage to prevent or minimize the marine pollution and such efforts can be compensated. Although there are many means to counter the marine pollution, the traditional salvage is acknowledged as an useful first defence thereagainst. This article is intended to examine the legal aspects of salvage for preventing and reducing marine pollution as provided under the 1989 Salvage Convention and underlined by some leading English cases. As Hong Kong through Merchant Shipping (Collision Damage Liability and Salvage) Ordinance 1997, and Mainland China, through Maritime Code of China 1993, are the parties to the Salvage Convention 1989, the discussion here will also be relevant in the local context. While the US law of salvage is not targeted by this paper, some passing references to them are occasionally made in the following discussion.

LINKS BETWEEN THE SALVAGE CONVENTION 89 AND THE LOFS

One of the most important principles in salvage law is "no cure no pay". That is to say the salvage operation will only be remunerated if it successfully salve the things in danger. This concept has been in existence as back as being incorporated in the 1910 Salvage Convention and is restated in Art. 12 of the Salvage Convention 89 which adopts the words "useful result" to refer to "success" or "cure". "No payment " in Art. 12 obviously mean not only no payment of "salvage expenses" but also no payment of "salvage profits". In fact under Art. 1(e) "payment" mean "any reward, remuneration or compensation". Though as fundamental as the "no cure no pay" is, it is found not to be able to meet the reality completely. So an exception to the principle has been designed and now can be found in Art. 14 of The Salvage Convention 89 to make it possible for a salver to receive special compensation even if the salvage operation either related to salvage of property or related to salvage of environment or both are not successful. The need for such an exception has been given a good summary by Lord Mustill in hearing *The Nagasaki Spirit(1997)*, the first case before The English House of Lords on interpreting Article 14 of the 89 Salvage Convention incorporated into the LOF 90 used in this case:

> ..... [A] salver who might perform a valuable service to the community in the course of an attempted salvage, by for example moving the vessel to a place where the escape of oil would be less harmful, would recover nothing or only very little. If in the end the ship was lost or greatly damaged. Something more was required to induce professional salvors, upon whom the community must rely for protection, to keep in existence and on call the fleets necessary for the protection of natural resources in peril. Some new form of remuneration must be devised.[see *The Nagasaki Spirit* at p.p.327 (1997)]

Several years before the Salvage Convention 89 has been available for signature, a similar concept, normally known as "safety net", has been used in the Lloyd's Open Form of Salvage Agreement 1980. Although at present the LOF has two additional recent versions in LOF 90 and LOF 95[see The Lake Avery(1997)], both of which have incorporated Art 14, among other things, as a part of salvage agreement which is in fact subject to the English law which includes the whole salvage convention 89, LOF 1980 has not been completely replaced and is still preferred to by the salvor for at least one reason: i.e. the geographic scope of the application of the safety net in LOF 80 is world-wide while that of the application of the Salvage Convention 89 is confined to coastal areas and its adjacent waters as provided in Art. 1(d). However, it seems that the salvor would expect stricter duty under LOF 80 in performing the salvage operation than under 89 salvage convention in that the former requires "best endeavours" in clause 1(a) while the latter only requires "due care" in Art 8(1)(b). As far as this difference is concerned, LOF 80 seems to be more environmental friendly than 89 Salvage Convention[see per Lord Diplock at p.p. 362-363, *The Eschersheim*(1976)]. In some other aspects, Salvage Convention 89 seems to rank higher in the environmental chart: the extent of special compensation for successful environmental salvage amounts to 30% of salvage expenses up to 100% in the Salvage Convention 89 compared with only 15% increment in LOF 80. Besides, Salvage Convention 89 has widened the scope of coverage of pollutants to include other pollutants than oil which is the only pollutant covered in LOF 80.

Given the differences between the contractual terms in LOF 80, LOF90, LOF 95 on the one hand and Salvage Convention 89 on the other, one may wonder which will prevail if there are conflicts between them. The answer can be found in Art. 6(1) which indicates that the salvage contractual terms can override the Salvage Convention 89's provision when there are such conflicts. But if there are no such conflicts the provisions of the salvage convention 89 can be implied into the salvage contract. However, if the terms of the salvage contract is unfair then they will be subject to the control of Art. 7 according to Art 6(3) which authorises the annulment or modification of the salvage contracts in such a situation. To require the "due care" for salving the environment but not the "due care" for salving the property seems to be the greenest article of the Salvage Convention 89. Above all, the LOFs have gained popularity over the years and can now in its recent two versions serve to execute as well as to promote the Salvage Convention 89.

The word "special" in "special compensation" used in Art. 14 gives away the nature of salvage of environment in that the compensation does not depend upon the success of the salvage operation and the special compensation payee/ owner of the vessel receiving such salvage only indirectly benefit from such environmental salvage in the sense that such a shipowner has been salved from the potential successful legal action from the pollution victims. But given the special nature of the environmental salvage, could such salvage stand alone without involving the salvage of property at all as that indicated in *The Whippingham* (1934). This is the issue to be discussed in the next section.

RELATIONSHIP BETWEEN ART 14'S SPECIAL COMPENSATION AND ART 13'S SALVAGE AWARD

A full incentive under the salvage convention 89 for environment salvage is more imagined than real. That is evidenced by the wording "in respect of a vessel" in Art 14 (1) qualifying the salvage operation to be awarded with special compensation. This has been acknowledged by Lord Mustill (at p.p. 327,332) in *The Nagasaki Spirit* (1997) and supported by travaux peparatoires [at p.p. 333, *The Nagasaki Spirit (1997)*] that the salvage of environment can not stand on its own. Rather salvage of environment is subordinate to traditional salvage of property as provided under Art. 13. The position of environmental salvage is to some extent comparable to life salvage[see *The Bosworth*(No.3)(1962)]. The award for either life salvage or environmental salvage are initially based upon the value of the salved property. When the salved property is <u>not enough</u> for funding the environmental salvage or there are <u>no</u> salved property for funding life salvage, the salvor of environment will be specially compensated and the life salvor may get nothing or may get some compensation from some national fund such as the U.K.'s Marine fund. In this respect, the award for life salvage is more dependent upon the property salved than the environmental salvage. But like life salvage, salvage of environment alone cannot be awarded with special compensation - an example could be that the pollution is caused by the oil leaked from an oil pipe on the sea bed. The dependence of Art 14's special compensation upon Art. 13's salvage award could be further reflected in the method of the calculation of the two amounts. That is, only when salvage expenses plus increment under Art. 14 exceed the salvage award under Art 13 should the shortfall between the two amounts be paid by the shipowner as special compensation. Bearing in mind that the life salvor can also share the special compensation(see Art 16(2) of the Salvage Convention 1989), the situation where the salvor can get the highest compensation amount - twice salvage expenses - is when neither life nor property has been salved in the same operation and there are no negligence on the part of the salvor causing any damage in the salvage(see Art 14(5) of the Salvage Convention 1989). Moreover, on top of the above amount, the salvor is entitled to interests and legal costs, if any, as that provided by Art 13.3. The situation where the salvor get the least or none of the special compensation is where the salvage expenses plus increment is less than the salvage award as calculated under Art. 13. As Art 13.1(b)(h)(i)(j) have been considered both in the calculation of Art 13's salvage award and Art. 14's special compensation there is a danger that these factors may be doubly considered. In the light of the law that the top ceiling for Art. 13's salvage award is the salved value, should Art. 13 award be fixed up to the salved value before the special compensation be assessed? The answer can be found in the Common Understanding contained in the Attachment 1 to the Final Act of the 1989 Diplomatic Conference (see Gaskell,, at para. 21-433, 1995)which provides that the court or tribunal entrusted to do the calculation can do it this way but is under no obligation to do it this way.

Above all, it is not easy to divide clearly what should be covered by Art. 13 and what should be covered by Art. 14. This difficulty indicates that the drafting of the Salvage Convention does leave rooms for improvement. In fact, one of the controversial issues about the construction of the Salvage Convention has just been exposed in the litigation in the English House of Lords which is to be seen in the next section.

NAGASAKI SPIRIT RULES UPON THE MEANING OF "FAIR RATE" AND DURATION OF SALVAGE

Art. 14 explicitly provides that "out of pocket" expenses plus a "fair rate" of personnel and equipment will be compensated to the salvors even if the operation of preventing and minimising damage to environment is not successful. In *The Nagasaki Spirit Case* there are no disputes as to the meaning of "out of pocket" expenses which shall refer to the direct costs given out in the particular salvage operation mainly related to the salvage of environment. Disputes do arise as to whether the "Fair rate" should include an element of profit which could serve as a further incentive to the salvor in the salvage of environment. Mr. Brice, Council for the salvor in the case and renowned for his book titled *Maritime Law of Salvage*, holds the view(see Brice at para. 4-113,1993) that "fair rate" should include profits, because the "rate" in its ordinary meaning may include an element of profits. So a yellow-page salvor who does not have its own salving tug would search the tug chartering market for the hiring rate when his salvage service is needed; such "rate" is normally referring to the daily rate of an amount of money for hiring a tug and such rate must include an element of profit as the tug owner would not let out his tugs merely for recovering back the operating and maintaining expenses as well as depreciation subject to the situations in the market. Such an interpretation is very true in the commercial world, but Lord Lloyd rules(see *The Nagasaki Spirit*,1997,at p.p.334) that the ordinary meaning of rate is not intended by Art. 14, which is supported by the travaux preparatories. Instead the fair rate only denotes. "... an amount attributable to the equipment or personnel used reasonably", which is obviously related to indirect costs or overheads only.

Such a holding is also based on the fact that the incentives have already been available to the salvor for carrying out such environmental salvage in the name of increment provided under Art. 14(2). Such increment, which is beyond the salvage expenses, should be regarded as a kind of profit despite the fact that the sum of increment is still worded as a kind of "compensation" rather than "remuneration or award" under Art. 14. It should be noted here that the word "compensation" in its ordinary meaning should be used to refer to the reimbursement of costs rather than referring to remuneration, reward or profits. Nonetheless, the increment here, whether it is named as compensation or not, must mean profits (see per Lord Mustill at p.p. 332, The Nagasaki Spirit, 1997).

The above notwithstanding, the fact that under Art. 14(3) the assessment of the fair rate should be based on the consideration of Art. 13(1), (h), (i), (j) gives rise to the problems of construction as well. Art. 13(l),(h),(i) and (j) read as follows :

(h) the promptness of the services rendered
(i) the availability and use of vessels or other equipment intended for salvage operations
(j) the state of readiness and efficiency of the salver's equipment and the value thereof

Strictly speaking, that the Salvor's expenses under Art. 14(2) are said to be "incurred" under Art 14(2) also indicate that the fair rate can not include profits because profits cannot be "incurred"(see per Lord Mustill at p.p. 332, The Nagasaki Spirit, 1997).

Besides, the whole paragraph 1 of Art. 13 is taken into account in ascertaining the conventional salvage award under Art. 13, but only paras. (h),(i) and (j) are taken into account in ascertaining the "fair rate" under Art 14. There is an argument by Mr. Brice (see Brice at p.p.198, 1993) that the consideration of (h),(i) and (j) itself under Art 14(3) implies that the fair rate include an element of profit. But the English House of Lords in *The Nagasaki Spirit* does not give a clear guide line as to how to apply the criteria in (h), (I) and (j). "Fair rate" under 14.2 should not be regarded as exclusively referring to the indirect costs related only to preventing or minimising the damage to environment as such environmental salvage is only subordinate to the salvage of property. If the "fair rate" of indirect costs cannot be intended as including profits for the purpose of Art. 14.2, neither should "fair rate" be so intended for the purpose of salvage of property under Art. 13 because property salvage award should also include the salvage expenses, direct or indirect, plus profits.

Even if "fair rate" has now been regarded as referring to indirect costs or overhead of a salvor having stand-by vessels, it is not easy to determine the exact amount of those costs. But the problem could always be solved by an agreement on an approximate figure if the parties do not wish to drag on in disputes or litigation later on. It is true that the ruling out the profit from the "fair rate" is a defeat for the salvage industry. Yet the salvage industry has a win on the other account, i.e. as to the issue that whether the salvage expenses should be those incurred for the whole period of salvage operation or those incurred only for the period when the threat to the environment exists, The English House of Lords concurred with the Court of Appeal's decision to the effect that the expenses of the whole salvage operation should be treated as salvage expenses(see per Lord Lloyd at p.p.334, *The Nagasaki Spirit*, 1997). This is reasonable because whether the threat to environment ends earlier or later, the salving ship has to incur costs to return to the port from which she sailed for the salvage location. Of course the duration of salvage should not be unreasonably prolonged, which is also not to the interests of the salvor. That said, the duration when the threat to the environment exist can be significant in ascertaining the increment when the salvage is successful.(see Gaskell at p.p. 412, 1995)

SALVOR'S POLLUTION LIABILITY AND ITS LIMITATION

The mandatory obligation to exercise due care to salve the environment is provided by Art. 8.1 (b) and by Art. 6.3 of the Salvage Convention 89, which cannot be contracted out. However, LOFs adopt the wording of "best endeavour" instead of "due care" as adopted under Art. 8.1(b). One commentator acknowledges that there are significant differences between these two phrases: "The requirement of due care is an objective one based on reasonableness, taking into account of the general standards in the salvage and marine industries. The emphasis on 'best' endeavours might indicate a more subjective test, looking to actual capabilities of the salvor in question"(see Gaskell at p.p.390,1995). If such a difference does exist, the LOF might be in this respect modified by Art. 8.1(b) because the Salvage Convention 89 does not mention that only those contractual terms that would reduce Salvor's environmental duty would be struck down as that happen in respect of Art. 3(8) of Hague Visby Rules. But as the above-mentioned commentator notes, that the IMO legal committee responsible for drafting may intend to erase translation by substituting the words "best endeavour" for "due care" in the final version of the convention. So, it is arguable that the interpretation of the ordinary meaning of those two phrases may well be ignored just as that the ordinary meaning of the word "rate" is ignored in the interpretation of the "fair rate" in *The Nagasaki Spirit.*

Breach of the obligation under Art. 8.1(b) would result in depriving part or whole of the special compensation off the salvor according to Art. 14.6. On the other hand, Art 14.6 does not expressly exclude other remedy against the salvor.

As between the salved vessel and the salvor, the owner of the salved ship may have to be surrogated to the right of the pollution victim, usually the citizen of the coastal states, to sue the salvor in the name of the pollution victim after paying the pollution victim the compensation normally under C.L.C. 1969 or C.L.C. 1992[see Hong Kong's Merchant Shipping (liability and Compensation for Oil Pollution)(amendment) Ordinance]. Alternatively, the owner of the salved ship may sue the salvor for financial losses. The above two channels of legal action have been tried in *The Esso Petroleum Ltd. v. Hull Russell*(1988) casebut failed for its special circumstances.

In fact, in both CLC 1969 and CLC 1992, Art. 3(5) provides that nothing in either of the two versions of C.L.C. shall prejudice any right of recourse of the owner against third parties.

As between the pollution victim and salvor negligently causing the pollution, Art. 3(4) of 1969 C.L.C. provides that no action under the convention shall be made against, among others, "agents of the owner" which could include an independent contractor like salvor; so the pollution victim could not sue the salvor concerned for breaching the C.L.C. obligation. More explicitly, Art. 4, 4(a) of CLC 1992 provides that no action for compensation for pollution damage under this convention shall be made against "any person performing salvage operations with the consent of the owner or on the instruction of a competent public authority". That notwithstanding, the pollution victim could still sue the salvor in tort. In the American case, the *Amoco Cadiz*(1984), Judge McGarr summarises this part of the law(at p.p.337) : "The CLC is not the exclusive remedy available to victims of oil pollution damage and does not prohibit such victims from bringing an action in tort outside the CLC against anyone other than the registered owner of the vessel or its mandataries or prognoses ('agents' and 'servants' in the English text of the CLC). All other parties may be sued and held liable, without limitation independent of the CLC".

As it has been held in the English case *The Tojo Maru*(1971) the claim for damage caused by the negligence of the salvor is exactly the same as that in the general law of torts. That is to say, so far as such damage has been found to be casually connected withthe negligence of the salvor, the injured party can sue the salvor for the damage which should not be limited to the amount of salvage remuneration.

As for the pollution damage caused by the act of a salvor, the salvor could be held liable for such pollution damage if his negligence has caused such pollution damage. But what if such an act is free from his fault? It is probable that the rule that the liability for pollution at common law is strict liability should not be applicable in this respect because a salvor's act without the element of fault could rarely be regarded as the responsible cause for the pollution damage.(See Bates and Banson, at para.4.222, 1993).

This direct action by the pollution victim against the Salvor is especially useful whether or not the owner of the salved vessel is able to exclude his liability totally under certain circumstances (see Art III(2) of both C.L.C. 1969 and C.L.C. 1992). In the face of such possibility of being sued by either the salved ship and the third party pollution victim, could the salvor use an exception clause or an indemnity clause to fend off such an obligation? In consideration of the prohibition of Art 6.3 of the Salvage Convention 89, such an approach seems doubtful. If the breach of the environmental duty of the salvor is caused by a third party including those on board the vessel receiving the salvage the salvor could well be able to sue these parties for either economic loss in tort or subrogated to the right of the pollution victim to sue these wrongdoers.

There is a chance that the salvor could limit his liability for the pollution, other than of oil, caused by his act under Art. 1(1) and Art. 2(1)(c) of the Convention on Limitation of Liability for Maritime Claim 1976. The former provides that the "ship owners and salvors, or hereinafter defined, may limit their liability in accordance with the rules of the convention for claims set out in Art. 2". The latter provides that "claim in respect of other loss resulting from infringement of rights other than contractual rights, occurring in direct connection with the operation of the ship or salvage operations". Both the action by the owner of the salved ship against the salvor for economic loss and the action under the subrogated right in the name of the pollution victim against the salvor are normally tortuous action. So the salvor may well be able to limit his liability in this connection. If the above is right, the pollution damage borne by the salvor should be limited before it is to be set off against the special compensation. That is the result of the adoption of the approach decided in *The Toja Maru*(1971) in this connection. That said, the salvor would not be able to limit his liability for oil pollution damage under the 1976 limitation of liability convention under which art. 3(b) excludes from its coverage the "claims for oil pollution damage within the meaning of the International Convention on Civil Liability for Oil Pollution Damage dated 29th November 1969 or of any amendment or Protocol thereto which is in force."

On the other hand, as salvors, like other third persons, cannot be sued under both the CLC 1969 or CLC 1992, salvor would not be able to limit his liability for pollution damage whether caused by oil or not there. But as we will see in the next section, the tanker owner may be able to limit his liability for special compensation as a kind of costs of preventive measures under the C.L.C.

PARTIES LIABLE TO PAY SPECIAL COMPENSATION

Contrasted with what is provided under Art. 13, Art. 14.1 expressly provides that the special compensation will be "from the owner of that vessel". However, Art. 14.6 provides that "nothing in this article shall affect any right of recourse on the part of the owner of the vessel". The "vessel" here obviously refer to the vessel receiving the salvage. But if the cargo beneficiary be bought in to bear the special compensation the special compensation will not be treated as general average because the York Antwerp Rules' rule v.(b) so provides(see Hudson, at p.p. 168, 170, 1980) However, it is possible that an indemnity clause could be inserted in the contract of carriage to make the cargo owner pay the whole or part of the special compensation unless such a clause is struck down as void clause under some statutes like Hague-Visby Rules.

Despite what has been said above, the cargo owner in the following situation does contribute to the cost of environmental salvage efforts and skills under Art. 13.1(b). In other words, when the special compensation is less than the salvage award for property under Art 13, the cost of environmental salvage has been contributed to by the cargo beneficiary in the name of salvage award for property.

In this aspect, the Salvage Convention 89 has inherited the situation from the LOF 80, where the similar arrangement of paying for oil pollution as that under Art. 13 and 14 is made as a result of the compromise between the paymasters behind the immediate scene: underwriters of ships/cargoes and the P & I Clubs. Logically, the formers are more concerned with the effect of the property salvage while the latters are more concerned with the effect of environmental salvage. As the dual functions of the salvage can not be totally separated, the P & I Club would not be willing to pay the salvage award for property while the insurers of hull or cargo would not be willing to pay the salvage award for pollution prevention or reduction. They ends up with a compromise of paying some of the other's bill. So, the insures of hull or cargo have to pay those arising under Art. 13.1(b) and the P & I Clubs have to pay the salvage expenses for salving environment provided under Art 14 which cannot separated clearly from the salvage expenses for salving ships or cargoes(see Clark, 1980). As we will see later that is also the arrangement in the new Institute Time clauses 1995 (Hull) used in the London Insurance Market and the arrangement provided in the York Antwerp Rules 1994.

If we agree to the view that special compensation could be treated as a kind of cost of preventive measures incurred by the tanker owner so that the tanker owner's liability for special compensation could be limited under the C.L.C., it is possible that if the tanker owner could not pay the special compensation under the C.L.C. under certain situations then the fund convention to which contributed by oil users will pay. In this way the cargo interests will indirectly pay the special compensation. The above is a scenario arising under the concept of liability salvage for which the award is based on the tonnage of the salved ships and not related to the costs or efforts of the salvor. However, this salvage of liability concept has not been accepted yet in law(see Brice, at p.p.283, 1993). Even if the concept of liability salvage is accepted, the Salvage Convention needs to be reformed to be in step with the C.L.C. at least in respect of the kinds of pollutants to be covered, i.e. oil or all pollutants.

In one situation noted by a commentator(see Gaskell, at p.p.409, 1995) where the special compensation need not be paid by the shipowner is where the pollutant cargo washed over board is due to the perils of the sea for which the carrier is not liable and its loss will not affect the safety of the ship. According to the wording of Art. 14.1 "in respect the vessel", the salvor cannot get special compensation from the shipowner. To this, the environmental group may raise an eyebrow and suggest a reform.

To make the payment of special compensation consistent with other liability regimes which have the tendency of adopting the two tiers system, it is suggested that a cargo fund should be set up to modify the arrangement under Art 14 and make cargo interests contribute to the special compensation in some situations(see Potts, 1996). On the other hand, it seems that the special compensation will have a less chance of being limited under the 1976 International Convention for shipowner's Limitation of Liability as special compensation like salvage award are not qualified for being treated as damage(see Brice at p.p. 32, 1990).

INSURERS' POSITION

The liability for paying the special compensation is a kind of third party liability which can be insured with a P & I Club. Although, as it has been mentioned previously, the insurers of ships or cargoes would be liable to pay for some pollution prevention efforts under art 13.1 (b) yet they are not liable to foot the bill of special compensation. This has been expressly so provided under clause 8.4.5 of the Institute Time clauses Hulls that the hull insurers is excluded from liability for

> pollution or contamination - or threat thereof, of any real or personal property or thing whatsoever (except other vessels with which the insured vessel is in collision or property on such other vessels) or damage to environment, or threat thereof, save that this exclusion shall not extend to any sum which the assured shall pay for or in respect of salvage remuneration in which the skill and efforts of the salvors in preventing or minimising damage to the environment as is referred to in Article 13 paragraph 1(b) of the International Convention on Salvage, 1989 have been taken into account.

As being mentioned previously, the above arrangement is in consequence of a compromise that the hull insurer as well as cargo insurer would contribute to some part of pollution prevention costs as that provided in Art. 13.1(b) of salvage convention in exchange for the total liability of paying the special compensation under art 14 being imposed on the P & I Club.

This hull insurance arrangement is consistent with the provision of York-Antwerp Rules 1994 in similar areas. As Rule IV of York Antwerp Rules 1994 provides :

(a) ... expenditure allowed in general average shall include any salvage remuneration in which the skill and efforts of the salvors in preventing or minimising damage to the environment such as is referred to in Art. 13 paragraph 1(b) of the International Convention on Salvage 1989 have been taken into account.

(b) Special compensation payable to a salvor by the shipowner under Art 14 of the said convention to the extent specified in paragraph 4 of that Article or under any other provisions similar in substance shall not be allowed in general average.

Thus, the above cited part of 1(a) of York Antwerp Rules 1974 is consistent with Art. 13 of Salvage Convention where the salved cargo interests are under the obligation to contribute to the salvage award taking into account some efforts of pollution prevention. On the other hand, Art 1(b) of the same Rules is in agreement with Art. 14 of salvage convention in that the salved cargo interests including his underwrite would not have to pay the special compensation as general average expenses otherwise the requirement of Art 14 that the salved cargo interests is not liable to contribute to the special compensation will be defeated.

That said, it should be noted again that it is difficult to distinguish clearly between what is covered by Art 13.1 (b) and what is covered by Art 14.

If the special compensation under Art 14 could be regarded as capable of being limited under C.L.C. 1969 or C.L.C. 1992, the salvor would be able to sue directly the P & I Club covering such special compensation. Such right of direct action against the insurer and the possible defences available to the insurer are expressly provided for in Art. VII (8) of both C.L.C. 1969 and C.L.C. 1992 as follows :

> Any claim for compensation for pollution damage may be brought directly against the insurer or other persons providing financial security for the owner's liability for pollution damage. In such case the defendant may, even if the owner is not entitled to limit his liability according to Art. V, paragraph 2, avail himself of the limits of liability prescribed in Art. V, paragraph 1. He may further avail himself of the defences (Other than the bankruptcy or winding up of the owner) which the owner himself would have been entitled to invoke. Furthermore, the defendant may avail himself of the defence that the pollution damage resulted from the wilful misconduct of the owner himself, but the defendant shall not avail himself of any other defence which he might have been entitled to invoke in proceedings brought by the owner against him. The defendant shall in any event have right to require owner to be joined in the proceedings.

In the light of the above provision, the P & I club would not be able to use the limitation for oil pollution which has been in the club rules for some time(But the limitation cap in respect of other claims against P& I Club was just introduced on 20/2/96, see Coghlin, 1996) to reduce its liability for the special compensation. Besides, as the above provision has been incorporated into English law by virtue of s.165 of Merchant Shipping Art 1995 and the Third Parties (rights Against Insurers) Art 1930 has been provided thereby not to be applicable to the direct action against insurers for pollution damage in this respect, the "pay to be paid" rule (see *The Fanti and Padre Island*, 1990) would not be a defence available to the P & I Club either. In other words, when a tanker owner is bankrupt before he has paid for the pollution damage to the third party pollution victim, the P & I club could not fend off the direct action against itself by the pollution victim by relying on the rule "that the P & I Club would only pay the member if the member has already paid the third party" which is normally found in the rule book of a P & I Club. Similar situations will arise in respect of financial guarantors under the compulsory insurance against liability for pollution as required by both U.S. Oil Pollution Act 1990 and U.K.'s Merchant Shipping and Maritime Security Art. 1997. As this part of the law is beyond the scope of this article, I would refrain from going any further here. Notwithstanding the possibility of limiting the liability of the shipowner for special compensation under C.L.C., it should be noted here that there is an inherent difficulty of such a limitation i.e. special compensation is in fact related to some property salvage expenses which should not be covered by the C.L.C. apart from the fact that the idea of limiting the tanker owner's liability for special compensation under C.L.C. is based upon the concept of liability salvage which is yet to be accepted in law and practice.

THE SALVAGE RETAINER APPROACH

In the face of increasing claims for special compensation and the unpredictability of the amount of such special compensation, P & I Clubs have proposed recently to have a big say in the control of the salvage so as to reduce the costs of salvage, i.e. to retain a contract with the chosen salvors before dangers arise. This approach has in fact been adopted for sometimes in U.S. in the wake of the coming into being of the Oil Pollution Act 1990 which follows The MARPOL in this respect. Under this OPA 90 the Vessel Response Plan is required to be provided by the tanker operator for up to the worst pollution accident. In this kind of plan a list of salvors should be mentioned as retained for an amount of fee so in case of emergency those retained salvors would be committed to giving the salvage service for the fixed rate of payment; yet on the other hand the tanker operators are not bound to use them(see Scott, 1989).

This new approach advocated by P & I Clubs obviously shows that the other means of cost control such as the measures to impose the efficiency of salvage response to pollution threats agreed between the International Salvage Union and the International Group of P & I Clubs as set in a code of practice relating to the Art. 14's special compensation are not sufficient to control the costs. However, this new approach if adopted will go to the heart of the conventional salvage which are, among other things, principally based upon the principle of "no-cure no pay" and "voluntaries". As has been mentioned previously, the "no-cure no pay" principle can be found in Art. 12, so if a salvor would be paid as fixed in the contract whether the salvage operation is successful or not, it is against the principle of no cure no pay. Besides, the principle of the voluntaries of salvage has been embodied in Art 17 which provides that only those salvage operation exceeding what is required by a contract as entered into before the danger arises would be rewarded as salvage under the convention. But the provision has not mentioned how the salvage contract, entered into after the danger arises, should be dealt with. It is now a popular practice of entering into a contract of salvage based upon the LOF after the danger arises.

Art. 8 also provides a duty for the salvor to observe in the performance of the salvage operation which should be distinguished from the contractual or public duty to commit the salvor to attending to the salvage before the danger arises. The rule that the salvage should be subject to the agreements from the owner or master of the ship in danger, which is also referring to the salvage agreement entered after danger arises, could be found in Art 19. Even for those contracts of salvage entered after the danger arises, they should also be based upon the "no cure no pay" principle. In such agreements, payment on the daily rate when the salvage is successful should still be regarded as being consistent with the "no cure no pay" principle, but not the approach that the payment, whether on daily rate or not, be still made even when the salvage is not successful, which is obviously unusual and against the commercial common sense. The approach of retaining salvage has just breached these two fundamental principles in that normally such retained salvors will be paid even there are no salvage operation undertaken, not to mention whether it is successful or not. Such retaining contract would impose an obligation upon the salvor to commit himself to attending to the salvage. None the less, since the no cure no pay principle does not apply to special compensation under Art. 14, to create another exception to the principle is really not a big problem. It should also be mentioned that the salvage retainer approach would also affect the interests of the Hull or cargo insurance whose interests in this respect very much depend upon the no cure no pay salvage. As the salvage of the property and the salvage of environment cannot be clearly separated, the P & I Club should not and could not act alone without an agreement from the hull or cargo insurers.

There are some mixed feelings from the salvage industry. The predominant one is against the move of the P & I Club to take more control With the technology improved, a traditional salvor would have to wait for a long time to get a no-cure no-pay job, so it is very difficult for him to survive that way. Thus, if a salvor could get paid even there are no accidents to attend to they would keep on going a longer time. This is the good effect of the salvage retainer approach on the salvage industry. In reality a salvor may not need such a new approach because lots of salvage companies nowadays have dual functions, i.e. when there are no salvage jobs they are engaged in the pure commercial towage jobs. They could even go to the extent to be a yellow page salvor who does not have their own salvage equipment and would hire in vessels when salvage is needed. So to adopt the retainer approach would not necessarily better their present circumstances but will deprive them of a chance of making a big profit.

As far as the P & I Clubs are concerned, if the retainer approach is adopted, the amount of special compensation will be predictable and low. In fact, for some big Clubs, they could even serve as the salvors themselves as they normally have correspondents or agents in the major sea ports all over the world. In order to put this new retainer concept into practice, an agreement or a compromise from the hull or cargo insurers is again needed. The retainer approach may cultivate a fire-brigade type of salvors who are under contractual rather than public obligation to salve - a situation bound to be welcome by the environmental group. Even if the P & I Clubs take over the salvage job, it is to the clubs' interests to maintain an effective salvage team. The price for adopting this retainer concept is to abandon the time-honoured salvage approach based upon the LOF's and the Salvage Convention, which may well be worth paying if one takes a long term look at the circumstances.

On the part of the salvors, they would prefer, as reported from this year's annual general meeting of the International Salvage Union in Gothenburg on July 31st, to maintain the parallel practices of using LOFs in the majority salvage operations and at the same time having an agreed rates structure for salvage services to deal with direct pollution threats, the latter is obviously a concession to the P&I club's recent move in respect of salvage, now contained in a proposal called "salvage 2000 concept".

What would be the final arrangement agreed between the salvors and the P&I club should come out soon. Probably, a new contract of LOF/ Salvage 2000 will be given birth to.

CONCLUSION

The Nagasaki Spirit case has ignited the start of a series of the judicial battles for construing Salvage Convention 89, which is very common for a new convention. Construction aside, the salvage convention may be subject to reform earlier than expected. The environmental group such as Green parties could be the driving force behind such a reform. Whilst it should be admitted that the Salvage Convention goes along the green movement yet it is not green enough in at least following aspects :

(1) Salvage of environment at High Seas cannot be compensated.
(2) Salvage of pollutant cargo not affecting the safety of ships cannot be compensated.
(3) A free-standing salvage of environment without involving a ship cannot be compensated.

As the P & I Club intends to push the retainer concept into practice, the fundamental principle of "no-cure, no-pay" may be modified further in the future reform of the Salvage Convention. Although the primary motivation for the P & I Clubs to adopt this new approach is to reduce the risk of paying unpredictable high special compensation, the end result could be anything but not environmental - friendly. Yet, the achievement of this end result will depend upon the agreement from the other parties concerned including Hull and cargo insurers and the salvors'union as well.

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U.S. Country Studies Program: Working Toward Climate Change Sustainable Development

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ABSTRACT

According to guidelines created during the United Nations Framework Convention on Climate Change (UNFCCC) all signatory nations are eventually required to report greenhouse gas emissions inventories and response (adaptation and mitigation) options. Developed countries have been carrying out an obligation to communicate to the Secretariat of the Convention for several years though developing and economy in transition countries will do the same in the foreseeable future. The United States and other donors are providing financial and technical support for developing and transition countries for their climate change country studies to help meet their needs, according to guidelines set forth at the UNFCCC, for future communications. The U.S. Country Studies Program (U.S. CSP) is currently assisting 55 country studies that address climate change towards sustainable development. There exist strong components for ocean and coastal assessment, adaptation and management in 38 of the 55 studies in the U.S. CSP. In addition to financial support, the United States provides technical assistance for conducting source and sink inventories of greenhouse gases, climate change impact vulnerability studies, adaptation and mitigation evaluations and policy options, which include the training of analysts, implementation of information sharing workshops, and an active scientist exchange program. Emphases have been placed upon the strengthening of human and institutional capacities to cope with global climate change issues, hence providing developing and transition countries with a sound foundation in order to work towards sustainable development and meet the goals of the UNFCCC.

INTRODUCTION

Recent observational data and scientific studies, summarized mostly by the Intergovernmental Panel on Climate Change (IPCC) under United Nation's auspices, have concluded that greenhouse gases resulting from human activities may have disturbed the earth's climate system. This assessment comes from more than 2500 IPCC scientists in 100 nations working on climate change and its related issues for a number of years. Recently, IPCC scientists and government experts have concluded and set forth, by consensus, the statement that "the balance of evidence suggests that there is a discernible human influence on climate changes."

The 1990 and 1992 IPCC scientific and technical assessments on climate change led to the United Nations Framework Convention on Climate Change (UNFCCC), signed by over 150 nations in 1992. The UNFCCC requires all signatory countries to communicate a national inventory of greenhouse gas (GHG) emissions by sources and removals by sinks (1). Moreover, each country is eventually required to describe the steps and actions it is taking to implement the principles and goals of the UNFCCC, especially response measures that contribute to adaption of climate change impacts and the mitigation of GHG emissions. Climate change studies are a first step for countries seeking to meet their national reporting and other obligations under the UNFCCC and marching towards sustainable development.

The purpose of this paper, in addition to introducing the U.S. CSP, is to: 1) provide an overview of U.S. CSP goals and approach for assisting developing and transition countries to conduct climate change assessments and analyses in their own country studies; 2) briefly describe the current status of the U.S. CSP; and 3) identify steps for countries as they seek to complete their obligations to the UNFCCC.

U.S. COUNTRY STUDIES PROGRAM

To help developing countries and countries with economies in transition meet their obligations, and to fulfill, in part, its own commitment to the UNFCCC, which is to provide financial resources to help developing and transition countries, the U.S. Country Studies Program (U.S. CSP) was created by the United States in 1992 (2, 3). In its first phase the $35 million U.S. CSP has provided technical and financial support to 55 developing and transition countries on five continents (Figure 1).

Objectives

The primary objectives of the U.S. CSP are as follows:

1)to enhance the abilities of countries and regions to inventory their GHG emissions, assess their vulnerabilities to climate change, and evaluate response strategies for mitigating emissions and adapting to the potential impacts of climate change (4,5);
2)to enable countries to establish a process for developing and implementing policies and measures to mitigate and adapt to climate change, and for re-examining these policies and measures periodically (6) toward sustainable development; and
3)to share information that can be used to further national, regional and international discussions of climate change issues (2).

Eligibility

Eligibility requirements for developing and transition countries who would like to participate in the U.S. program include:
1. Signatory of the U.N. Framework Convention on Climate Change (UNFCCC);
2. Pledge to officially adopt and widely share the results of a study in an appropriate international form; and
3. Establish appropriate institutional structures to direct the study and provide a basis for developing and implementing future policies to address climate change and sustainable development.

Resources

The original U.S. support for Country Studies was $25-million to be administered for two years. The U.S. Country Studies Program now supports 55 country studies with a total budget of more than $42-million after four years of implementation. Ten U.S. government agencies pooled resources under a presidential initiative to assure an implementation program that is broad based and accounts for all major resource sectors. The Country Studies Management Team (CSMT), with full and part-time personnel drawn from EPA, DOE, U.S. AID, DoS and NOAA, manages the day-to-day operations.

Bilateral Cooperative Agreement

The initiation of an individual country study for the participating nation started with a formal diplomatic request from the country for financial and technical support. Steps for developing the individual bilateral agreement ensure its national interest and statewide integration for the study. After the developing and transition country's proposal satisfied the technical peer and program review processes, the participating country entered into the **bilateral cooperative agreement** with the U.S. financial and technical support is provided through the implementation of the bilateral cooperative agreement.

Technical Cooperation

Technical support and cooperation with study teams from developing and transition countries is a major element of the U.S. CSP (3). In addition to the direct funding of climate change studies, the program devotes 25% of its resources to hands-on training of participants in assessment techniques, development and sharing of contemporary analytic tools, short-term analyst exchange programs, and technical support of studies through site visits. The U.S. CSP has developed and distributed a guidance handbook of vulnerability and mitigation assessment techniques (4). The analytical phase of the U.S. CSP has been in effect for approximately three years, and various technical outputs have been reported (4). In cooperation with a number of international and intergovernmental organizations, the U.S. CSP and developing and transition country participants have organized regional workshops to share preliminary results from their studies (2).

Current Status of Country Studies

The climate change country studies implemented in cooperation with U.S. CSP are generally divided into three topics: inventory of GHG emissions, assessments of vulnerability to climate change, and identification of mitigation measures. The overall goals of the U.S. CSP-sponsored technical support include: 1) building developing and transition countries human and infrastructure capabilities; 2) providing analytical tools, hands-on training and support throughout the country study; and 3) promoting exchange of information among participating countries and with the international community (4). To meet these goals, countries may use a variety of technical approaches, depending on their characteristics and priorities. The U.S. CSP has endeavored to communicate the current scientific elements and concepts that should be part of the vulnerability assessment, and mitigation and adaptation measures, and has made available alternative methods that are transparent and, in many cases, comparable with recommended IPCC methodologies.

Most of the GHG inventory work of all country studies in U.S. CSP have been completed. Climate change vulnerability assessments, and identifications of adaptation and mitigation measures of country studies are near completion. Many regional workshops have been conducted or planned for comparisons of results and exchange of study experiences. There have been more than 30 international workshops sponsored or co-sponsored by the U.S. CSP. In collaboration with other co-sponsors (e.g., OECD, Germany GTZ, UNEP, other donor governments, and participating country governments), the U.S. CSP has provided participating (and other) countries with an opportunity to discuss methodological issues and report their preliminary assessment results at regional workshops convened in various places around the world, (e. g. Mexico, Poland, Republic of Korea, Tanzania and Russia). These workshops addressed a variety of technical topics, including: 1) vulnerability assessments; 2) GHG mitigation options in energy, forestry, agriculture, waste; and 3) coastal resource management sectors, involving processes, adaptations and strategies for policy development and implementation. The workshops also provided a forum for reviewing emerging initiatives developed to support the UNFCCC, such as the OECD Climate Technology Initiative. Technical papers presented at the workshops were subjected to peer-reviewed and have been (or will be) published in special issues of *Environmental Management* , *Interciencia*, *Ambio* , *Ocean & Coastal Management, and others.*

Final study tasks and preliminary reports for all participating countries will be completed by the end of 1997. The U.S. CSP, with editorial leadership from developing and transitional country analysts, have assembled summaries of country assessments and reports. Researchers from participating countries are preparing papers for publication in scientific literature on specific parts of their mitigation and adaptation assessments. All of these scientific assessments are designed to develop country and regional vulnerability assessments and GHG stabilization strategies which will provide the foundation for national climate change action plans toward sustainable development.

International Cooperation

The U.S. CSP complements the UNFCCC enabling activities implemented by other donors, including multilateral programs (e.g., Asian Development Bank, U.N. Development Program, OECD, European Commission and the Global Environment Facility) and bilateral programs (e.g., Denmark, Germany, Japan, the Netherlands, Sweden). Closely linked activities include co-financed studies in individual countries, jointly organized training, and analytical and information sharing exercises. An electronic, global, information system on climate change country studies, CC: INFO (climate change information), is maintained and operated by the UNFCCC Secretariat. Informal reports on country study progress are offered by participating countries to the Intergovernmental Negotiating Committee (INC) , Conference of the Parties (COP), and meetings of the UNFCCC subsidiary bodies. For more information regarding the U.S. CSP, please visit the U.S. CSP website at: http://www.gcrio/CSP/webpage.html or send an e-mail to: csmt@igc.apc.org.

Next Steps and Conclusions

Building on the results of climate change country studies in developing and transitional countries, the U.S. has begun helping countries to use the results of their studies to prepare national climate change action plans and meet their UNFCCC commitments (1). Announced at the First Conference of the Parties, Berlin, April, 1995, the U.S. CSP "Support for National Action Plans" will assist countries with evaluations of climate change technology needs and the development of initiatives to promote technology sharing (6, 7). The U.S. CSP recently provided financial support to eighteen countries for the preparation of their national plans or technology assessments. The countries are as follows: China, Czech Republic, Egypt, Indonesia, Mexico, Micronesia, Philippines, Russian Federation, Venezuela, Bangladesh, Bolivia, Bulgaria, Hungary, Kazakhstan, Tanzania, Thailand, Ukraine, and Uruguay.

The U.S. CSP, in cooperation with non-governmental organizations, such as the International Institute for Energy Conservation (IIEC), International Utilities Efficiency Partnership, Inc. (IUEP) and others, are providing support to countries interested in conducting assessments of energy efficiency initiatives for climate change mitigation. Key tasks include developing a network of donors, lenders and private sector partners to help support pilot projects; developing a guidance document for undertaking technology assessments in support of national action plans; and documenting model energy efficiency strategies for developing and transitional countries. Similarly, the U.S. CSP, in cooperation with American Forests, initiated a new program to help developing and transitional countries identify and develop forest sector carbon offset and bio-energy projects. American Forests is working with governmental and non-governmental organizations in nine countries to achieve this goal. U.S. CSP technical support is also provided to countries on topics of CH_4 mitigation and renewable energy options with the assistance of the U.S. Environmental Protection Agency and U.S. Department of Energy, respectively. In all sectors, this assistance will seek to identify technological needs, opportunities for sharing, and the development of pilot and demonstration projects to overcome these barriers (3).

The potential contributions of technical and financial support for the analysis of GHG emission stabilization and climate change response options are far-reaching (6). Enabling activities help strengthen institutional and human capacity in developing and transitional countries to help support the goals and principles of the UNFCCC and for sustainable development. To date, over 2000 individual analysts, scientists and engineers, in 55 countries have received both technical and financial support from the U.S. CSP. Informal technical assistance has been offered to another 30 countries. Analysis of current and future GHG emissions and identification of cost-effective mitigation options will help governmental, intergovernmental, and non-governmental organizations to rationally evaluate appropriate measures and options. As climate change country studies, technology assessments and national plans are completed over the next few years, developing and transitional countries will have an improved foundation and the human and institutional infrastructure to sustain a process for evaluating and implementing the most beneficial response policies and measures for sustainable development.

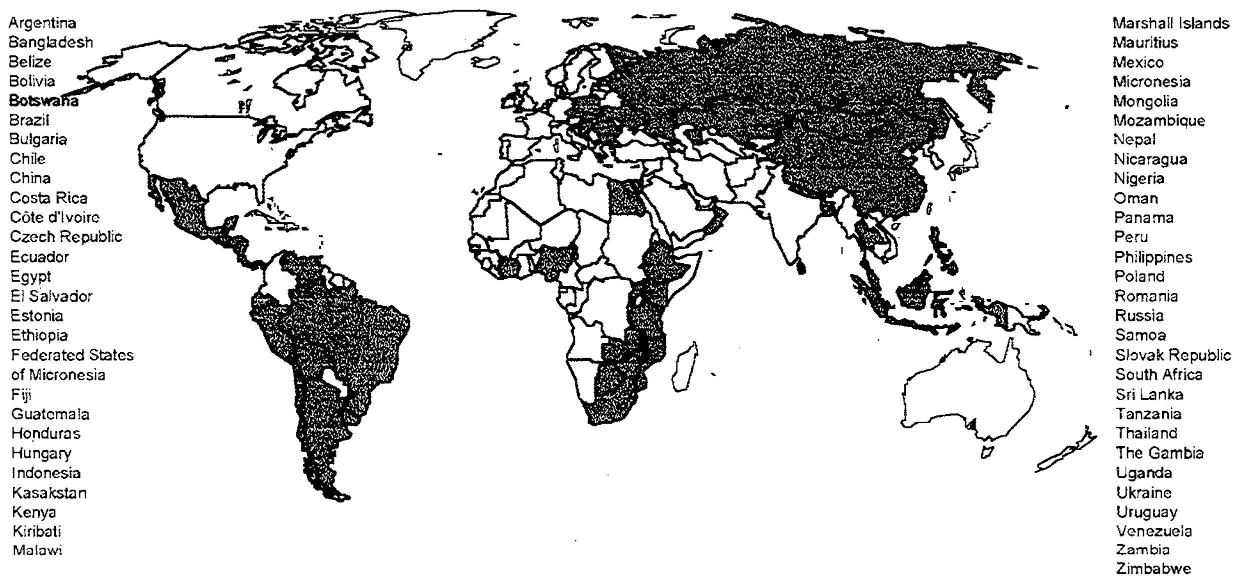

Figure 1. Countries participating in the U.S. Country Studies Program

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THE COMPREHENSIVE INVESTIGATION OF GUANGDONG ISLANDS RESOURCES AND ITS APPLICATION

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ABSTRACT

The comprehensive investigation of Guangdong Islands Resources was one of the 10 key scientific and technological projects of the Eighth Five-Year Plan (1991-1995) of Guangdong Province. The comprehensive investigation was carried out in 1989, which lasted six years. The investigation preliminarily found out the quantities, area, distributions, environment and resources situation of the main islands within Guangdong Province. The islands' function zones were divided according to natural conditions and resources, social economic conditions of the islands. The programmes of exploitation and utilization were proposed and the experiments were carried out. All of this work provided a sound scientific basis for developing marine industries and island economy. After finishing the vestigation, a 24 volume monograph has been published. 290 volumes of data have been compiled and 1307 piece drawings have been drafted. The investigation yielded fruitful results. Currently, on the conditions of "Regeneration the Marine Economy by Science and Technology", we could take full advantage of the results to rationally exploit islands resources, coordinate the development with protection, promote the islands' resources effective utilization and the sustainable economic development of islands.

The comprehensive investigation was a large scale, long-term, comprehensive science and technology investigation, according to the requirements of the State and Guangdong Province, which was a part of the key scientific and technological projects of the State's Eighth Five-Year Plan (1991-1995).

INTRODUCTION

There are 1431 islands in Guangdong Province, belonging to 30 coastal cities and counties. With the rapid development of economic construction, to exploit ocean and develop marine economy is much more valued. Islands would become a focal point for regenerating the marine economy, taking advantage of ocean superiority establishing marine industries. Carrying on the comprehensive investigation was to obtain and gather fundamental information of natural environment and social economic situations, to find out preliminary islands resources and give an evaluation. Making programmes for comprehensive development and utilization of islands, raising protection and management measures in order to provide scientific basis for economy construction, State defense construction, environmental protection, land dredging and islands management.

Adhere to the Investigation Methods of Planning, Scientific and Practice

The investigation must proceed according to the specifications of investigation of the State and some requirements to combine Guangdong's realities. First, the relevant departments worked out "Detailed rules for Guangdong Islands resources comprehensive investigation", investigative programmes and archives administration detailed rules, as the basis of investigation work.

According to Guangdong characteristics, the islands were divided in seven investigation districts from east to west in order to investigate and summarize. They are: Shantou district, Honghai Bay-Jieshi Bay district, Daya Bay, Zhujiang Estuary, Chuanshang district, Yangjiang district and Zhanjiang-Maoming district. The investigation covered about ten professional aspects: climate, hydrology, marine, chemistry, geology, landforms, soil, forestry, vegetation, biology, land utilization, social economy, etc. The comprehensive investigation results were obtained on the basis of profession investigation.

The technical methods of investigation: the concentrating investigation combined with professional investigation to improve qualities and efficiency; the regular investigation combined with advanced remote sensing to raise accuracy of investigation. Investigation combined with offering data, information and results to localities at the same time for development and construction as soon as possible; investigation combined with exploitation experiment to spread the experiences. The investigation also adopted the methods of social inquiry and collecting the fruits that owned by predecessors, especially adopted to consult the results and data of coastal zones, so the investigation results became more systematic. In the field operation, the contigent organized relevant units to synchronize the investigation of islands and ocean. First, they obtained various kinds of specimens to assure the data was representative, accurate and comparative. Then they supplemented the investigation again according to needs for specialized subject and carried on major investigation and monographic study combined with local needs. When the phrase work finished, the contigent reported the findings of the investigation to local governments and relevant departments, listening to their ideas and proposals.

Build the Cooperation Network

The investigation was a large scale comprehensive investigation that is subsequent to the comprehensive investigation of Guangdong coastal and mudflat resources. The Guangdong Province government decided that the former leader group of the comprehensive investigation of Guangdong coastal and mudflat resources continued to organize the work for islands investigation and exploitation experiment. The members of the leader group came from the Guangdong Science and Technology Commission, the Planning Commission, some relevant departments, Guangzhou Military Command and eleven coastal cities and counties. The leader group set up the office, the comprehensive investigation contingent, the technology consultation group the archives examination and acceptance group.

The Office was the system for managing the investigation. It consisted mainly of members from the Guangdong Centre for Marine Resources R & D which is affiliated with the Guangdong

Science and Technology Commission. The Office carried out the decision of leader group and took charge of coordinating the work, dealt with day-to-day affairs, offered various guarantee and logistics support for the investigation and organized the concrete exploitation and experiment work of islands resources.

The Comprehensive Investigation Contigent was a system for executing. It consisted of one hundred odd technical personnel who came from South Sea Branch, State Oceanic Administration, Guangzhou Geography Research Institute etc. ten odd units. Eighty percent of the science and technology personnel were the former backbone who had joined the Coastal Zones Investigation. The contigent set up ten odd professional groups: climate group, ocean hydrology chemistry and environment quality group, ocean biology group, geology mineral group, landforms and land resources group, social economy group, remote sensing group, drawing and comprehension group.

The group of technology consultants was a supervision system for investigation, engaging 19 experts to consult and guide the investigation as well as to examine and appraise investigation results.

The group of archives examination and acceptance was a management system for investigation archives. It consisted of technical experts who served at Guangdong Archives Bureau to examine, guide and accept the archives management.

The Guangdong Islands Investigation was valued and supported by the State and Guangdong province, supported and coordinated by coastal governments, garrison and relevant departments, forming a network to offer effective guarantee for investigation tasks.

Results of Investigation

Fruitful Investigation Results

The 24 volume monograph has been published early and later which includes 12 volumes of specialized investigation reports, 3 volumes of thesis collection, compiled 86 volumes of specialized reports according to each sea zone, sorted out 230 volumes of information, drew up 1307 pieces professional drawings, filed away 858 volumes and worked out a 36 volume catalogue. The investigation results which were achieved through about 100 technical personnel's hard working, were fruits of cooperation and unity and were valuable to the State.

The results of islands investigation filled in a gap which hitherto existed in ocean environment and research of resources comprehensive investigation within Guangdong Province. Its investigation quality, science research value and practical significance were fully approved and set a high value on. It was also well received at the results reporting exhibition that was held in Beijing and Guangzhou. The islands investigation results was one of a fruit of ten tackling key problems of the Eighth Five-Year Plan of Guangdong and won the first award of the Science Technology Progress in 1996.

Development and experiment achieved some effect

On the basis of investigation, the Contigent assisted localities in establishing the brine cultivation base of haliotis and lepstor on the Naozhou Island, Zhangjiang, establish cultivation and processing base of shellfishes and five bases of brine multiplication and cultivation on Chuanshan islands, to obtain obvious economic efficiency and to drive the development of brine cultivation industries in localities. The key islands exploitation experiment was subsidized by the State and funds raised by localities. The Nanao experiment for precious artificial breeding and Huidong experiment for perna viridis Linnaeus cultivation, produced on effect, got experiences from aspects of technology and management. Nanao was listed as one of the six comprehensive zones of islands resources. In several years, the investigation contigent and office positively supported the work of Nanao Experiment Zone with development strategy research, wind power exploitation and harbour choosing, made great efforts for Nanao's economic construction and sped up Nanao development and construction.

Application

Because of holding on the principles of developing and protecting islands, the Contigent reported the situation and the present state of islands investigation to local governments and relevant departments, presented the concept of development and utilization, presented the proposal of islands protection, and translated these results into application. These results have played an important role in local government, social economy development programme, scientific research and economy construction.

Apply to government decision-making

The Guangdong government held two marine working conferences, formulated the "Notice for Policies of Speeding Islands Development" and a whole set of documents organized and formulated into the "Guangdong Marine Industries Development Plan", and applied a vast amount of islands investigation basic data to set up three Islands Economy Development Zones: Nanao Island, Hailing Island and Donghai Island with comprehensive development zones at Shangchuan Island and Xiachuan Island.

Apply to planning of social development, exploiting and protecting islands resources

The coastal governments and relevant departments valued the experts' ideas and suggestions, applied these results to plan social development, to develop and protect marine resources. The relevant departments applied a vast amount of islands investigation results while they complied the Marine Resources chapter, "The China 21 Century Agenda-Guangdong Implement Programme" and development plan of marine science technology, put forward the tentative idea of "Guangdong Regenerating the Marine Economy by Science and Technology". The Contigent accomplished nine programmes of special topics early or later, had been adopted by local governments. Examples include the programme of Nanao fresh water resources exploitation and development and protection of wind power groups, the proposal of mining stone control at the mouth of the Pearl River and the suggestion for shaking off poverty in Xingliao Island. The results strongly drove the islands' economy development and utilization and protection.

Apply to science and technology

The islands investigation results were important basic data for the research work for drawing up "Guangdong Marine Function Zones" and Ocean Exploitation Programme. The series monograph of islands investigations has gradually applied to State land planning, environment protection, scientific research, education and economy construction to promote the Blue Lands consciousness to the masses through publicity and exhibition.

Strategies for Driving Results Transformation

Guangdong islands were restricted by special environment and resources, influenced by science technology conditions at present. Most of the islands were in initiative development conditions. During the process or "Regenerating the Marine Economy by Science and Technology" and developing islands economy, to take full advantage of these results, to depend on science and technology progress, to drive to transist these results into productive forces, to serve for islands economic construction and sustainable development for resources and environment.

Intensify our efforts to publicize these results

This islands investigation was the first comprehensive investigation, got a lot of data that possess practicability, comprehension and systemization, was of very wide application and play a long-term role for development and construction of the islands. Therefore, we should intensify our efforts to publicize these results through news media, relevant meetings, printing and distributing. We should publicize and popularize these results, including the published twenty-four volume series monograph, rich archives information to relevant units, coastal and islands' departments, and we should widen influence and promote effective utilization for the investigation results.

Built the feedback control system for results utilization

The archives of islands investigation are carriers for the results. The major results and scientific research archives are concentrated and kept at the Guangdong Centre for Marine Resources R & D, about ten units that joined the investigation kept professional results and original data, forming an information management network taking the Guangdong Centre for Marine Resources R & D as the centre. We should take advantage of the network to feedback and control the results, to establish the system of feedback and control, to gather the effects and ideas through different channels, after the results have been used. We should regularly research and analyze the object, the way and the methods of using the results, and sum up regular and experiences of using the results to carry on utilization services, to enhance the utilization effects and raise utilization ratio.

Built the management information system for islands resources and environment

Resources and environment sustainable development of Guangdong islands and coastal zones is the important part of Guangdong economic sustainable development. How islands and coastal zones give first priority to develop, resources and environment sustain develop are significant issues to formulate scientific policies for governments at different levels and relevant departments. Therefore, using the results and data to establish a system of decision supporting for islands and coastal zones sustainable development by computer multimedia technology, offer advanced consultation services and links to Guangdong Golden Sciences Network. On the basis of what has been mentioned above, to publish CDs in order to offer user convenience and to promote the results transformation.

Take advantage of former work basis to carry on technology services

With the situation of "Regeneration the Marine Economy by Science and Technology", we should solve focal and difficult problems of the islands economic construction and social development depending on science and technology progress. Therefore, we should take full advantage of cooperation worknet that have been formed during the islands investigation, initiatively keep in touch with relevant departments. Using the results and data serve the governments and relevant departments for the programme, engineering construction and monographic study on aspects of ocean. It may increase efficiency and quality of work, avoid redundant work, cut down cost and expense and produce a good effect of the results.

Focus further efforts on demonstrate the experiment of development and utilization, review and spread the experience

The islands investigation conducted investigation, utilization and exploitation at the same time, so the development zones and experiment projects have won initial success. But it is just a beginning for islands development. And the success of development will depend on its long-term and comprehensive benefit. Therefore, we should proceed to management, technical support and further proof for the experiment that have been carrying on. We should continue to review and spread the successful experience, take actual effect for demonstration. Meanwhile, we should continually strive for support from various aspects, make further efforts to carry on marine development research and regenerate the islands economy.

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PORT STATE CONTROL AND ITS IMPLICATION ON SHIP SAFETY

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ABSTRACT

The development of Port State control (PSC) in Europe under the Paris Memorandum of Understanding 1982 has extended to the Asia Pacific Regions, Caribbean and South America. The aim of participating States to achieve an inspection rate of 25 per cent of non flag state shipping calling in their ports, results in a significantly higher rate of ships trading being inspected between ports of participating States.

Whilst the prime responsibility rests with the flag States, the weaknesses or difficulties in maintaining standard of ship by flag State necessitate inspections by port States. Many flag States are unable to maintain a proper control on the standard of their ships on their respective registers. This situation amplifies the role of the port State control in ensuring that ships continue to comply with acceptable standards of maritime safety, pollution prevention and on-board living and working conditions.

Recognising that single port State could not eliminate the operation of substandard ships singled handed, the lesson of 15 years of port State control in Europe demonstrates also that no one region can effectively eliminate the operation of sub-standard ships. However, substandard shipping persists as and where substandard owners take refuge for continued operations in exotic registers and areas of lower standards. Thus the Memorandum of Understanding (MOU) is being reinforced in the wake of spectacular disasters. More casualties and more incidents have supported the view that more attention must be paid to shipping management.

INTRODUCTION

The demand for ships is derived from the need to move large quantities of goods from one part of the world to another, in the cheapest and most reliable way possible. It is estimated that 85% to 95% of all international transport takes places by sea. It follows, therefore, that the demand for sea transport would be affected by the level of world economic activity and this in turn, would be expected to have a significant impact on the supply of ships and hence, the size of the world merchant fleet.

The effects of these developments on the world merchant fleet were two-fold. The first was a rapid increase in the supply of ships to meet the additional demand for the sea transport. The second was a marked change in the size distribution of ships within the fleet, as economies of scale were being explored to the fullest, especially by Japanese, Greek and Norwegian shipowners who sought a competitive edge in the market.

THE OPEN REGISTRY

One of the principal means by which owners may seek to cut costs is to register their vessels under the flag of an open register or flag of convenience country.

Much is made of the fact that in excess of 50% of the world's tonnage is registered under flag of convenience. It is also a fact that vessels registered under certain of such flags appear in the casualties statistics and in the defect reports of port states on a much more regular basis than whose registered under the flags of the traditional maritime states. That is not to say however, that all ships registered under flags of convenience are substandard nor that all vessels registered under traditional maritime flags are beyond reproach. Some flags of convenience operate with accident rates which are less than those achieved by certain of the established "national" flags.

An Open Register may be national or international. However, particular attention will be paid to the International Open Ship Registers (or Flag of Convenience) which have been set up for the purpose of earning revenue by offering shipowners internationally, attractive legal and commercial terms for the operation of their ships.

The economic benefits to a shipowner that may be had from using an Open Register seem to vary from one to another as followings:

- Non taxable operating profits or no fiscal control;
- Flexibility to negotiate wages with crews of virtually any nationality;
- Limited financial liability to single ship company;
- Freedom of trade without political restrictions;
- Simple and accredited mortgage formalities, and
- Safety regulations imposed by flag state are limited to the minimum internationally agreed standards.

In articles of the Law of the Sea Convention 1982, whilst giving every state the right to set its own conditions for ship registration, further requires that there must exist a "genuine link" between the registered state and the ship. However, in the absence of a definition for what constituted a "genuine link" under the Convention, helped to preserve the ease with which a shipowner could gain access to an Open Register and transfer from it at his option, without restriction. Moreover, it became almost impossible for any concerted international action, questioning the legitimacy of Open Registers, to succeed.

The Competence Of Open Registry Administration

The enforcement of IMO and ILO Conventions requires that Flag States adopt or incorporate the rules embodied in these conventions, into their national legislative system. This depends solely upon the desire and degree of commitment by Flag States to ensure and maintain internationally acceptable standards of quality within the maritime industry. The IMO and ILO generally have no powers in this area and hence, this has been regarded as the basic defect of these conventions.

With respect to Open Registries, UNCTAD [1981] has identified the following basic reasons why non-observance of standard is likely to be greater under these registries:

- Real owners are not readily identifiable and are therefore in a position to take more risks by comparison with owners in normal.

- Real owners can change their identities by manipulating brass-plate companies and consequently avoid being identified as repeated substandard operators or risk taker.

- Since the master and key shipboard personnel are not nationals of the flag state, they have no need or incentive to visit the flag state and can avoid legal action;

- Owners who reside outside the jurisdiction of the Flag State can defy the flag State by refusing to testify at an inquiry by the flag State and avoid prosecution.

The open registry seems to be all tied to very easy ship registration laws and manning requirements that have been identified as basic features of Open Registries. Furthermore, the very little import/export requirements of these registers results in most of the ships using Open Registers never having to call at the ports of their Flag States, thus adding problem of enforcement. Thus the whole question of there being a "genuine link" between the ship and the Flag State looms once more, and seems to be the root cause of some enforcement problems being faced by Open Registers.

Sub-standard ships

The following distinct characteristics of a typical sub-standard vessel are:

- It is frequently near the end of its operation life;

- It is inadequately manned in terms of both numbers and qualifications;

- It is poorly maintained;

- it is badly navigated, and / or

- suffers from equipment failure.

A sub-standard ship may have one or more of the above deficiencies. It is noteworthy that these characteristics amply emphasise both the technical and human aspects that are essential to the maintenance of standards on board the ship.

Standards are being introduced at a time when concern about shipping standards is growing. After a decade in which the number of serious casualties at sea steadily declined, the trend has recently begun to move in the opposite direction. The world fleet is getting older because owners are no longer renewing their ships as frequently as they used to. The fleets of the traditional maritime nations - which generally have good safety records - have shrunk while the fleets of other countries, many with little or no shipping experience, have grown. The crews on ships have tended to become smaller over the years, while the technology of shipping has become more complex. Crews today are more international than they were, raising doubts about the ability of crew members to communicate with each other as well as with other people.

Therefore, despite favourable ratification of the relevant international conventions on safety, by Flag States, their implementation and enforcement have failed to live up with the expectations of the IMO, ILO and other administrations within the maritime industry. These inadequacies, coupled with the IMO's lack of power in this area, have resulted in a deterioration of standards of safety in shipping, which poses a serious potential pollution threat to the marine environment and coastlines, as a result of ship casualties.

ENFORCEMENT OF STANDARDS

Following the 1978 disaster of the Amoco Cadiz in the English Channel, international agreement of the maritime authorities of 15 European States was made in Paris in 1982 as a Memorandum of Understanding (MOU) known as the Paris Memorandum, whereby inspection of ships would be undertaken by maritime authorities of the port States - or port State control. The Canadian Coast Guard became a 'co-operating authority' as did the US Coast Guard, and the maritime authorities of Croatia, Japan and Russia, with the IMO and ILO as observers. The Paris Memorandum was further acceded to by Poland in January 1992) and Canada (as full member) (May 1993).

Provisions for Port State Control and the standards and regulations are under international instruments developed through International Maritime Organisation (IMO):

1954 International Convention on Prevention of Pollution of the Sea by Oil;

1966 International Convention on Load Lines;

1969 International Convention on Tonnage Measurement of Ships;

1972 International Convention for Safe Containers;

1973 International Convention for Prevention of Pollution from Ships, and the 1978 Protocol

1974 International Convention for Safety of Life at Sea (Solas), and the 1978 Protocol;

1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers;

1994 Solas Conference amendments to Solas Regulation 1/1 9

1994 United Nations Conference on Law of the Sea (Unclos) 1982.

Certain IMO Conventions (e.g., Solas) require that the inspections and surveys be carried out by officers of the flag State or officers nominated by them for the purpose, or organisations recognised by them, such as classification societies. A port state may, at the request of the flag state, cause a ship to be surveyed and certificates issued or renewed if the ship passes inspection, but in such cases they would not take action against a failing ship - they would just refuse or renew a certificate. However, under the MOU; the port State has the authority to take enforcement action, as it does under Marpol. In exercising their rights and performing their duties, States shall not discriminate in form or in fact against vessels of another State.

The aim of participating States to achieve an inspection rate of 25 per cent of shipping calling in their ports, results in a significantly higher rate of ships trading between ports of participating States. Whilst the prime responsibility rests with the flag States, the weaknesses or difficulties in flag State control necessitate inspections by port States, whose inspectors have a difficult job by the fact that the ship has to come into port, and by the volume of ships.

Latin American Agreement (Acuerdo de Vina del Mar)

During a regional meeting which took place in Chile in early November 1992 an agreement for co-operation on port State control was signed by the maritime authorities of Argentina, Brazil, Colombia, Chile, Ecuador, Mexico, Panama, Peru, Uruguay and Venezuela. This agreement follows very closely the Paris Memorandum although it was adapted to the special characteristics and circumstances of the Latin American region.

Asia-Pacific Agreement (Tokyo MOU)

The Memorandum of Understanding on Port State Control in the Asia-Pacific Region was signed by the maritime authorities of Australia, Canada, China, Fiji, Indonesia, Japan, Malaysia, New Zealand, Papua New Guinea, Philippines, Republic of Korea, Russian Federation, Singapore, Solomon Islands, Thailand, Vanuatu, Vietnam and Hong Kong. A Committee, to meet once a year, composed of a representative of each maritime Administration and observers from IMO, ILO and other organisations which the Committee may deem appropriate.

Caribbean Agreement

Maritime Authorities of twenty Caribbean States and Territories have agreed on a Memorandum of Understanding on Port State Control. The Memorandum was signed on 9 February1996 at a final meeting held in Barbados, bringing to a conclusion a two-year period during which an ambitious set of measures to improve the maritime administrative infrastructure of region States and territories were prepared.

The Caribbean MOU is a practically identical to other MOUs on port State control which are in operation in other areas of the world, including the Paris MOU in Europe, the Tokyo MOU in the Asia Pacific region and the Vina del Mar Agreement in Latin America.

Port State Control in practice

When directed to inspect a vessel in a specific area of the harbour the PSC officer selects the most neglected looking vessel. After some experience he will learn to recognise the flags and classification societies which are deserving of his attention. If a ship flies the flag of a state which is not party to one or more or the relevant conventions, "no favourable treatment" will be given to such a vessel.

In conducting PSC inspections, the PSC officer will first check all the relevant certificates and documents. If these are all in order then he must have "clear grounds" for believing that the condition of a ship or its equipment, or its crew does not substantially meet the requirements of one of the conventions before demanding to carry out a more detailed inspection.

By "clear grounds" is meant one of the followings:

- a report or notification by another authority;
- a report or compliant by the master, a crew, or any person or organisation with a legitimate interest in the safe operation of the ship, shipboard living and working conditions or the prevention of pollution, unless the authority concerned deems the report or compliant to be manifestly unfounded.
- other indications of serious deficiencies having regard to the various IMO resolutions and other relevant official guidelines.

If the ship is badly maintained, the PSC officer will normally carry out a more detailed inspection during the first visit. After noting a few deficiencies which renders the ship unsafe to sail, he will complete PSC Inspection Form A and Form B containing details about the vessels and identified deficiencies and provide copies of these forms to the master or other senior officer in charge of the vessel. The master, owner or the agent will be advised that the vessel will not be permitted to sail from the port until the deficiencies are rectified and the ship is rendered safe.

When the deficiencies have been made good, the master or the agent will be required to arrange a re-inspection by the PSC officer. During the re-inspection, should additional deficiencies be detected by the officer, he will list out these additional and any outstanding deficiencies on PSC Inspection Form B-1. Depending upon the seriousness of these outstanding deficiencies, the officer may allow the vessel to sail but a period will be set for the vessel to rectify the deficiencies. In such a case, the officer may advise the vessel's next port of call to confirm rectification of those deficiencies, or he may place the vessel on the watch list for a further follow up inspection on its next return to this port. In some cases he may allow the vessel to proceed to a repair port subject to certain conditions.

If no deficiencies are found during the initial inspection, a 'NIL' Form B will be issued. In case of minor deficiencies, the Officer may allow up to 14 days for the owner to rectify the deficiencies without the need of detaining the vessel.

Difficulties With Port State Control Inspection

As matters presently stand the system of port state control remains the most effective weapon against substandard shipping. However it is not without its difficulties:

- vessels exercising right of innocent passage through coastal waters but not calling in port are not subject to inspection;

- theoretically, pursuant to Solas and various other conventions, an inspector must accept a ship's certificates at face value. A more detailed inspection cannot be undertaken unless there are "clear ground" to suspect that the ship does not correspond with the certificates;

- port states lack the general right to turn away substandard shhips prior to those vessels entering their ports;

- port state inspectors are generally in a position to make limited inspections only. Vessels remain in port for relatively short periods of time and full access to construction details and plans is often not available. It is also probable that access to parts of the whip will be obstructed by cargo or ballast or otherwise not open to ease of inspection;

- assessment of a crew's competence and the operational efficiency of the vessel is difficult in the short time which is general available;

- flag states may attempt to defeat the effectiveness of port state control by issuing exemptions when defects or absence of equipment in the vessel are discovered;

- vessels have the right to claim compensation if they are found to have been unduly detained;

- limitations as to resources and differing standards of competence and experience amongst port state inspectors;

- follow up action may be difficult where a vessel is permitted to sail to another port for repair, for example, this may be permitted if the repair facilities at the port of inspection are not adequate or when the cost of repair is comparatively cheaper in the other port.

- owners of good quality ships may be subjected to repeated and inconvenient inspections when their ships are calling ports of different MOU regions.

CONCLUSION

The spread of port state control has shown the international recognition of the problem and the resolve to take direct action against it. The Paris Memorandum in Europe has shown that it is effective. The new memoranda and agreements in major world areas gives recognition of PSC and the consensus of agreement to extend it to as wide an area of the world as possible. It is based on international standards, operates by commitments of national maritime authorities, but requires national and regional co-operation and information exchange with uniformity of standards and interpretation to be effective.

In commitment, it requires individual states to provide the resources for inspection, control and information sharing. It would be unfair imposition of further charges to require a contribution from all shipowners and operators.

The consensus clearly shows that, while port state control is not, and must not become, a substitute for flag state control, it is an effective means of directly getting at substandard shipping. Reactions to the problem lead port states to shoulder the additional cost, and to share the cost and efforts of regional co-operation. By regional and inter-regional co-operation significant steps have been taken to combat substandard shipping and enhance safety at sea. By eventual removal of substandard operations, it will put good shipowners and operators on an even field in respect to operational economics. Meanwhile the effect of the system can be maximised by targeting; sharing and circulation of information; more publication of results of inspections and records; emphasis on crew qualifications and standards as well as standards of condition of the ship and her equipment; and examination of ship management as well as ship operations.

The success of the Paris Memorandum has shown the greater regional success than the individual efforts of member states alone. Inter-regional port state control develops the principle to potential world wide success given the consistency of efforts and co-operation in the areas of the new Memoranda of Understanding, but the teeth must bite into the economics of the substandard operators. Port state control is the best way to enforce standards with quick results, subject to regional co-operation to close all areas to substandard ships.

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SHIPS, WASTE AND PORTS

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ABSTRACT

Ships may be considered as small floating towns which generate and/or carry waste which can be deposited anywhere in the world's oceans. Liability and penalties can vary in different locations. It is worth noting that liability and jurisdiction may differ, there being three distinct locations covering disposal of waste. Whilst the paper deals mainly with ships, it may also apply to any other floating structure, such as oil rigs, exploration platforms, barges, dredgers and construction equipment.

The paper, whilst defining and detailing waste generated on, and disposed from, ships, deals also with legislation, liability and penalties relating to disposal of waste in different locations.

The Marpol 1973 Convention (MARPOL, 1993) covers the discharge of sewage, garbage and oil from the vessel on the high seas and in coastal waters whilst local ordinances generally cover treatment/disposal in ports. A new, more restrictive, protocol to the Marpol convention was adopted in December 1996, aimed at making shipowners dumping waste at sea liable to clean up costs.

The voluntary implementation of the ISO14001 (ISO14001, 1996) standard on board ships is clearly redundant. ISM code implementation, which includes protection of the environment as one of its key aims, will be compulsory on most vessels in 1998 and all vessels by 2002.

THE SHIP AS A WASTE GENERATOR

There are three distinct locations covering disposal of waste:

- The high seas, ie, anywhere outside territorial waters.
- Coastal limits, ie, within a 12 mile line drawn from the coast of a state.
- Port limits, ie, as defined by local ordinance.

A ship may be defined as a small town confined within a floating structure carrying a cargo from one port to another. Just like a small town on land it generates waste of different forms in differing amounts which may pollute the environment if not handled correctly. This pollution may be generated from the ship itself or from the cargo it carries.

<u>Waste generated by the ship itself:</u>

- Sewage.
- Domestic waste.
- Exhaust fumes.
- Ballast water.
- Bilge water.

Sewage

The definition of sewage is:

a. Drainage and other wastes from any form of toilet, urinal and WC scupper.

b. Drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises.

c. Drainage from spaces containing live animals, or.

d. Other waste water when mixed with the drainage defined above.

Sewage may be generated by passengers, crew and/or animals on board the vessel. Whilst the amount generated may be small compared to that generated by shore based communities, there are thousands of ships travelling all over the world, every hour of the day, generating sewage. Until recently, sewage was pumped directly over the side of the ship for dispersal at sea. It was also discharged directly into the waters of ports without any treatment.

Garbage/Refuse

Garbage is defined as all kinds of victual, domestic and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically except those substances which are defined or listed in other Annexes to the Marpol 1973 Convention.

Fumes

The propulsion and electrical generation machinery on board ships generate exhaust fumes into the atmosphere. Whilst there is no international convention in place to cover the emission of fumes, most ports and local authorities have ordinances in place to cover such eventualities.

Ballast Water

Larger, ocean going ships, have double hulls at the bottom for the retention of various liquids including fresh water, fuel oils and ballast water. These spaces are known as double bottom tanks. When the ship has no cargo on board, the double bottom ballast tanks are filled with sea water to lower the centre of gravity and improve stability. The water may be pumped directly into the tanks from the harbour where the last cargo is being discharged.

It is not often that a ship loads another cargo at her last port of discharge and regularly has to travel in a ballasted condition to her next port of loading. Sometimes this can be on the other side of the world. During loading of her next cargo the ballast water must be pumped overboard to allow loading of the maximum weight of cargo to earn the maximum freight for her owners or charterers. The ballast water from one side of the world may cause contamination and pollution of the load port on the other side of the world.

Bilge Water

All liquid, and some solid, wastes drain down to the bottom of the ship's spaces. These are known as bilges, there being bilges in the engine room and cargo holds. The bilge water in the engine room may contain a combination of fresh water, sea water and oils. Hold bilges may contain waste from the cargo combined with fresh water from rain or sea water from spray or leakage. As may be seen the hold bilges can contain anything.

Waste generated from the cargo or cargo spaces

Pollution and or waste may be generated from the cargo spaces of the many different types of vessels and their cargoes, eg, oil tankers, bulk carriers, general cargo ships, gas carriers, chemical tankers, passenger ships, ferries, tugs, barges, etc.

The range of vessels does not give a true indication of the thousands of different types of cargoes carried and possible pollution which may occur, usually as a consequence of collisions, groundings and sinkings.

Waste from cargo spaces may be in the form of dunnage, ie, the timber packing used to compress the cargo in the hold to prevent movement. Pallets may also be considered to be waste which may be discarded overboard once past their useful life. It is also general practice once a ship is at sea, having discharged her cargo at the last port, to clean holds ready for the next cargo. The waste is usually discharged directly overboard into the sea.

During heavy weather both 40 foot and 20 foot containers may be lost or fall overboard. These, like logs lost overboard, can cause significant damage to ships causing further pollution incidents. Whilst logs may not pollute the seas, containers carry cargoes which are many and varied. These may also be spilled into the sea.

The worst case has to be oil pollution. As a consequence of some of the worst oil pollution incidents such as the Exxon Valdez, Amoco Cadiz and Braer, the shipping industry has more recently been under closer scrutiny from society. The USA has introduced the OPA 90 Act (OPA 90, 1990), bringing in the most stringent regulations to prevent pollution of their waters, including the requirement for oil tankers to have double hulls. Alcohol consumption by senior members of the crew is also under close scrutiny (a ship can be stopped at sea in USA waters and the senior officers breathalised at any time) with an officer losing his certificate and livelihood if found with blood alcohol above a certain limit.

WASTE DISPOSAL ON/FROM SHIPS

Sewage

Until 23 years ago raw sewage was discharged directly overboard at sea, in coastal limits and in port. Some ports had reached the stage where the dock water was a black mass of foaming, bubbling, noxious liquid. As a consequence of the Marpol 1973 convention, ships were required to have holding tanks or treatment for sewage in coastal limits, with port authorities having their own regulations.

Holding tanks were the initial choice of owners, with the raw sewage being pumped directly overboard once at sea. Just how far from the coast the discharge takes place is open to question as policing the convention is difficult. However, vessels can be delayed in port causing disposal problems when holding tanks are full.

As environmental pressure became greater both by the public and passengers, owners began to build in bacteriological treatment plants. These plants were designed for pure water to be pumped overboard, with the sewage being broken down into sludge which could be dried and incinerated.

However, despite recent developments in sewage treatment, raw sewage is still pumped directly overboard and, in the main, goes undetected due to the difficulty in policing the convention. The author has served as a senior engineer officer on a cruise ship operating on weekly cruises around the Caribbean Sea with up to 1,000 passengers and 400 crew on board. At the time of service, the sewage treatment plants on this vessel were inoperative and as a consequence raw sewage was pumped directly overboard both at sea and in some of the most beautiful ports in the world.

Garbage/Refuse

Like sewage, garbage is thrown overboard at any time at sea and occasionally in coastal waters. In port it tends to be stored on the after end of the vessel, rarely in skips, until the vessel returns to sea where it is discharged. Most garbage contains packing material which is not biodegradable and remains on the sea bottom indefinitely. The author has served on board an oil rig supply ship which carried a beam trawl on board. This was used on a number of occasions and trawled more rubbish than fish.

Larger vessels built in the last 20 years tend to have incinerators fitted. However, our regular inspections of ships on behalf of P&I Clubs (see later) reveal many of these to be defective and/or unused. There is also evidence that domestic garbage is being thrown overboard before vessels leave port limits, let alone coastal limits.

Fumes

It is a well known story amongst seafarers that New York City has one of the most stringent pollution ordinances in place. The old Queen Elizabeth (last seen on her side in Hong Kong harbour) had 24 boilers generating steam for propulsion which emitted large clouds of black smoke during manoeuvring in New York harbour. Whenever she berthed in New York, Cunard Line, her owners, had the cheque made out to New York City in advance.

I am not aware of any current ordinance in place restricting the amount of exhaust fumes emitted into the atmosphere in Hong Kong. However, it is likely that when air pollution becomes a more sensitive issue, an ordinance will be drafted and adopted and fines will be high.

Ballast Water

Ballast water in a ship's double bottom tanks may have come from an area of the world where there are problems with marine growth. There are many examples where specific types of weed have been transplanted to other ports, eg, Japanese weed into the River Fal in Cornwall, UK, in the early 70s. Some port authorities have more recently invoked local regulations to prevent the discharge of foreign ballast in port which is causing severe logistical problems to Masters. Vessels are now expected to completely change their water ballast whilst on the high seas, prior to arrival in another port.

Bilge Water

Bilge water tends to be pumped directly overboard at sea. However, since bilge water may contain oil, oily water separators (OWS) are required to be fitted on ships over 400 GRT. Fitted in the discharge line are a 15 ppm alarm and shut-off valve to prevent discharge of oily mixtures. However, the bilges may also be pumped directly overboard from higher capacity bilge pumps to prevent loss of the vessel in the event of flooding of spaces. These pumps are regularly used to pump bilge water directly overboard from the engine room and hold bilges at sea without any separation.

Our regular inspections of ships on behalf of P&I Clubs (see later) reveal there to be little pollution prevention on board many vessels in our region, with evidence that oily water is pumped directly overboard without any separation. The capacity of most oily water separators is enough to handle small amounts of surface oil. The amount of oil found in some ship's bilges could never be handled by the OWS on board their vessels and is clearly pumped overboard at night.

DISPOSAL IN PORT AND FACILITIES

Hong Kong has a number of gazetted ordinances in force to deal with refuse, sewage and oil pollution of its waters, listed below together with the relevant responsible Government departments.

Sewage	Garbage/Refuse	Oil Pollution
Responsible Department:		
EPD	Urban and Regional Services Departments Marine Department RHKP Transport Department Agriculture and Fisheries Department EPD	Marine Department RHKP EPD
Policing:		
Monitoring the source, to ensure sewage is treated properly before discharging into drainage then into the sea	Prosecution can be carried out by public officers from any of the responsible departments listed above.	Launches from both RHKP and MarDep visit large and small vessels at regular intervals.
	Urban/Regional Council have ongoing programmes in the educational and promotional aspects.	Ship's Master has the obligatory duty to report any oil discharge from own or other vessel.
		Inspection of plant and factory which might cause oily substances to be discharged in to the sea is the work of EPD.
Ordinance:		
Water Pollution Control Ordinance (Cap. 358)	Summary Offences Ordinance (Cap. 228)	Shipping and Port Control Ordinance (Cap. 313)
Waste Disposal Ordinance (Cap. 354)	Dumping at Sea Ordinance (Cap. 466)	Merchant Shipping (Prevention and Control of Pollution) Ordinance (Cap. 413)
	Waste Disposal Ordinance (Cap. 354)	Merchant Shipping (Liability and Compensation for Oil Pollution) Ordinance (Cap. 414)

Table 1. Hong Kong Waste Disposal Ordinances.

There are approximately 37 vessels available in Hong Kong to deal with refuse/sewage/oil disposal from vessels. These are owned/operated by MarDep/EPD authorised/licenced companies as shown above. These are kept very busy with collection and disposal and some delays are currently being experienced by shipowners.

LEGISLATION

High Seas and Territorial Waters

Sewage

In 1973 the Marpol convention (Annex IV) was brought into force to prevent the overboard discharge of raw sewage within coastal limits. The Convention was enacted and signed so that vessels could only discharge raw sewage outside coastal waters, ie, 12 miles. Treated sewage may be discharged outside a 4 mile limit. The convention applies to all ships over 200 gross tonnes and ships under 200 gross tonnes which are certified to carry more than 10 persons. Ships are subject to surveys to check that they have the appropriate and approved equipment, with a certificate being issued for the vessel, lasting 5 years.

Vessels which operate within coastal limits must have an approved sewage plant or holding tanks to retain the sewage on board. All Governments which have signed the convention must provide facilities at ports for the reception of sewage, without causing undue delay to ships and adequate to meet the needs of the ships using them.

There are many ships around the world carrying livestock. There is the sheep trade from Australia/New Zealand to Arab states, and the cattle trade from Australia/New Zealand to Japan. The sewage generated by a couple of thousand sheep can be considerable and facilities must be provided to prevent discharge within coastal waters.

The regulations do not apply:

- Where the discharge of sewage is necessary for the purpose of securing the safety of the vessel and those on board.
- Where the discharge of sewage resulting from damage to a ship or its equipment provided all reasonable precautions have been taken before and after the occurrence of the damage for the purpose of preventing or minimising the discharge.

Garbage

The 1973 Marpol convention (Annex V) provides regulations to prevent pollution by garbage from all ships and includes offshore platforms. It also defines Special Areas where the adoption of special mandatory methods for the prevention of sea pollution by garbage is required, eg, the Mediterranean, Baltic Sea, Black Sea, Red Sea, Gulfs area, North Sea, Antarctic area and the Wider Caribbean Region, including the Gulf of Mexico and the Caribbean Sea.

Disposal of garbage outside special areas:

a. The disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags is prohibited.

b. The disposal into the sea of the following garbage shall be made as far as practicable from the nearest land but in any case is prohibited if the distance from the nearest land is less than:

   i. 25 nautical miles for dunnage, lining and packing materials which will float.
   ii. 12 nautical miles for food wastes and all other garbage including paper products, rags, glass, metal, bottles, crockery and similar refuse.

c. Disposal into the sea of garbage specified in subparagraph b.ii. of the regulation may be permitted when it has passed through a comminuter or grinder and made as far as practicable from the nearest land but in any case is prohibited if the distance from the nearest land is less than 3 nautical miles. Such comminuted or ground garbage shall be capable of passing through a screen with openings no greater than 25 mm.

d. When the garbage is mixed with other discharges having different disposal or discharge requirements, the more stringent requirements shall apply.

Disposal is also prohibited from fixed or floating platforms, eg, oil rigs, and from all other vessels when alongside or within 500 metres of such platforms. Disposal into the sea of food wastes may be permitted when they have been passed through a comminuter or grinder from fixed or floating platforms located more then 12 nautical miles from land and all other ships when alongside or within 500 metres of such platforms. Such comminuted or ground garbage shall be capable of passing through a screen with openings no greater than 25 mm.

All Governments which have signed the convention must provide facilities at ports for the reception of garbage, without causing undue delay to ships and adequate to meet the needs of the ships using them.

The regulations do not apply:

- Where the disposal of garbage is necessary for the purpose of securing the safety of the vessel and those on board.

- Where there is escape of garbage resulting from damage to a ship or its equipment provided all reasonable precautions have been taken before and after the occurrence of the damage for the purpose of preventing or minimising the escape, or.

- Where there is accidental loss of synthetic fishing nets, provided that all reasonable precautions have been taken to prevent loss.

A new protocol to the Marpol convention was adopted in December 1996, aimed at making shipowners dumping waste at sea liable to clean up costs. It also requires that preventive measures are taken it the dumping is thought to be harmful to the environment. It replaces the 1972 convention which permitted the dumping of some waste provided certain conditions were met, whilst the new Protocol is much more restrictive. It prevents the dumping of any wastes or other material with the exception of certain materials. These include dredged material, sewage sludge, fish waste, inter and organic material of natural origin.

An interesting addendum is that the new convention allows the dumping of bulky structures such as defunct oil platforms and ships where no other practical alternative exists.

The only exceptions to the new Protocol are contained in article 8, which permit dumping to be carried out "in cases of force majeure caused by stress of weather, or in any case which constitutes a danger to human life or a real threat to vessels."

In recent years concern has been expressed at the practice of exporting wasted which cannot be dumped at sea under the 1972 convention to non-contracting parties. As a result, the new protocol states that "contracting parties shall not allow the export of wastes or other matter to other countries for dumping or incineration at sea." (See Later)

A key provision of the protocol is the so called 'transitional period', which allows new contracting parties to phase in compliance with the convention over a period of 5b years. This provision is supported by extended technical assistance provisions.

Ports:

As covered by various Ordinances listed in Table 1 above. Responsible Government departments and methods of policing are also listed in Table 1. above.

Penalties

In Hong Kong, disposal of certain prescribed wastes can only be undertaken if a licence has first been obtained from the Director for Environmental Protection. If these types of waste are disposed of or otherwise deposited without prior authority, an offence is committed under the Waste Disposal Ordinance (WDO). Simple possession of a class, quantity or other description of waste as is prescribed under the WDO could also attract criminal liability.

Jurisdiction can be a problem with other international conventions and offences since a ship's owners, charterers, operators, crew and managers may be from different countries, whilst the ship may be registered and insured in different jurisdictions. However, in the case of oil and sewage pollution, jurisdiction lies with the country where the offence takes place providing they are a party to the Marpol Convention. Local ordinances may also apply which have been drafted to include the provisions of the Marpol Convention.

The penalties are high in Hong Kong:

i. In the case of unlawful disposal, for the first offence, a fine of HK$200,000 and imprisonment for up to six months can be imposed.

ii. For a second or subsequent offence, the fine can be as high as HK$500,000 and again, the offender could be sentenced to a maximum of six months imprisonment.

iii. In addition, if the offence is a "continuing offence", a fine can be imposed of HK$10,000 for each day during which it is proved to the satisfaction of the Court that the offence has been continued.

iv. For possession-related offences, the first offence carries a fine of HK$100,000 and for a second or subsequent offence, conviction could attract a maximum fine of HK$200,000 and a maximum term of six months imprisonment. A similar provision to iii. above is made for "continuing" offences for possession.

<u>Defences</u>

The defences available to a Shipowner are extremely limited. There is no need for the prosecution to show that the acts or omissions in question were accompanied by any intention, knowledge or negligence on the part of the defendant as to any element of the offence. In other words, they need not establish *mens rea.*

In contrast, the amended Ordinance implementing the 1989 Basel Convention affords a statutory defence of due diligence. Hence, if the Shipowner or carrier is charged with an offence under this part of the WDO (viz. Part IVA), the onus is on the defendant to prove that all reasonable precautions were taken and that due diligence was exercised in order to avoid the commission of the offence.

So far as I know, no prosecution has so far been brought under this particular part of the amended Ordinance. It would thus appear that the defence is untested. It is therefore difficult to accurately assess the prospects of it succeeding in the circumstances where, for example, shipper-packed containers are received at the load port and false information has been supplied to the carrier's port agent as to the nature of the contents.

It is becoming clear that port authorities, in response to pressure from environmentalists, are tightening up on waste discharge in their waters. This is evidenced by the Australians having introduced new legislation to cover the dumping of cargo waste/dunnage overboard within a 3 mile limit around the coast as reported by Fairplay, 27 March 1997.

THE SHIP AS A CARRIER OF WASTE FOR DISPOSAL

This area will not be covered in detail, except for some practical matters which should be taken into consideration as your own Mike Melwood Smith is the expert in this area and has assisted with the preparation of this section.

Waste, in various forms, can be carried by ships as a cargo, ultimately for disposal, for the purpose of earning freight.

In circumstances where a shipping order is placed for shipment of plastics, metal and metal alloys, or paper products and no opportunity is given to the Shipowner/carrier for prior inspection, the carrier should endeavour to satisfy himself that the requisite permits have been issued by the 'competent authorities' in the jurisdictions concerned. If it transpires that the cargo is waste of a kind specified in the schedules appended to the WDO and no permits have been obtained, it becomes illegal traffic.

Mere possession of illegal traffic can attract criminal liability under the WDO. If the cargo is not taken up/received by the consignees and the carrier is compelled to place the cargo in storage, costs and potential fines may far exceed the value of the cargo.

Recall of waste to the country of dispatch necessarily requires the involvement of the competent authorities in the jurisdictions concerned, eg, EPD and/or corresponding departments or ministries for the environment. Bureaucratic red tape and potential political fall-out are two important factors which affect the speed with which the cargo in question can legitimately be returned to the country of dispatch. It can also generate extremely adverse publicity for the carrier and responsible government alike.

Interim storage costs, together with costs of ensuring that the cargo's condition over time does not deteriorate to as to pose a health hazard or environmental risk, are likely to escalate to a significant level.

LIABILITY

So who is liable for the fines and how can one protect against liability?

Generally, the carrier or Shipowner is liable for the penalties imposed in the case of sewage/garbage/oil pollution from the vessel itself. The Charterer or hirer of the vessel is not generally liable. In the case of waste as a cargo, EPD will generally try to prosecute the Hong Kong Consignee and failing this may well prosecute the Shipowner.

Shipowners can insure against this liability. Generally the ship's hull and machinery are insured or underwritten by Underwriters based at organisations such as Lloyds. However, this form of insurance does not cover penalties incurred for waste possession or disposal.

Other risks are generally covered by P&I Clubs. These Protection and Indemnity associations are formed from groups of Shipowners who mutually insure each other by contributing to a central fund managed on behalf of the Shipowners by professional managers. These Shipowners are known as members and hence the organisations have become known as P&I Clubs. There are approximately 30 major P&I Clubs in the world, mainly based in Europe, the largest being the UK P&I Club.

Pollution risks are also generally covered by P&I Clubs and for the sake of brevity I will not quote the P&I Club Rules relating to this area.

Owners could also cover their liability by being part of the Tanker Owners Voluntary Agreement concerning Liability for Oil Pollution (TOVALOP) scheme. Tankers having such a certificate were covered for up to US$86 million for oil spills, this being the key compensation scheme. However this scheme was abolished in February 1997 leaving only The 1969 Civil Liability Convention (CLC) which has a US$20 million maximum liability. Some countries have, however, increased this cover to US$86 million in line with the abolishing of the TOVALOP scheme, particularly, Europe, Japan, Mexico and Oman. The reason for the ending of the TOVALOP scheme is suggested to be because many countries have still not ratified CLC. Tankers visiting countries which have not ratified CLC will not have the US$20 or 86 million cover of CLC.

It is also becoming clear that port authorities, in response to pressure from environmentalists, are tightening up on waste discharge in their waters. This is evidenced by the Australians having introduced new legislation to cover the dumping of cargo waste/dunnage overboard within a 3 mile limit around the coast as reported by Fairplay, 27 March 1997.

FUTURE DEVELOPMENTS

Introduction of the ISM Code

On 4 November 1993, Resolution A.741(18) was adopted at IMO (the shipping arm of the United Nations), introducing the International Management Code for the Safe Operation of Ships and for Pollution Prevention (International Safety Management (ISM) Code).

As its title implies, the objectives of the Code are to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular to the marine environment, and to property.

There is one big difference between the ISM Code and the ISO 9000/14000 codes. Unlike the ISO 900014000 codes which are voluntary (except for most Government contracts), the ISM Code becomes compulsory for most ships (passenger ships, tankers, gas carriers, bulk carriers and mobile offshore units) and shipping companies on 1 July 1998.

The specific section on Safety and Environmental Protection Policy states that companies should establish a safety and environmental protection policy and ensure that the policy is implemented and maintained at all levels of the organization, both ship-based as well as shore-based.

This clause clearly identifies those areas currently covered by ISO14000 and appears to make ISO14000 redundant in ship operators and ships. It is to be hoped that if the ISM Code is correctly enacted and implemented with appropriate auditing and penalties, that the prevailing waste disposal offences will be reduced.

ACKNOWLEDGMENTS

Mr Mike Melwood-Smith, Lawyer, Richards Butler, Hong Kong.
Mr F. C. Chan, Marine Officer, Pollution Control Unit, HK Marine Department.

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ISO14001. 1996. 1996 is the ISO Standard for "Environmental Mangement Systems - Specification with Guidance for Use".

MARPOL. 1973. International Convention for the Prevention of Pollution, 1973.

OPA 90. 1990. United States of America's Oil Pollution Act, 1990.

Toxic Diatoms Belonging to the Genus *Pseudo-nitzschia* from the Coast of Southern China

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Abstract

Only two species of potentially toxic diatoms have been observed in the waters of southern coastal China, *Pseudo-nitzschia multiseries* Hasle and *P. pseudodelicatissima* (Hasle) Hasle. *Pseudo-nitzschia multiseries* was first described for coastal China by Dickman (1996) and *P. pseudodelicatissima* from coastal China is described here for the first time. In addition to these two potentially toxic species, five non-toxic species of *Pseudo-nitzschia* were observed *(P. subpacifica, P. pungens, P. seriata, P. Sinica* and *P. multistriata)*. *P. sinica* is a new species (Qi *et al.* 1994) and *P. subpacifica* and *P. multistriata* were observed for the first time in southern China by Qi and Zheng (unpublished data). *P. pungens* was observed at all stations surveyed along the entire southern-central coast of China. It was present most of the year except for late winter.

In June of 1990 a bloom of *Pseudo-nitzschia* species (140,000 cells L^{-1}) was observed in Mirs Bay (Tai Pang Wan). This was the highest *Pseudo-nitzschia* density reported for the coastal waters of southern China. The highest density of *Pseudo-nitzschia* in Hong Kong, occurred in September of 1996 (109,000 cells L^{-1}).

Because identification of the different species of *Pseudo-nitzschia* necessitates the use of a scanning electron microscope (SEM) the ratio of potentailly toxic to non-toxic species was inferred from SEM. The ratio ranged from 74-100 non-toxic for every potentially toxic species identified under the SEM.

It is important to monitor the abundance of potentially toxic species of *Pseudo-nitzschia* as a number of cases of amnesic shellfish poisoning (ASP) have been reported from various parts of the globe where the death or severe memory loss of numerous individuals has occurred. By monitoring the plankton for the presence of *Pseudo-nitzschia* it should be possible to alert shellfish industries about the safety of harvesting shellfish for public consumption.

INTRODUCTION

To date, only two potentially toxic species of diatoms, *P. multiseries* (formerly *P. pungens f. multiseries*) and *P. pseudodelicatissima* have been observed along the south-central coast of China (Fig. 1). *P. multiseries* (Figs. 2A & B) has been previously reported (Dickman 1996), however, this is the first report of *P. pseudodelicatissima* for south-central coastal China waters.

Pseudo-nitzschia pseudodelicatissima

P. pseudodelicatissima is 80-90 µm long and only 2 µm wide with one row of intercostal poroids and 4 poroids per µm (Figs. 3A & B). This species has 20-24 keel punctae (interfibula punctae) and 34 to 37 costae in 10 µm. A short form *of P. pseudodelicatissima* measured (40-45 µm X 1.5 µm, Fig. 3A). The short form has 3 poroids in 1 µm, 37-42 costae in 10 µm and 17-20 keel punctae in 10 µm. Both forms of *P. pseudodelicatissima* (short [3A] and long [3B]) have a central pseudonodulus (i.e., the central keel puncta is larger than any other keel punctae).

P. pseudodelicatissima differs *from P. delicatissima* in a number of ways. *P. pseudodelicatissima* has pointed ends while the valve tips of *P. delicatissima* are rounded. Also, the fibulae of *Pseudo-nitzschia pseudodelicatissima* are not as regularly spaced as those of *P. delicatissima* and there are 25 fibulae in 10 µm (verses 31 in 10 µm for *P. delicatissima). P. pseudodelicatissima* appears in Hong Kong waters while *P. delicatissima* does not.

Pseudo-nitzschia sinica

Pseudo-nitzschia sinica like *P. pseudodelicatissima* has a central pseudonodulus (Fig. 4). But unlike, *P. pseudodelicatissima, P. sinica* has only one row of poroids between each pair of costae (i.e. one row of intercostal poroids). *P. Sinica* is 70-107 µm long by 3.7-4.6 µm wide, has 8-10 keel punctae in 10 µm and 15-17 costae in 10 µm. The species was first described by Qui *et al.* (1994). Its valve is quite narrow, lanceolate and the frustule ends are rounded. The frustule begins to taper about 1/6th of the way from the tip. The canal raphe is excentric and the poroids are circular to square (2 to 3 in 1 µm). Some of the poroids are covered with a perforated membrane.

Pseudo-nitzschia pungens

Pseudo-nitzschia pungens valves are 4-5 µm wide with no pseudonodulus and 3-4 poroids in 1 µm (Figs. 5A & B). The species displays two to three rows of intercostal poroids. Valves of *P. pungens* like those of all *Pseudo-nitzschia* species exhibit a long tapered shape with one margin slightly more curved at its tip than the other (Fig. 5B). Sibling valves overlap by less than 1/5th of their total length. Pore size is quite constant and valve length ranges from 75 to 144 µm (mean = 105 µm) and width ranges from 6.5 to 8 µm (mean of 7.5). The thickness of the frustule (pervalvar axis) is about 5 µm and there are 12 to 18 fibulae (arched supports) and 12 to 18 costae in 10 µm. The maximum chain length observed was 80 cells.

Pseudo-nitschia cf. multistriata

This species looks like *P. pseudodelicatissima* (35-40 X 2.5 µm) but does not display a pseudonodulus. *P. multistriata* (Fig. 6) has 2 rows of intercostal poroids with 8-10 poroids per µm, 25 fibulae (keel punctae) in 10 µm and 36-40 costae in 10 µm.

An unknown Pseudo-nitzschia species

This unknown species (Fig. 7) looks like P. pungens but has a slight swelling on one side of its valve near its center (i.e., the center of its more curvilinerar longitudinal axis). Its length is 62-70 µm and its width is 3 µm with 50 costae in 10 µm, 12 keel punctae (fibulae) in 10 µm and 2-3 poroids in 1 µm. Like *P. pungens*, two rows of intercostal poroids are present. This unknown species looks like *P. pungens* but it has a pseudonodulus and *P. pungens* does not. Hasle (1965) places a great deal of emphasis on the presence or absence of the "pseudonodulus" as a conservative character. We accepted this view until recently when one of us, Zheng Lei, isolated a single cell of *P. pungens* and after some weeks growing it in culture, a few cells appeared which displayed a pseudonodulus Assuming that no culture contamination took place, it may be necessary to reconsider the taxonomic implications of the presence or absence of a "pseudonodulus".

Toxicity Testing

This is the first time that a second potentially toxic species of *Pseudo-nitzschia* has been reported for southern China. Toxicity tests of *P. pseudodelicatissima* were based on UV HPLC gas chromatography analyses of *P. pseudodelicatissima* collected from Tai Pang Wan (also known as Mirs Bay). To date, none of these cultured *P. pseudodelicatissima* have tested positive for domoic acid.

According to Haya *et al.* (1991), plankton tows containing *Pseudo-nitzschia pseudodelicatissima* from one area of the Bay of Fundy were toxic while tows containing the same species in another area of the Bay of Fundy were not. Thus it is possible that even though samples of this species collected from Hong Kong waters were not toxic, the same species collected from other areas in southern China where nutrients and growing conditions are different may produce domoic acid.

Tables 1 and 2 summarize the main characteristics observed in the 7 taxa of *Pseudo-nitzschia* species observed in the coastal waters of southern China

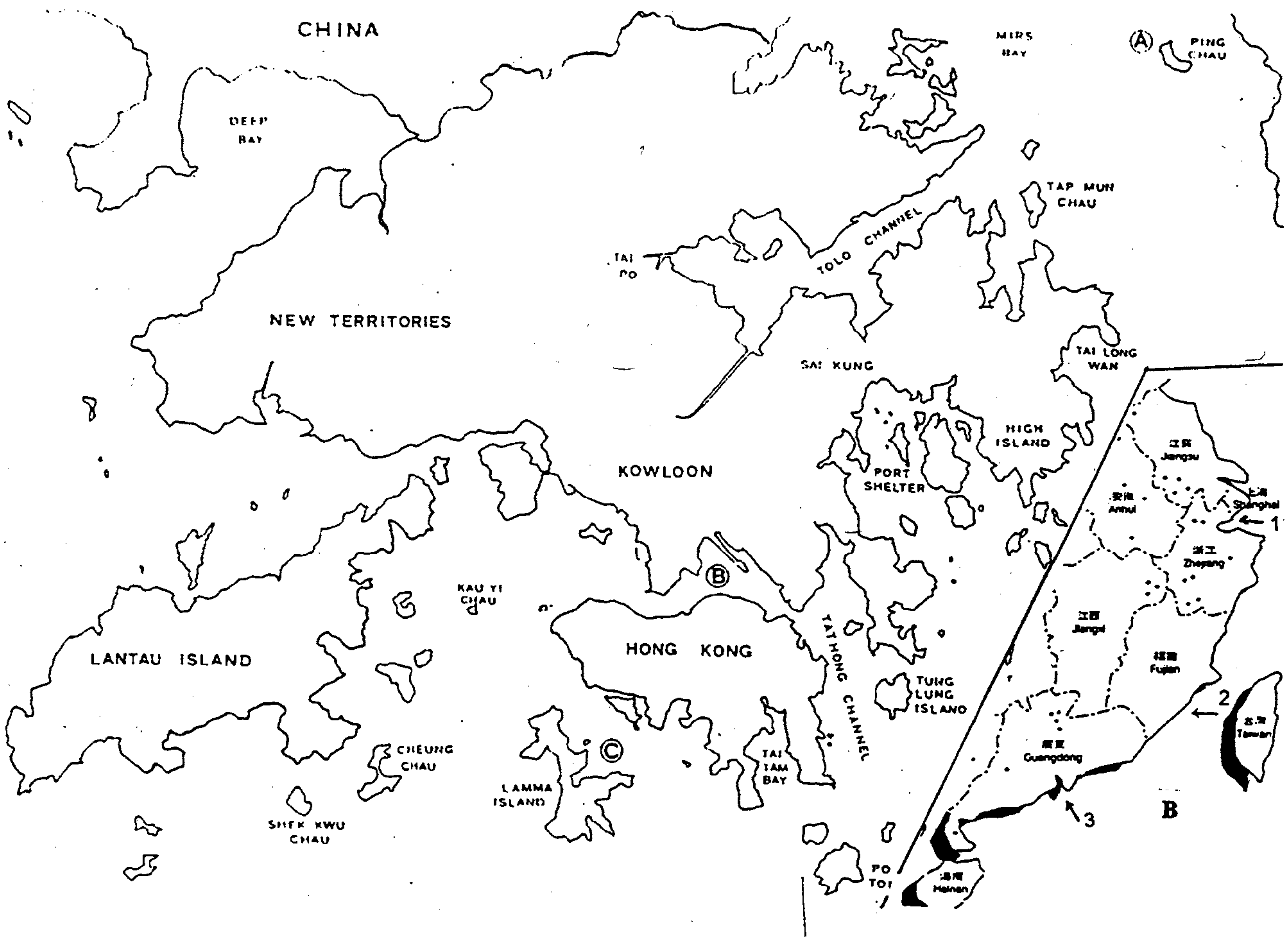


Figure 1. Map of Hong Kong with inset of coastal southern China in lower right hand corner. Coastal China sample sites near Shanghai (1), Xiamen (2) and Hong Kong (3). Sites in Hong Kong are represented by the letters (A) Mir's Bay, (B) Victoria Harbour and (C) Lamma Straits.

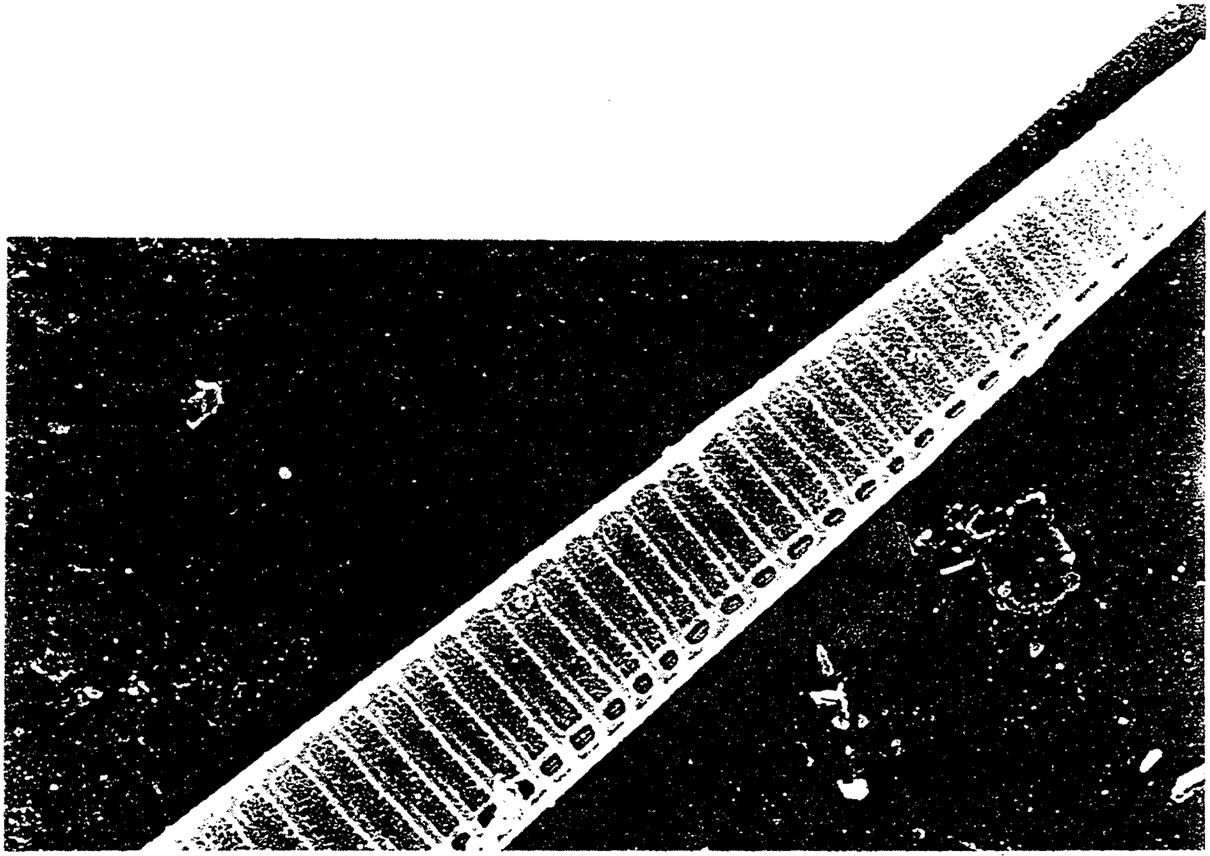


Figure 2a. *Pseudo-nitzschia multiseries* Hasle (SEM magnified 8.64 thousand times) from Mo Tat Wan Bay of Lamma Island, Hong Kong, China. 3.2 μm wide by 60 μm long.

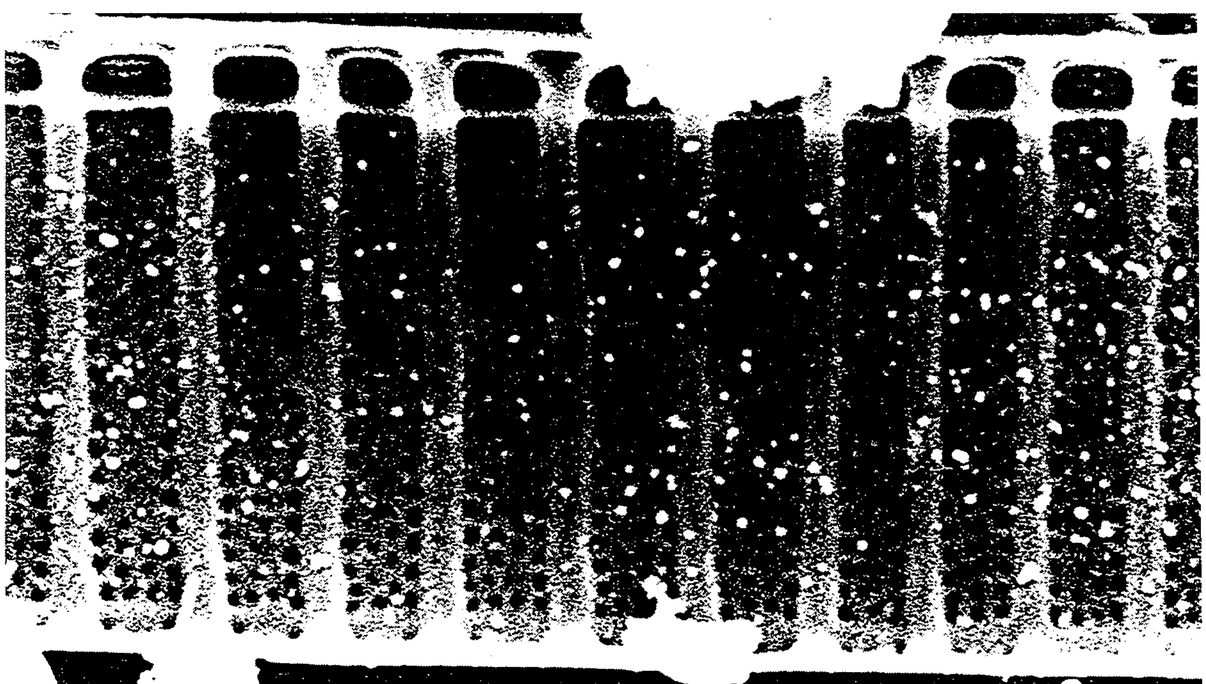


Figure 2b. *Pseudo-nitzschia multiseries* Hasle (SEM magnified 24 thousand times) from Mo Tat Wan Bay of Lamma Island, Hong Kong, China. 3.6 μm wide by 67 μm long. Note the 3-4 rows of poroids in central area that distinguish this potentially toxic species.

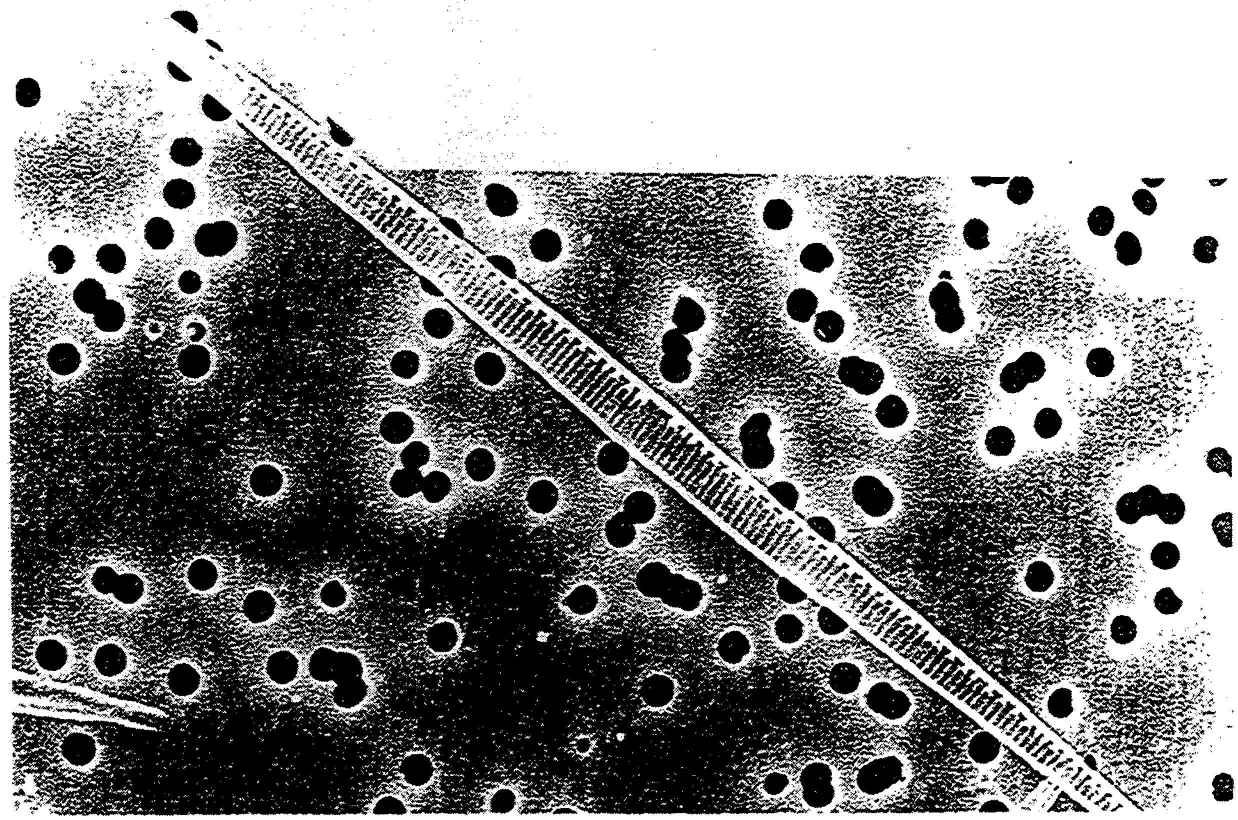


Figure 3a. Short form of *P pseudodelicatissima* (1.9 µm wide by 42 µm long) (SEM magnified 4.8 thousand times).

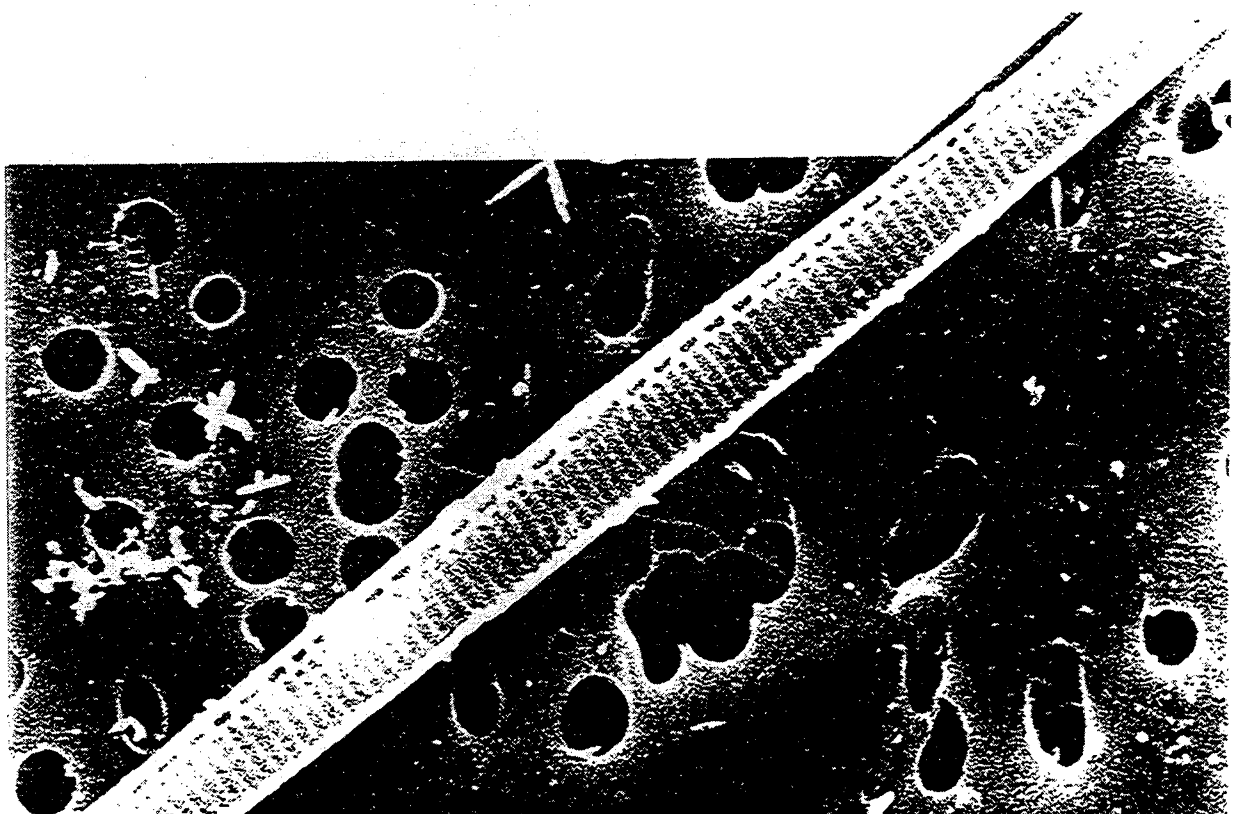
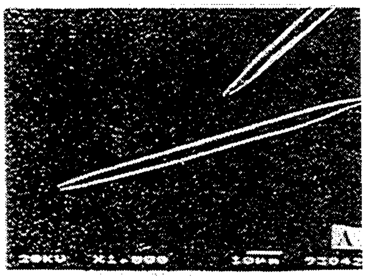
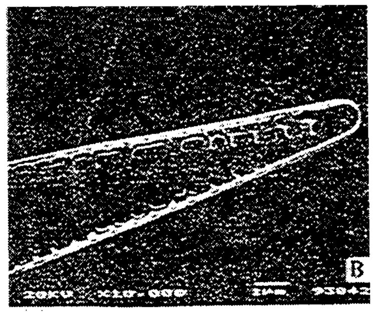


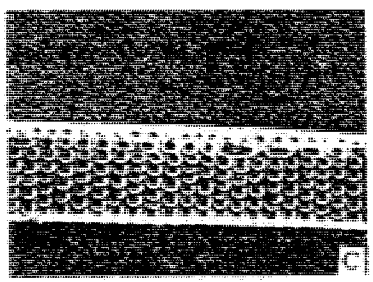
Figure 3b. Long-thin form of *P. pseudodelicatissima* (1.5 µm wide by 89 µm long) (SEM's magnified about 9.6 thousand times). Note the single row of intercostal poroids.



Pseudonitzschia sinica
Width: 3.75 µm
Length: 62.4 µm

Pseudonitzschia sinica
Width: 2.5 µm





Pseudonitzschia sinica
Width: 4.2 µm

Figures 4a-c. *P. sinica* (2.5-4.2 µm wide and 60-70 µm long) (SEM's magnified .64 to 6.4 thousand times). Note that the single row of intercostal poroids are relatively square in shape in comparison to those of *P. pungens* (Fig. 5a).

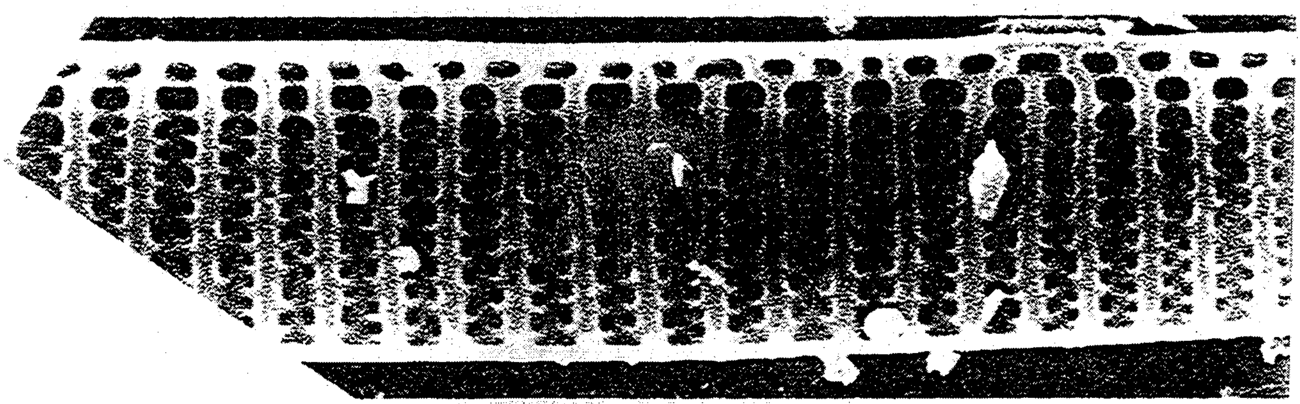


Figure 5a. *P. pungens* (3.17 µm wide by 98 µm long) (SEM's magnified 13.01 thousand times). There are 7-9 poroids over the width of the valve.

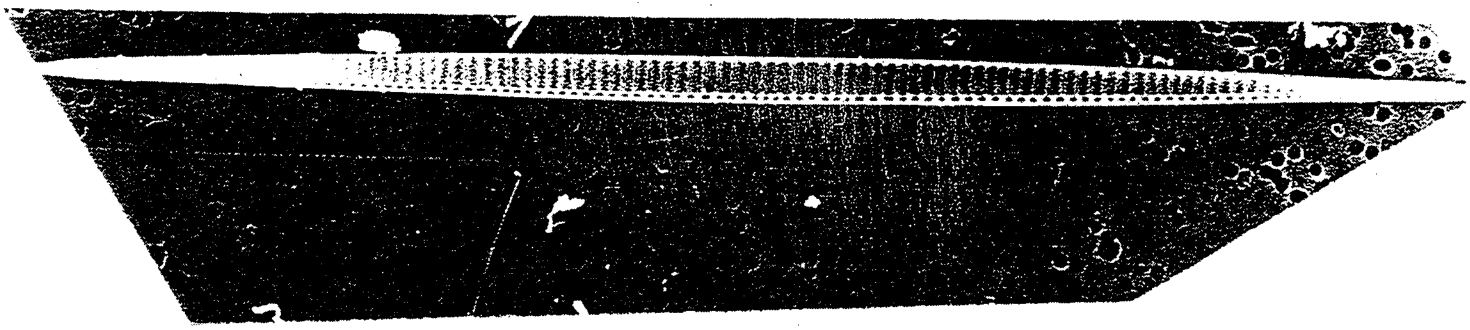


Figure 5b. *P. pungens* (3 μm wide by 92 μm long) (SEM's magnified 2.03 thousand times). Note that the tips of the valve are assymetrical; they are more curved on one side than the other.

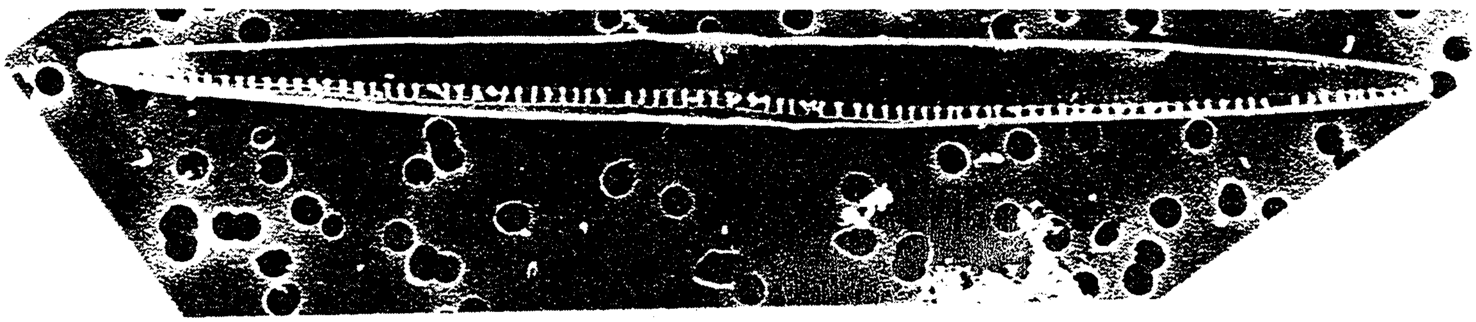


Figure 6. *P. multistriata* (2.7 μm wide by 45 μm long) (SEM's magnified 4.77 thousand times). The light coloured lines are the fibulae which arch over the raphe canal.

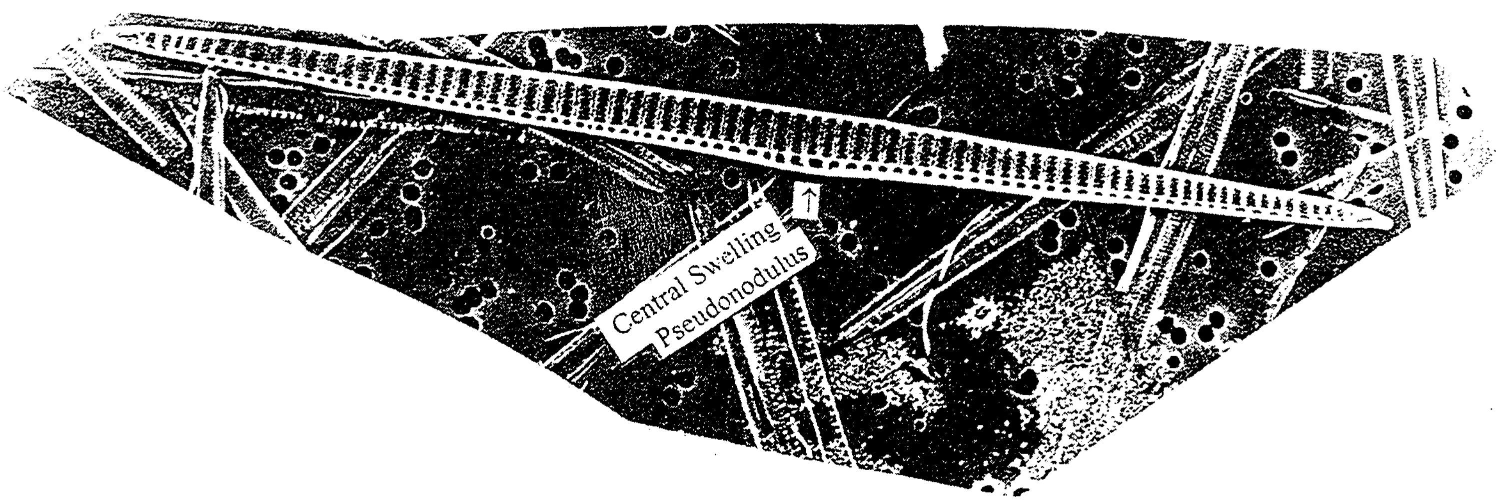


Figure 7. This unknown species looks like *P. pungens* but has a slight swelling on one side of its valve (i.e., in the center of its more curvilinear longitudinal axis) and a pseudonodulus. It is not known whether this variation can simply be ascribed to the natural variation of *P. pungens*. The swollen pseudonodulus (arrow) and the slightly swollen tips of the valve are indicative of *P. inflatulata*.

Table 1

A Simple Key to Five Species of *Pseudo-nitzschia* from Hong Kong

1. With central nodule (pseudonodulus) ------ (go to) 2
1. Without a central nodule (pseudonodulus) --------- (go to) 4
    2. One row of intercostal poroids -------------(go to) 3
    2. Four rows of intercostal poroids ------------ *P. multiseries*
3. Costae fine and dense (34-39 in 10 μm) -------- *P. pseudodelicatissima*
3. Costae coarse (15-17 in 10 μm) --------------------- *P. sinica*
    4. Two to three rows of intercostal poroids ----------- *P. pungens*
    4. Two to three rows of intercostal poroids ---- *P. multistriata*

Table 2

Seven *Pseudo-nitzschia* Taxa from Hong Kong Waters

Species Name	Length X Width (μm)	Pseudo-nodulus Present	# Fibulae in 10 μm	# Costae in 10 μm	# of poroids in 1 μm
P. pseudodelicatissima	30 X 100	yes	10-13	10-13	4-6
P. sinica	80-107 X 3.7-4.6	yes	9-11	15-17	2-3
P. pungens	75-144 X 3.5-5.5	no	9-18	9-18	3-4
P. multistriata	35-40 X 2.2-2.8	no	22-28	36-40	8-10
P. multiseries	68-140 X 4-5	no	10-13	10-13	4-6
Unknown species	60-70 X 2.5-3.5	no	10-15	9-13	2-3

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A FISHERIES RESOURCE PROFILE PRIOR TO ARTIFICIAL REEF DEPLOYMENT IN HONG KONG

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ABSTRACT

The Hong Kong Government plans to commence artificial reef (AR) deployment in late 1997. The first ARs will be sited in marine parks in Hong Kong's inshore, north eastern waters. AR project planning, management and evaluation requires baseline data on fisheries resources of these areas. Studies are underway to collect the required data prior to AR deployment. Fishers have been interviewed on the fishing grounds and their catches, fishing gear and fishing effort recorded. Underwater surveys by SCUBA divers and fisheries acoustic surveys are being undertaken. A programme of regular constant-effort fishing at selected sites has been completed.

A preliminary analysis of fisheries resource data obtained in the present study is summarised and compared with available historical data. It is apparent that fish resources are depleted and fishing effort is high. Most small boat fishing is part-time. Inshore trawling by larger boats to provide feed for the local mariculture industry is aimed at small pelagics but causes a significant level of mortality amongst juvenile commercial fish. While almost 200 fish species have been recorded in the present study, a limited number of small, low-value species comprise the majority of the catch. Opportunities for increasing production of a number of higher-value species through AR deployment are discussed. Such efforts will require the introduction of new fisheries management measures.

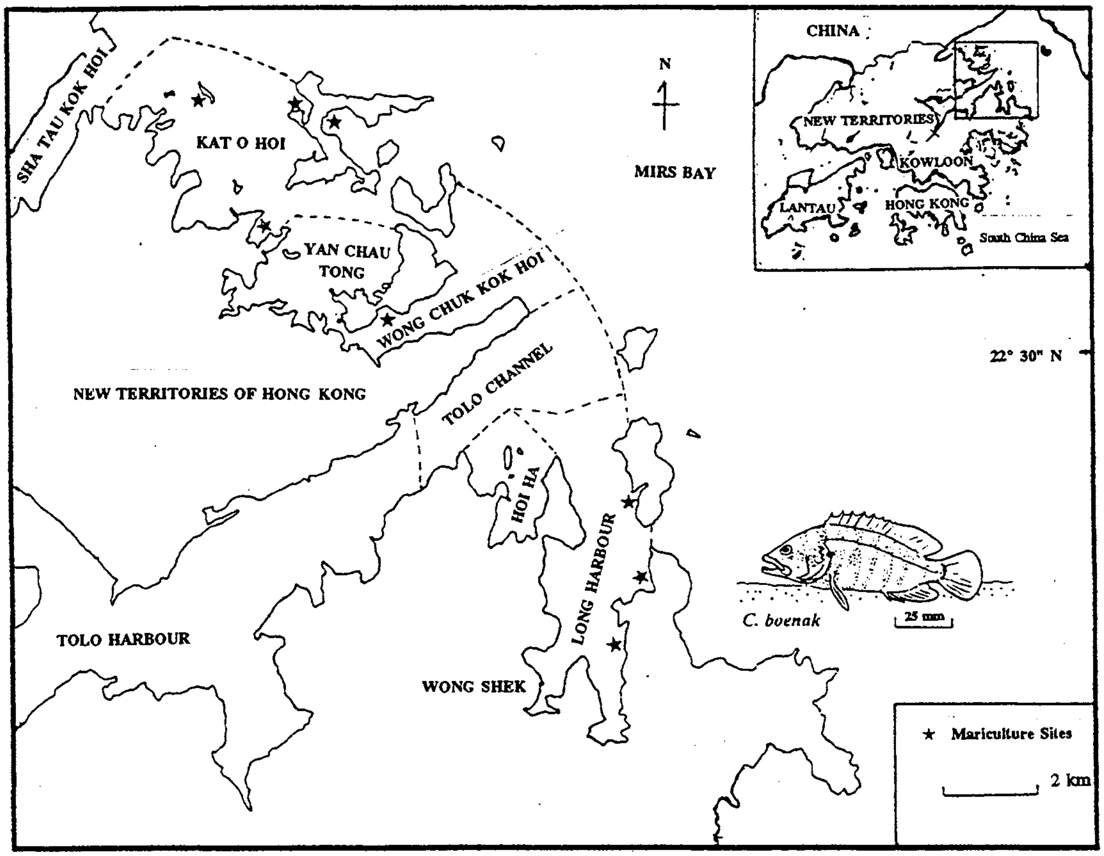
INTRODUCTION

Estimated landings by the Hong Kong fleet peaked in 1989 at 233,578 tonnes and by 1996 were about 21% lower (AFD, 1990-96 & in prep.). While most vessels over 15 m operate in more distant waters, the annual catch from Hong Kong waters, by craft below 15 m, was estimated in 1991 at about 15,000 tonnes (Wilson & Wong, 1995). Larger demersal species were rare in this catch and over 90% by weight were pelagics. In 1996, as part of a drive to improve the local marine ecosystem, Government designated two marine parks and one marine reserve and commissioned a major study of fisheries resources and fishing operations, (ERM, 1997). Results of this study will be used to develop new fisheries management measures. Also in 1996, Government launched a five-year artificial reefs (AR) project with a capital budget of HK $80.3 million (equivalent to US $10.4 million). The objectives of the AR Project are to promote biodiversity and rehabilitate and enhance fisheries resources in Hong Kong waters.

For AR project planning, management and future project evaluation purposes we require a wide range of data prior to deployment. Even before selecting AR as a tool for use in fisheries management, we need to confirm that habitat is limiting (Polovina, 1989). This paper summarises the results of a range of baseline studies of the fisheries resources of a small area of inshore waters where AR are due to be deployed in late 1997. Catches are examined from small-scale fishing methods aimed mostly at demersal species. We identify factors which contribute to existing levels of overfishing. Recognizing the dangers of AR simply aggregating fish and increasing overfishing (e.g. Leung *et al*, 1997) we indicate the need to restrict fishing effort on AR following deployment.

THE STUDY AREA

Figure 1: Location of the study area in north eastern Hong Kong.



The first phase of AR deployment will be in Hong Kong's first two marine parks, namely Yan Chau Tong (or Double Haven) and Hoi Ha Wan ('Hoi Ha'). These and the neighbouring waters of Long Harbour, Tolo Channel, Wong Chuk Kok Hoi, and Kat O Hoi comprise our study area of 51 km^2 (see Figure 1). Herklots and Lin (1940) and Chan (1968 & 1976) give accounts of some of the main species of commercial fish which were landed in Hong Kong in the past and include some notes on their distribution within Hong Kong. While more recent studies have looked at selected aspects of fish resources in the area (e.g. Leung, 1997, Leung *et al*, 1997) there is little available, detailed information in the literature on commercial catches from Hong Kong's inshore north eastern waters.

Located at around Latitude 22° 30" North, the climate is semi-tropical with sea surface temperatures varying between about 15-30°C, according to season. Though subject to occasional typhoons the study area is usually sheltered from rough seas. About 60% of the seabed of Hoi Ha and 74% of Yan Chau Tong Marine Park is soft, flat and muddy. Sediments were found to be 6 to 10 metres in depth and fairly uniform silty-clay or clayey-silt with less than 10% combined sand and gravel content. No areas of high relief and very little rocky ground is present except along the rocky shoreline and in depths less than -4 m CD. (Cook, 1996). Coral colonies, except in a few areas, are relatively scarce and scattered.

Many corals below -2.5 m chart datum were killed by an exceptional hypoxic event in July 1994 (Binnie Consultants Ltd., 1995). Under water visibility down to 8 m depth is usually around 3-4 m but at greater depths is often about one metre. Most seabed in the area is at 11 to 15 metres depth.

SURVEY METHODS

Inshore Fishing Sector

A total of 33 daytime field-interview trips were undertaken at regular intervals, weather permitting, between 8 February 1996 and 22 April 1997. Except during February and March 1997, when the trip was extended into Sha Tau Kok Hoi, the same round trip was followed on each occasion, commencing at Wong Shek and proceeding to Kat O Hoi, via Long Harbour, Hoi Ha, Tolo Harbour, Wong Chuk Kok Hoi, and Yan Chau Tong, before returning to Wong Shek. There were two objectives to such trips. One was to determine levels of different types of fishing effort and the second, the higher priority, to locate and interview actively fishing operators of small fishing vessels. Usually all dinghy fishers encountered were requested to respond to interviews but selection of fishers to interview was, on occasion, biased towards those methods for which we had least information. In addition, during the season for Red pargo[1] "fry" (mostly juveniles 15-90 mm in length) four 24 m pair trawlers were approached, when hauling nets, and samples of the catches on deck were purchased.

Fishers were asked to respond to a formal questionnaire. Response was varied, about 10% of those approached said they were "too busy" to respond. Fishers in Hong Kong try to maintain their catch alive, in wells in their craft, to command higher prices. In order to save time and reduce the level of stress to catches, weights of different species, the numbers, average and maximum lengths of species were estimated rather than measured. A tape measure was carried to check length estimates.

Constant-effort Trial Fishing at selected Sites

Monthly fishing with handlines, long lines and trammel nets was conducted between April 1993 and November 1996 at Hoi Ha, Double Haven and Long Harbour. Between January 1995 and December 1996, night fishing using a 15 m, traditional hulled bright-light purse seiner was conducted by private fishers under contract to, and supervised by the present study. The same fishing stations were used on each trip. In each study area fishing sites were chosen which comprised: (i) flat mud, (ii) mud/sand interspersed with a few boulders and (iii) a predominantly rocky bottom. One aim was to investigate catch composition according to substrate and another to investigate seasonality. Baseline data for catch per unit effort (CPUE) from such constant-effort fishing would also be gained from such surveys. Line and gillnet fishing was carried out by a team of three fisheries staff who had extensive previous experience of this type of fishing. The bright-light purse seining (purse seining) was conducted at night at the sites mentioned above, on a monthly basis. Basic hydrographic data were collected during all trial fishing trips. The size and type of gear used was similar to that used in the area by local fishers.

Acoustic and SCUBA Surveys

Regular acoustic surveys in Yan Chau Tong, Hoi Ha and Long Harbour commenced in January 1996 using a scientific echosounder, BioSonics model DT 4000, linked to a laptop computer. Further

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[1] For scientific and Chinese names refer to Table 2 and Appendix 1.

details of our acoustic survey methodology are in Cook & Fok (1996). SCUBA diving was used for a variety of purposes during the present study including visual fish censussing along 50 x 3 m transects.

LOCAL FISHING ACTIVITY

Table 1 summarises records of vessels seen actively fishing during 33 survey trips to the study area. Excluding seasonal "fry" trawlers (aiming for juvenile Red pargo), an average of almost six trawlers, of estimated length 18-26 m, were encountered per trip in the study area. The trawlers fished the study area to 8 metres depth, in some areas, and to within 100 m of the shore. Pair trawlers over 20 m in length made up 68% of the total sightings of trawlers while 25% of this total were shrimp trawlers.

Registration numbers of dinghies actively fishing were recorded on 268 occasions and included a total of 136 different boats. Of these 40% were sighted on only one or two occasions. Either dinghy fishing is a part-time occupation or the dinghies are wide ranging. Three helicopter trips at monthly intervals over the majority of north and eastern inshore waters, in good weather, failed to find more than 54 dinghies fishing on any one day. Most dinghy fishers also work in the mariculture industry and state they do little night time fishing. Dinghy fishing is therefore a part-time occupation for many P4 operators.

CATCHES BY LOCAL FISHERS

A summary of the species, other than "fry", comprising the largest proportion by weight of the catches of P4 boats and M6 gill netters[2] is given in Table 2. Specifications of some of the gear used by small-scale fishers is given in Appendix 2. Forty seven species of fish were recorded in the dinghy gill and trammel net catches (usually referred to as gill net catches in Hong Kong, although most nets used are trammel nets) but only six species comprised more than 2.5% by weight of the gill net catch (Table 2). Rabbitfish made up the greatest proportion of the gill net catch, at 35% by weight. Crabs with carapace width over 100 mm made up 20.8%. Smaller individuals of various crab species when enmeshed were routinely crushed into small pieces as the least time-consuming method of removal. One higher-value species, Black seabream, made up 3.1% of the gill net catch. Other higher-value species recorded in the gill net catch, but in very small quantities, were: Yellow grouper, Russell's snapper, Red pargo and Goldlined seabream; the largest having a maximum total length (TL) of 200 mm. While dinghy gill netters invariably fished along the edge of rough ground close inshore, M6 netters fished further out, over muddy bottom. This explains the absence of Rabbitfish, fewer crabs and cephalopods and the high proportion of sciaenids (31%) and carangids (15%) in the catch of the larger boats.

Cephalopods (Cuttlefish, 35.7%, Squid 15.2% and Octopus 2.2%) made up 53.1% of the total dinghy handline catch recorded. Only three species of fish each comprised over 2.5% of the handline catch, these were Rockfish at 18.9%, Brown coral cod, at 15.5% and Black seabream at 4.2%. The average fork length (FL) or TL of these three species fish in the handline catch sampled was 116, 104 and 200 mm respectively. Also caught in very small quantities were a number of higher-value fish including four species of groupers, two snappers, Chicken grunt, Painted sweetlip, and Red pargo. The maximum recorded TL of any one of these species was 350 mm, being an Orange-spotted grouper. The average CPUE of the dinghy fishing examined was 0.33 kg/crew/hour, some crew using more than one line at any one time. This figure is very low in comparison with figures given for tropical reef fisheries by Dalzell (1996).

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2 For explanations of the terms M6 and P4 boats see the Legend of Table 1.

Table 1: Numbers of Sightings of Boats actively fishing and Methods employed in given Areas.

Area Code*:	LH	HH	TL	WK	YT	KO	TOTALS	% of Total
	Numbers of Vessel Sightings by Area in 33 surveys							
Type of Boat & Method								
M6 Pair Trawling	30	6	58	22	0	14	**130**	**51.0**
M6 Stern Trawling	8	2	4	1	0	0	**15**	**5.9**
M6 Shrimp Trawling	17	2	23	1	3	2	**48**	**18.8**
M6 "Fry" Trawling	5	0	0	2	1	25	**33**	**12.9**
M6 Clam Dredging	0	0	2	0	0	0	**2**	**0.8**
M6 Gill/Trammel Netting	2	7	0	7	6	5	**27**	**10.6**
Total M6 Boats	**62**	**17**	**87**	**33**	**10**	**46**	**255**	**100**
% M6 Boats by Area	**24.3**	**6.7**	**34.1**	**12.9**	**3.9**	**18.0**	**99.9**	
P4 Gill/Trammel Netting	26	10	6	17	25	32	**116**	**36.1**
P4 Handlining	11	5	3	9	2	5	**35**	**10.9**
P4 Cage Trapping	16	9	0	4	3	2	**34**	**10.6**
P4 Pair Trawling for "fry"	4	8	2	36	28	10	**88**	**27.4**
P4 Pair Trawling not fry	0	4	0	2	10	6	**22**	**6.8**
P4 Long Lining	1	1	1	1	3	0	**7**	**2.2**
P4 Diving	0	0	0	1	0	2	**3**	**0.9**
P4 Urchin Hooking	0	2	0	2	0	1	**5**	**1.6**
P4 Shellfish Collecting	0	0	0	1	0	7	**8**	**2.5**
P4 Unidentified (too far)	0	0	0	1	2	0	**3**	**0.9**
Total P4 Boats	**58**	**39**	**12**	**74**	**73**	**65**	**321**	**99.9**
% P4 Boats by Area	**18.1**	**12.1**	**3.7**	**23.1**	**22.7**	**20.2**	**99.9**	

LEGEND

(i) M6 pair, stern and most shrimp trawlers are wooden hull, modern design, 18-30 m in length and diesel-powered. M6 gill/trammel netters and fry trawlers are wooden, diesel-powered, traditional hulls 12-16 m in length. P4 boats are mostly fibreglass dinghies, petrol outboard powered and mostly 5-6 m in length.

(ii) Area Codes* represent areas marked on Figure 1, namely: LH - Long Harbour, HH - Hoi Ha Wan, TL - Tolo Channel, WK - Wong Chuk Kok Hoi, YT - Yan Chau Tong, KO - Kat O Hoi.

(iii) Combined total area is 51 km^2.

(iv) "Fry" is the term commonly used in Hong Kong for juveniles of Red pargo which are caught by various types of trawlers during January to early April, at fork lengths of from 15 to 90 mm.

Table 2: Composition of Catches of Local Fishers. Key: %W - % total catch by weight, AL - Estimated Average Fork Length in mm, ML - Estimated Maximum Length in mm., ( ) - where AL is taken from sub-sample >50% of those caught, [+] - includes 260 Red pargo fingerlings.

CATCHES (Gill net catches include trammel net catches):		P4 GILL NET 52 Catches, 349 kg 201 boat hr			P4 HAND LINE 22 Catches, 84 kg 252 crew hr				P4 CAGE TRAP 15 Catches, [30+] kg 110.5 boat hr				M6 GILLNET 16 catches, 217 kg 77 boat hr		
SPECIES		%W	AL	ML	No.	%W	AL	ML	No.	%W	AL	ML	%W	AL	ML
Apogon fasciatus, Cardinalfish	蔬蘿								264	20.2	90	120			
Caranx spp., Trevally	鰺魚												15.0	(200)	210
Cephalopholis boenak, Brown co. cod	烏絲				410	15.5	104	175	236	25.4	100	200			
Chromis notata, Damselfish	石剎	5.5	120	125											
Clupanodon punctatus, Gizzard shad	黃魚	2.9	140	180									14.2	(150)	160
Gymnothorax spp,. Moray eel	油鎚								8	11.4	(570)	610			
Halichoeres dussumieri, Wrasse	牙衣								48	6.0	(125)	150			
Leiognathus brevirostris, Ponyfish	油力	2.9	100	110									9.5	(80)	120
Rastrelliger kanagurta, Mackerel	花鮫	4.3	162	200									13.9	200	210
Sebastiscus marmoratus, Rockfish	石狗公				940	18.9	116	150							
Siganus canaliculatus, Rabbitfish	泥鯭	35.0		250					174	29.7	(60)	230			
Sparus macrocephalus, Black seabream	黑鱲	3.1	190	350	12	4.2	200	325					4.4	220	300
Sciaenidae (5 spp) Croakers	鰔魚												31.1		280
Fish Spp. < 2.5% W; ML excluding eels. [No. spp.]		13.0 [41]		500		8.3 [16]		350		7.3 [8+]			7.8 [12]		400
Cuttlefish, squid, octopus	墨魚,魷魚,八爪魚	12.5				53.1									
Mainly *Portunus spp.*, Crabs	蟹	20.8											4.2		

Rabbitfish at 29.7% made up the highest proportion by weight of the cage trap catch with an average size markedly smaller than the gill net catch. Brown coral cod were 24.4% of the cage trap catch and a Cardinalfish 20.2% by weight. The cage trap catch included 260 Red pargo and 10 Yellow-finned seabream fingerlings. While larger crabs were not recorded in the traps, probably because of the small entrance size, small crabs of a variety of species were caught in substantial quantities. These small crabs together with numerous small reef fishes including Damselfishes and Anemonefishes were usually retained by the fishers and used as mariculture feed.

The first fishing for juvenile Red pargo ("fry") of the season was recorded on the first survey of the year, 28 January. Boats ceased trawling for juvenile Red pargo between late March and early April. The numbers of sightings of boats fishing for "fry" are given in Table 1, according to area. Only on one occasion was a boat encountered which was fishing for fry other than Red pargo, in this case Goldlined seabream fry, (TL 12-15 mm). The study area was worked by ten M6 boats of registered lengths of 12 to 15 m using twin 7.3 metre beam trawls. Their average daily catch per boat was around 2,000 juveniles of FL mostly 15 to 70 mm. A total of 40 different dinghies were found pair trawling for Red pargo juveniles. Many dinghy operators claimed to fish six or seven days per week. The dinghies fished closer inshore and the average size of the juvenile Red pargo caught appeared larger than those caught by the M6 boats, some juveniles reaching 90 mm FL by mid March. Daily catches by dinghies pair trawling for Red pargo juveniles ranged from 500 to 1000 per day. At the end of the 1997 season, seven pairs of dinghy "fry" fishers reported season's catches ranging from 20,000 to 110,000. The mortality rate of Red pargo juveniles during capture, estimated from sampling the by-catch, varies between about 5 and 10%.

The fishery for juvenile Red pargo results in high mortalities of other fry and juveniles of many other species which are retained and used as mariculture feed. Samples of the by-catch were collected, sorted by species and recorded during the present study. The composition of the by-catch was found to be highly variable and included juveniles of many commercial species. Fry fishers interviewed during the survey informed the survey team on a number of occasions that juveniles of Mud grouper and Red snapper were previously common in "fry" catches but are now never caught.

Four 24 m trawlers fishing Long Harbour, in February and March 1997, were using codends having a stretched-mesh size of about 12 mm. Sampling indicated that small pelagics, mostly anchovies and sprats, made up over 90% of the catch of these trawlers and that up to 158 juvenile Red pargo and 25 juvenile Cardinal seabream were caught by them per hour's trawling. These juvenile seabream and small juveniles of several other commercial species, also found in the trawl catches sampled, are normally sold with the anchovies and sprats as mariculture feed. As an estimated average of six large trawlers fish the study area every day, mortality of juvenile fish caused by such inshore trawling is high.

CONSTANT-EFFORT TRIAL FISHING RESULTS

An analysis of catches from constant-effort trial fishing at established stations is given by Leung *et al* (1997). A total of 180 species were recorded, 109 from purse seining, 84 from gill netting, 71 from hand lining, and 28 from long lining. Small low value species dominated the catches. Sizes of fish caught were broadly similar to those caught by local fishers. Overall CPUE rates e.g. 0.1 kg/line/hour for the line fishing and 0.72 kg/hr for 550 m (Yan Chau Tong) and 880 m (Hoi Ha) x 1.3 m trammel netting were very low in comparison to catches from reef fisheries quoted by Dalzell (1996). The CPUE of the constant-effort purse seining was much lower than the local commercial catch, possibly reflecting the fact that local purse seiners fish in more open waters. The trial purse seining catch yielded mostly low value small pelagic fish, hairtails, ponyfish and included juveniles of many commercial species.

ACOUSTIC AND SCUBA SURVEY RESULTS

From the acoustic surveys we obtained estimates of average fish biomass of from 4.4 to 167 kg/hectare for fish occurring more than 250 mm above the seabed. Long Harbour appeared to have higher densities of fish than Hoi Ha and Yan Chau Tong. Numerous schools of small fish were detected but their occurrence does not appear to fit any particular pattern. The estimated average size of fish detected varied according to surveys from 15-110 mm. Echoes from fish over 150 mm in length were practically absent from the data for at least six of the months surveyed and at low densities during the remainder.

Over 33 hours SCUBA diving was carried out in the area, per buddy team, undertaking a variety of tasks. During these dives about 4 km of sea bed in the study area was swum, whilst maintaining watch for fish. Only 27 individual fish, between 150-300 mm (maximum) were encountered in underwater horizontal visibility of between 3-5 m. During 12 visual census counts of fish in a total of nine 50x3 m contour belt transects at three or eight metres depth, over rough and sandy bottom, only one fish over 150 mm was recorded, a 200 mm Longfin grouper. At depths of 10 m and below, low visibility renders visual censussing ineffective. A ghost-fishing gear removal exercise removed a total of 5.6 km of ghost fishing gill and trammel nets in one day from Hoi Ha. These contained quantities of small fish and crabs. Schools of an estimated 100 to 300 juvenile Chicken grunt, a higher-value species, were found aggregating in summer 1996, around chains from five mooring buoys in Yan Chau Tong Marine Park.

Five dives were carried out on two wooden fishing boat wrecks, 12 and 18 m in length, lying on muddy bottom in the area. On both wrecks over 20 high value fish, over 200 mm in length, were encountered on each dive. On the first visit, the larger vessel held two grouper, one 700 mm in TL (probably Orange spotted) and one Painted sweetlip of 350 mm. On each visit the wreck held between 10-15 Mangrove snapper of 300 to 400 mm and numerous Russell's snapper of 100-200 mm. The smaller wreck on each of two occasions held at least 20 Chicken grunt, about 10 Black seabream and eight Spotted butterfish. After a few minutes diving on either wreck, on most dives, sizes and numbers of high value fish exceeded those seen on the 33 hours diving, referred to above, over other seabed in the area.

CONCLUSIONS

Herklots and Lin (1940) record the size and occurrence of "50 Common Marine Food-fishes of Hong Kong". A number of the species they describe probably occurred in the present study area 60 years ago and apparently often reached sizes over 600 mm in length. These include the Mud grouper, not recorded by the present study; their "fry" being noted by Red pargo "fry" fishers as formerly abundant but now absent from their catches. The Mud grouper was considered by Herklots and Lin as *"one of the most common food fishes available in the markets all the year. Caught by long line or net; especially abundant in the months between October and March. Common size 1 to 2 feet, reaches 3 feet or more."* Chan (1968) considered that small Mud grouper were ... *"mostly caught from inshore waters. It is one of the most abundant of groupers in Hong Kong."* Chan lists the Estuary grouper as *"Common size from 18 inches to 24 inches. Specimens of 3 feet are also common. It is one of the most abundant groupers in the market occurring widely along the coast from inshore waters of bays and estuaries ... it is captured by all types of fishing boats. When a giant specimen is caught, it is always tied to the side of the boat...."*

The Red grouper which is the highest priced epinephelid in Hong Kong, was *"captured primarily from rocky grounds east of Hong Kong. Previously, considerable quantity of this Grouper was taken from Port Shelter and the Nine-pins of the Colony.* (Port Shelter is bay 6 km south of Long Harbour and Nine-pins a group of islands just 5 km from the entrance to Port Shelter.) These and most other non-grouper species which attained large sizes (>600 mm) in local waters, in the 1930's, were absent from the commercial catches examined in the present study. Two of the three croakers described by Herklots and Lin are recorded as having common sizes "3 to 4 feet" and "2.5 to 3.5 feet". They add that both species reached five feet (1524 mm). The largest of the five species of croaker recorded by this survey had a TL of 280 mm.

The commonest grouper caught in the present study, the Brown coral cod, had an average size of about 100 mm (4 inches). This species is regarded by Heemstra and Randall (1993) as being *"too small to be of commercial importance"*. Chan (1968) notes that this species *"is never caught by trawlers"* and it was absent from recent samples of local trawl catches (ERM, 1997) although Heemstra and Randall (1993) consider that it may be trawled (in other countries). Sadovy (in press) considers that the size of sexual maturation of the species is <110 cm TL. This was confirmed by the present study, three females of TL 99 to 109 mm were found to have gonads which were maturing, or mature and active. It would appear that small size at sexual maturity and a behavioural preference for rough, and therefore shallow substrate (in this study area), have enabled this grouper to avoid trawlers and thrive in these waters. Other grouper, like other higher value fish, are now greatly reduced in distribution, abundance and size.

The abundant fish species which made up the largest proportion by weight of the catches examined (other than Red pargo "fry") during the present study, are not mentioned by Herklots and Lin. We conclude that this was because of the high availability of other species earlier this century, which were of higher value and larger size. Although those species which now make up the majority of local catches are still abundant, they are small and fast maturing. Our study area clearly suffers from both growth and recruitment overfishing (e.g. Pauly, 1994) of many previously common, higher-valued species.

Factors which are likely to have contributed to overfishing locally include open-access, unrestricted fishing effort, inshore trawling using small mesh nets for mariculture feed, trawling for juvenile Red pargo, use of very fine, small mesh monofilament gill and trammel nets having a working life of only two to four weeks, ghost fishing from discarded, lost or abandoned nets, small mesh traps and retaining most by-catch as mariculture feed. The situation is further aggravated by part-time dinghy fishers earning much of their income from non-fishing employment. This is important as levels of overfishing may now be higher than otherwise possible as many fishers now do not have to earn a full wage or cover all overheads by selling their catches. Fishing can now continue on a subsidised or 'hobby' basis long after resources have reached such low levels that fulltime fishing is economically unrewarding.

This study has shown that some higher-value fish species, albeit few in number and individuals mostly small in size, are still to be found in the study area, especially in the vicinity of sunken wrecks. These include a number of groupers (Serranidae) snappers (Lutjanidae) Seabream (Sparidae) and Grunts (Haemulidae). These species show most potential for benefiting from resource enhancement through AR deployment. A substantial volume of recent literature stresses the need for adequate control of fishing effort on ARs if they are to form any enhancement function rather than simply aggregating fish and worsening any already existing level of overfishing (e.g. Leung *et al.* 1997). If AR deployment is to have any beneficial effect on fish stocks in local waters as a whole, it is clear from the present study that a range of fishery management measures need to be introduced which extend well beyond the limits of areas where AR are to be deployed and effectively reduce and regulate fishing effort. The benefits to be derived from establishing refugia where non-migratory fish can achieve maturity and full fecundity to supply eggs and recruits to harvested areas (Plan Development Team, 1990) should not be overlooked. ARs deployed in marine protected areas should form the basis for such refugia (Wilson and Cook, in press).

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APPENDIX

Appendix 1: Main Species Names Not Covered by Table 2

SCIENTIFIC	ENGLISH	CHINESE	LOCAL
Engraulis japonicus	Anchovy	公魚	Kung yue
Epinephelus akaara	Red grouper	紅斑	Hung paan
E. awoara	Yellow grouper	黃斑	Wong paan
E. brunneus	Mud grouper	泥斑	Nai paan
E. coioides	Orange spotted grouper	花斑	Fah paan
E. malabaricus	Estuary (or Malabar)	花斑	Fah paan
E. quoyanus	Longfin grouper	金錢斑	Kam chin paan
Evynnis cardinalis	Cardinal seabream	扯旗鱲	Chea kei lap
Lutjanus argentimaculatus	Mangrove snapper	紅魰	Hung yau
L. erythropterus or L. malabaricus	Red snapper	紅魚	Hung yau
L. russelli	Russell's snapper	火點	For tim
Pagrus (= Pagrosomus) major	Red pargo/Jap. seabream	紅鱲	Hung lap
Parapristipoma trilineatum	Chicken grunt	雞魚	Gai yue
Plectorhyncus pictus	Painted sweetlips	細鱗	Sai lun
Rhabdosargus sarba	Goldlined seabream	金絲鱲	Kam see lap
Scatophagus argus	Spotted butterfish	金鼓	Kam ku
Sparus latus	Yellowfin seabream	黃腳鱲	Wong keuk lap
Spratelloides gracilis	Sprat (or, locally, Anchovy)	公魚	Kung yue
Trichiurus haumela (mostly)	Hairtail	牙帶	Ngar taai

Appendix 2: Specifications of the main small scale fishing gear used in the study area

GEAR	MAIN SPECIFICATIONS	No. of UNITS	SOAK TIMES
Trammel net c.f. 'gillnet'	Outer (stretched) mesh 200 mm, inner 50 mm for fish and 105 mm for crab. Net size: 1.3 m x 55 m. Monofilament nylon bs. 8 lb (outer) & 4 lb (inner)	from 2 (hobby) to 120	from 20 min (driving fish) - 5 days (crabs)
Handline	Hooks No. 16. Monofilament line 3-4 lb bs.	One hook per line	-
Cage Trap	Fry : 300x300x300 mm, Wire mesh: 10x10 mm *Siganus*: 450x450x450 mm Wire mesh: 20x20 mm	50-360	x2 day & overnight *Siganus*: overnight

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FRESHNESS DETERMINATION METHODS OF COMMON SEAFOOD SPECIES IN SOUTH CHINA COASTAL REGION

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ABSTRACT

Seafood is one of the most important basic food in Asia. Freshness is the most critical criterion in determining the eating quality and market price of marine products. Six local common seafood, Black Seabream (*Mylio macrocephalus*), Russelli's Snapper (*Lutjanus russelli*) and Head Grunt (*Pomadasys hasta),* Brown Spotted Grouper (*Epinephelus bleekeri*), Gold-lined Seabream (*Rhabdosarga sarba) and* Gei Wai Shrimp (*Metapenaeus ensis)* were undergone investigation for determinating their specific Seafood Freshness Indices (SFI). Four freshness testing methods: Trimethlylamine (TMA) assay, Hypoxanthine (Hx) test, Microbiological test and Sensory Evaluation were investigated and developed. The experimental results showed all tests correlated well with each other except Hypoxanthine test, because Hypoxanthine continued to degrade after its formation.

Two categories of SFI were compiled, one indicated fresh seafood and the other showed upper limit of acceptability for consuming. All SFI of fresh seafood were similar in five investigated marine fishes and Gei Wai Shrimp, that was 0-0.1mg/100gm of seafood tissue. On the other hand, different seafood, even the same genus but different in species, showed variation in SFI of upper limit of acceptability. Black Seabream, TMA content was 13-15 mg/100gm and Hx content was 7.2-7.4 μM/gm. Russelli's Snapper, TMA content was 16-17 mg/100gm and Hx content was 8.0-9.0 μM/gm. Head Grunt, TMA content was14.0-14.2 mg/100gm and Hx content was 13.0-14.0 μM/gm. Brown Spotted Grouper, TMA content was 6.0-7.0 mg/100gm and TBC was 600,000-650,000 per gram of fish. Gold-lined Seabream, , TMA content was 8.0 mg/100gm and TBC was 50,000-60,000 per gram of fish. Other from marine fish, Gei Wai Shrimp showed upper limit of TMA content of 10 mg/100gm of shrimp. The threshold of TMA was the lowest in Brown Spotted Grouper and the highest in Russelli's Snapper.

INTRODUCTION

Seafood is very common worldwide basic food with high nutrition values. Freshness Determination Methods are good tools for seafood mongers and buyers in the quality control of their marine food products. These methods can also facilitate the investigation in the study of seafood preservation (Yu & Choi, 1995). Seafood post-mortem deterioration are caused by internal enzymatic autolysis, bacterial degradation as well as oxidation.

Trimethylamine (TMA) is a metabolite derived by bacterial enzyme action (Shewan, 1977) from trimethylamine oxide (TMAO). TMAO is an odourless substance that naturally present in seafood species. When a marine species dies, TMAO is degraded to TMA which contribute fishy smell (Laycock, 1971). Since TMA is universal in all seafood species, and numerous studies showed TMA in muscles of various spoiling seafood has correlated well with sensory scores (Sikorski, 1981), TMA test was chosen to be an objective chemical determination method to quantify the seafood freshness.

Different from the formation of TMA, the formation of Hypoxanthine (Hx) is due to autolysis. Hypoxanthine is the degradation product of nucleotides, such as ATP by endogenous enzymes (Greene, 1990). After the fish is dead, the endogenous enzymes of the fish act on ATP and a series of de-amination and de-phosphorylation reactions occur to yield inosine. These reactions will continue to react for the ultimate formation of hypoxanthine, xanthine, and finally uric acid (Ko, 1989). Hypoxanthine is also responsible for the fishy smell of spoiled seafood.

In addition to the above two tests, microbial enumeration is a very useful technique for the detection of spoilage in marine products (Fieger, 1961). Numerous bacteria occur naturally on the body of seafood. After the dead of a seafood species, the degradation actions of bacteria contribute the major task of spoilage. Bacterial growth and their abundance are indicators of seafood spoilage.

Other evaluation methods for seafood freshness include measuring K-value (Greene, 1990), Trimethlylamine (Bystedt, 1959), Total Volatile Basic Nitrogen (Pierre, 1989), Biogenic amines (Karmas, 1981) and free fatty acids (Barassi, 1987). Most researches on seafood freshness were done in the West (Charalambous, 1986), thus, there is a lack of information on the local common seafood species, especially those in the South China coastal region. In this report, five common local sea fish, Black Seabream (*Mylio macrocephalus*), Russelli's Snapper (*Lutjanus russelli*), Head Grunt (*Pomadasys hasta*), Brown Spotted Grouper (*Epinephelus bleekeri*), Gold-lined Seabream (*Rhabdosarga sarba*), and a well-known local Gei Wai Shrimp, *Metapenaeus ensis*, from Mai Po Marshes were chosen for the study of Seafood Freshness Indices (SFI). These indices can be used as valuable reference for quick guide of seafood freshness and quality control.

MATERIALS & METHODS

Sample collection and preparation

The conduction of seafood freshness tests were done in two phases. In Phase I, maricultured fish samples, Black Seabream (*Mylio macrocephalus*), Russelli's Snapper (*Lutjanus russelli*) and Head Grunt (*Pomadasys hasta*) with size range from 250 to 300 grams were collected from local fish farm in Sai Kung. All living fish samples were transferred to an ice box and were killed simultaneously. Iced fish samples were then rinsed for three times and were individually bagged without sealing. All fish samples were refrigerated in chiller at 0-4°C and were analyzed at Day 0, 7, 10, 14 and 28. Essay samples were replicated for four times. In Phase II, maricultured fish samples, Brown Spotted Grouper (*Epinephelus bleekeri*), Gold-lined Seabream (*Rhabdosarga sarba*), with size range from 300 to 350 grams, were selected Other than sea fish, matriculated

Gei Wai shrimp were also undergone investigation. Gei Wai Shrimp, *Metapenaeus ensis*, were collected from Mai Po Marshes and the same killed simultaneously by icing. The shrimp size range was from 35 to 50 grams. Iced shrimp samples were also rinsed for three times before individually bagged. They were kept at 0-4°C and were analyzed at Day 0, 7, 14, 21, 28 and 36.

Phase I

Trimethylamine test

Same parts of fish fillet, with skin and scale, from individual fish sample was cut for TMA test. TMA test was conducted according to the procedures outlined in Official Methods of Analysis (1995) 971.14 - Colorimetric Method, Association of Official Analytical Chemist. TMA containing in seafood tissues was extracted in 7.5% trichloroacetic acid. The extracted TMA in toluene will then react with a toluene of picric acid to from trimethylamine picrate which was bright yellow in colour. The yellow colour was quantified by colorimeter measured at 410 nm.

Hypoxanthine test

Hypoxanthine (Hx) test for seafood freshness was introduced by Burt J.R., 1977. Same parts of fish fillet in TMA test were prepared for Hx test. Hypoxanthine in seafood tissue was extracted in 70% perchloric acid. Under the catalytic action of xanthine oxidase, Hypoxanthine was oxidized into uric acid, xanthine oxidase itself would be reduced. The blue DIP was in turn reduced by reacted xanthine oxidase to become colourless. The change in blue colour intensity was then be measured by colorimeter at exactly 2.5 minutes, with absorbance at 600 nm.

Sensory Evaluation

Sensory Evaluation was contributed by three categories: odour, texture and appearance (Sawyer, 1987). In appearance, it was further divided to observe three parts: gills, eyes and skin. The sensory test was conducted by a 12-point scoring system. Scoring 12 represented excellent and limit of acceptability was 6. All assessors were trained by learning the standard scores on different attributes on both fresh fish and deteriorated fish. At least seven well-trained panelists were invited for each Sensory Evaluation. Panel knew nothing about the fish samples to avoid any expectation error. Testing area, working bench, lighting and air-conditioning were the same in every test. Other equipment such as the containers of samples were identical for all samples to minimize variation in experimental conditions.

Because the judgment ability of each assessor might also vary according to the body and mental condition, a quality assurance design was also set up to ensure the evaluation ability of each panelist. A fresh sample with marked scores was prepared in each test for reference. It could standardize the scores given by each panelist. Another fresh sample, with same species, was also mixed with the tested samples. If a panelist scores this fish sample too far from the standard, the whole set of his data would be deleted in that test.

Since Hypoxanthine continued to degrade after its formation, it had problem to judge the freshness of the seafood, whether it was in the ascending stage or it had already reached the descending of Hypoxanthine stage. On the other hand, the testing procedures of Hypoxanthine were more complicated and time-consuming than TMA test. Hypoxanthine test was replaced by microbiological test in Phase II experiment.

Phase II

Microbial enumeration

Microbiological test reflected the actual hygiene index for the eating safety of the samples. It also gave direct explanation on the deteriorating effect on seafood. Total Bacterial Count (TBC) per gram of fish fillet, with skin and scale was conducted according to the standard procedures in Bacteriological Analytical Manual in Association of Official Analytical Chemist, 1995. The weighted sample was cut aseptically and then placed in a sterile Stomacher Bag, homogenized with sterile peptone water in a Stomacher 400 (Tekmar Co., Cincinniati, OH). Total Bacteria Count was determined by Pour Plate Method.

Modified Sensory Evaluation

Sensory Evaluation was modified from a 12-point scoring system to a 9-point system (Stone, 1985) because consumers were difficult to tell the difference in previous fine divisions. In a 9-point system, seafood quality was simply belonged to three grades: Good (score 7 to 9), Fair (score 4 to 5) and Bad (score 1 to 3). The limit of acceptability would become 5. Sensory Evaluation of shrimp was different from fish. According to Pedraja, 1970 , shrimp was examined for odour, texture (flesh and shell), appearance (shell sliminess, shell integrity and shell colour). Other arrangements were similar to the Sensory Evaluation of sea fish.

RESULTS & DISCUSSION

Phase I

The sensory scores in all three tests decreased against days of storage. Similar results were occurred in different attributes of Sensory Evaluation including odour, texture and appearance. It reflected the fishes were deteriorated against time. Both TMA and Hx content increased almost linearly against storing time. It showed that TMAO contained in fish muscle was continued reducing to TMA by bacteria action at a steady rate, causing linearly increase of TMA content. Postmortem catabolism of nucleotides was also progressed steadily by endogenous autolytic enzymes, causing linear increase in Hx. The arrows in the graphs shows the limit of acceptability, that is 6 in Phase I experiment.

For Black Seabream, it maintained the good quality condition on the first five days (score 12 to 9), where the graph showed TMA and Hx content was 0-5.0 mg/100 gm of fish and 2.9-11.0 μM/gm of fish respectively. After 10-day storage, it deteriorated to fair condition, sensory scoring 6, which was the limit of acceptability. TMA and Hx content was 13-15mg/100gm of fish and 7.2-7.4 μM/gm.

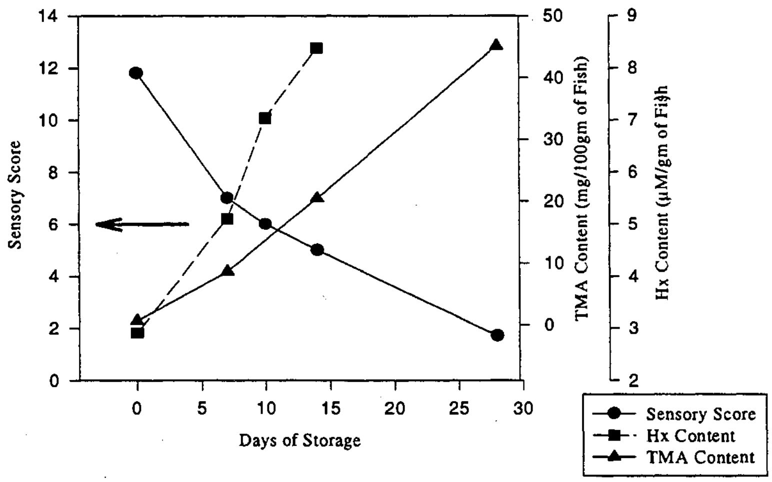

Figure 1. Sensory scores, TMA and Hypoxanthine content changes for Black Seabream, *Mylio macrocephalus*, stored at 0-4°C.
Arrow indicates the minimum acceptable score on a 0 to 12 scale.

For Russelli's Snapper, it was kept fresh from Day 0 to Day 4, which TMA and Hx content were 0 to 4.0 mg/100 gm of fish and 1.2-12 µM/gm of fish respectively. The result was very similar to Black Seabream. However the deterioration rate of Russelli's Snapper was slower than that of Black Seabream as it reached the limit of acceptability after 14-day storage, where TMA content was 16-17 mg/100 gm of fish and Hx content was 8-9 µM/gm of fish. Two numerical data was also found higher than that of Black Seabream.

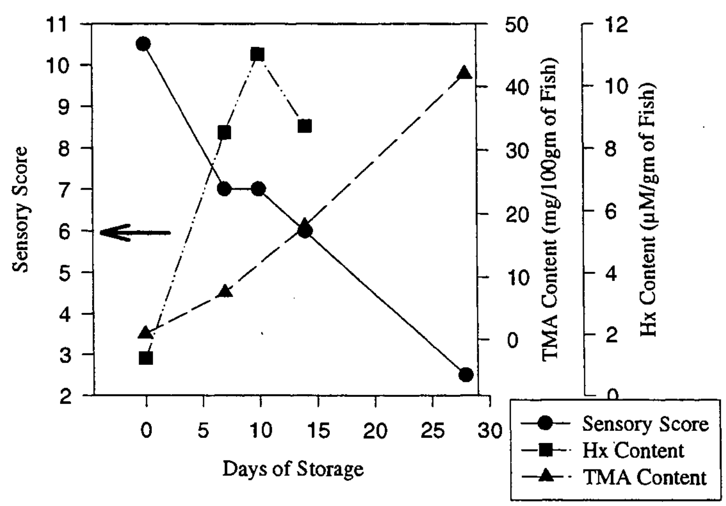

Figure 2. Russelli's Snapper, *Lutjanus russelli*

On the other hand, Hx content of Russelli's Snapper showed its accumulation peak content on Day 10. The degradation rate was faster than the formation rate of Hx at that moment, causing the accumulated content to decline. Its peak Hx content in this experiment was 11.0 µM/gm of fish. Both Black Seabream and Head Grunt had not reached their peak Hx content after 15-day storage. Maximum measure of Hx were 8.4 μM/gm of fish and 13.0 μM/gm of fish for Black Seabream and Head Grunt respectively. The limit of acceptability lasted the longest in Head Grunt. It was 18-19 days when TMA and Hx content were 14.0-14.2 mg/100gm of fish and 13.0-14.0 μM/gm of fish respectively.

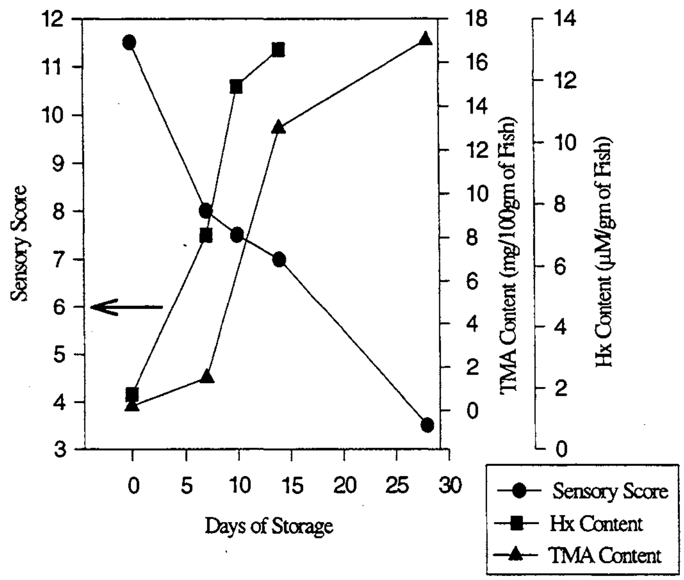

Figure 3. Head Grunt, *Pomadasys hasta*

The starting sensory scores and TMA content among three fishes were very similar. Sensory scores were between 11 to 12 and TMA contents were 0 to 1.0 mg/100 gm of fish. Great difference was in the starting Hx content. The most abundance was in Black Seabream with 2.9 μM/gm of fish, followed by Head Grunt of 1.8 μM/gm of fish. The least was in Russelli's Snapper which had 1.2 μM/gm of fish.

Among three species of fish, TMA changes in Black Seabream and Russelli's Snapper were very similar. On the other hand, the rate of increasing TMA in Head Grunt was much slower. After storing for 28 days, TMA content in previous two had already reached 42 to 45 mg/100 gm of fish while in Head Grunt, it still maintained with 17 mg/100 gm. Nevertheless it could not yet concluded Head Grunt was more resistant to spoilage than the other two because the rate of spoilage was directly affected by the starting abundance of degradation bacteria. Difference in degradation rate might due to difference in starting bacteria number, not the nature of seafood itself. Microbial Enumeration was arranged in Phase II experiment and thus the degree of vulnerability of different seafood could also be evaluated.

Phase II

The sensory scores in all three tests were also decreased as in Phase I and TMA contents increased against days of storage. As bacteria grew by cell division and thus increased its number logrimatically, the growing curves of bacteria were presented in log of Total Bacteria Count (TBC). It was found that log TBC increased synchronously with the increasing TMA curves both in Brown Spotted Grouper and Gold-lined Seabream. The results agreed with the close correlation between number of bacteria and the formation of TMA.

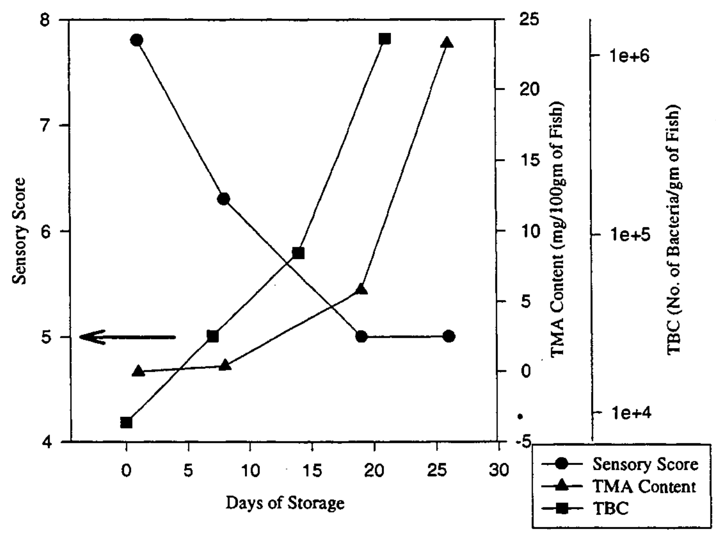

Figure 4. Sensory score, TMA Content and microbiological changes for Brown Spotted Grouper, *Epinephelus bleekeri*, stored at 0-4°C.
Arrow indicates the minimum acceptable score on a 1 to 9 scale.

From the graph of Brown Spotted Grouper, *Epinephelus bleekeri*, it maintained its good quality at first 5 days (scoring 9 to7) when TMA content was 0-1.0 mg/100 gm of fish and TBC was 9,000-20,000 per gram of fish. It deteriorated to fair condition between Day 18-19 which the sensory scores reached the limit of acceptability of 5, TMA content and TBC were 6-7 mg/100 gm of fish and 631,000 per gram of fish respectively.

Gold-line Seabream, *Rhabdosarga sarba*, kept its good condition from 0-2 days, which was the shortest time among six investigated seafood. TMA content was 0-1.0 mg/100 gm of fish while TBC was about 4,000 per gram of fish. It was rejected by the panel after only 8-day storage, when TMA content was 8.0 mg/100 gm of fish and TBC was only 50,000 to 60,000 per gram of fish. Special attention should be paid on the bacteria number. The starting bacterial count in Gold-lined Seabream , 4,000 per gram of fish was less than in Brown Spotted Grouper, 9,000 per gram of fish. However Gold-lined Seabream deteriorated much faster than Brown Spotted Grouper. The panel rejected Gold-line Seabream on Day 8 while Brown Spotted Grouper was rejected on Day 18-19. Gold-lined Seabream, in this way, could be commented as more vulnerable. However since the composition of microflora in two fishes might be different. The degradation activities of different bacteria might also be different too. Bacteria *Pseudomonas putrefaciens* was responsible for 80% TMA production (Laycock, 1971). Dominant with these kinds of bacteria might speed up the spoilage process. Further research are needed to be done for investigation on the composition of microflora.

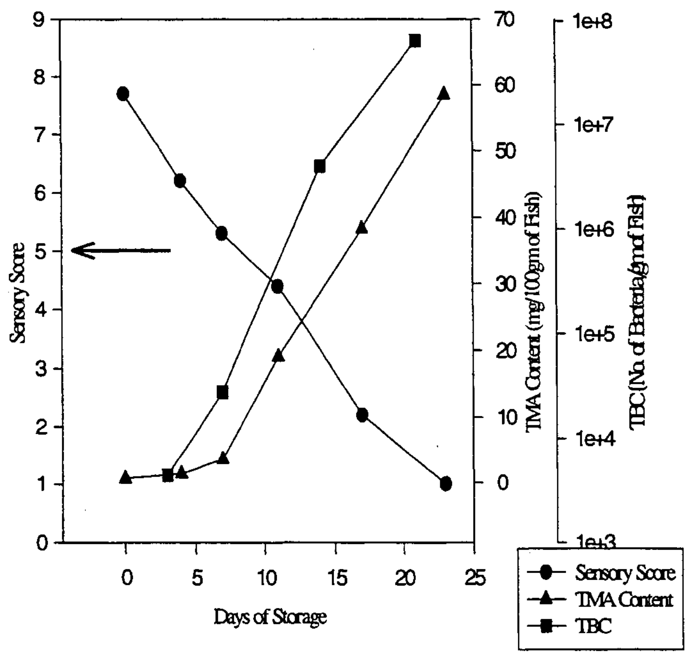

Figure 5. Gold-lined Seabream, *Rhabdosarga sarba*

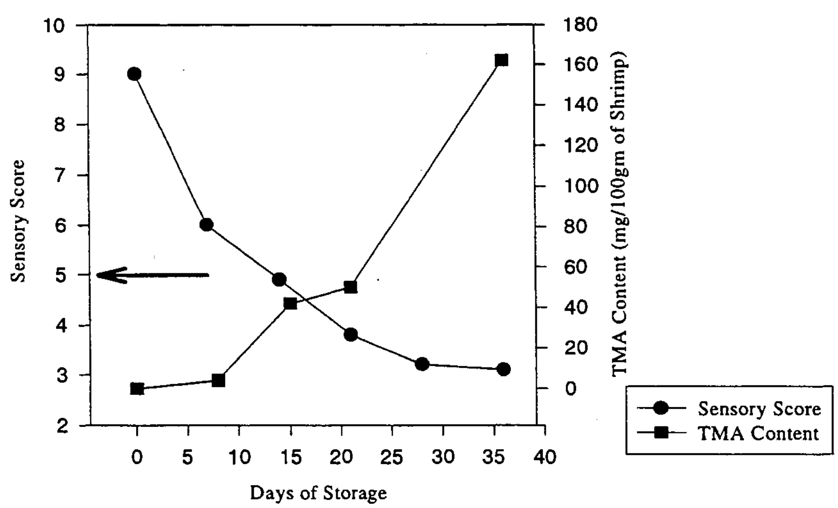

Figure 6. Relationship between Sensory Score and TMA Content of Gei Wai Shrimp, *Metapenaeus ensis*, stored at 0-4°C for 36 days

Gei Wai Shrimp, *Metapenaeus ensis*, was the only seafood other than marine fish chosen in the experiment. The classification, body structure, flesh texture and biochemical composition of shrimp were totally different from that of fish. The experiment was targeted to compare the TMA change between two kinds of seafood. The result showed Gei Wai Shrimp could also be kept in good condition on Day 0 to Day 5 when TMA was 0-1.0 mg/100 gm of shrimp. That was very similar to that of fish. Its upper limit of acceptability reached on Day 14 when TMA content was 10 mg/100 gm, which was still in the range of fish, that was 6 to 15 mg/100 gm of fish.

From the series of experiments, two categories of Seafood Freshness Index (SFI) could be achieved. One indicated SFI for fresh seafood with excellent quality and the other showed SFI of upper limit of acceptability, which indicated the threshold of unfresh substance, the consumers still accepted the quality marginally. The SFI findings of different seafood species were summarized in Table 1.

Table 1. Summary of Seafood Freshness Index (SFI) of fresh seafood and upper limit of acceptability

Fish Species	**SFI of fresh**	**SFI of upper limit of acceptability (threshold)**
Black Seabream (*Mylio macrocephalus*)	TMA 0-1 mg/100gm Hx 2.9 μM/gm	TMA 13-15 mg/100gm Hx 7.2-7.4 μM/gm
Russell's Snapper (*Lutjanus russelli*)	TMA 0-1 mg/100gm Hx 1.2 μM/gm	TMA 16-17 mg/100gm Hx 8.0-9.0 μM/gm
Head Grunt (*Pomadasys hasta*)	TMA 0-1 mg/100gm Hx 1-8 μM/gm	TMA 14.0-14.2mg/100gm Hx 13.0-14.0 μM/gm
Brown Spotted Grouper (*Epinephelus bleekeri*)	TMA 0-1 mg/100gm TBC 8,000-9,000/gm	TMA 6-7 mg/100gm TBC 600,000-650,000/gm
Gold-lined Seabream (*Rhabdosarga sarba*)	TMA 0-1.0 mg/100gm TBC 4,000/gm	TMA 8.0 mg/100gm TBC 50,000-60,000/gm
Gei Wai Shrimp (*Metapenaeus ensis*)	TMA 0-1.0 mg/100gm	TMA 10 mg/100gm

The experiments showed Sensory Evaluation, TMA test and Microbial numeration correlated well with each other. SFI of fresh seafood were similar in five investigated sea fishes and Gei Wai Shrimp. The threshold of TMA was the lowest in Brown Spotted Grouper while the highest in Russelli's Snapper

Different seafood, even the same genus of seafood but different in species, showed variation in SFI. For example, Brown Spotted Grouper, when TMA accumulated over 6-7 mg/100gm of fish, the quality of the fish would be rejected by panelists. However the same content of TMA in Russelli's Snapper, as judged by the same scoring sensory panel, would indicate the fish was still in a fairly good condition. Thus, different seafood species possesses different specific SFI.

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AN EFFICIENT AND LOW POLLUTION FEED FOR THE MARICULTURE INDUSTRY IN HONG KONG

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ABSTRACT

Marine fish culture in Hong Kong traditionally uses trash fish as feed but this practice has several disadvantages. Firstly, feed wastage and leaching of organic waste from trash fish contributes to pollution to fish culture zones. Secondly, fish fed with trash fish commonly suffers from malnutritional disease since trash fish may not satisfy the nutritional requirements of the cultured species. Thirdly, the supply and quantity of trash fish is unstable.

In 1994, the Agriculture and Fisheries Department started to promote an artificially formulated feed to marine fish farmers as an alternative to trash fish and this new feed is now generally accepted by the mariculture community. The artificial feed provides a more balanced diet to the cultured fish and hence achieves a higher feed conversion efficiency than trash fish. Consequently, the growth rate of fish fed on artificial feed is higher, and the growout period is shortened. The artificial feed also improves the fish health and hence reduces the chance of loss due to fish disease problem. Compared with trash fish, the artificial feed is more convenient to use. This helps lower the labour cost associated with feed preparation and feeding. Altogether, these advantages of the artificial feed enhance the production efficiency of marine fish culture in Hong Kong.

The artificial feed is superior to trash fish in terms of pollution impact. Because of its lower water content and higher conversion efficiency, the quantity of artificial feed needed to feed the same number of cultured fish is only one-third that of the trash fish. The amount of feed loss and leaching are therefore greatly decreased. Furthermore, with the presence of a suitable binder in artificial feed, the amount of feed loss as particulate and dissolved matters is again reduced. The adverse effects of feeding on the water quality and seabed community of fish culture area are therefore reduced with the adoption of the feed.

INTRODUCTION

Marine fish culture has developed in Hong Kong over the past twenty years and production has increased drastically from 565 tonnes in 1978 to 3860 tonnes in 1991.

In the late eighties, a number of serious fish kill occurred in the fish culture zones, mainly attributed to oxygen depletion or red tide. Mariculturists complained that the fast urban development in Hong Kong had led to deterioration of water quality, leading to frequent incidents of red tide and oxygen depletion. Since then marine fish culture production appeared to decrease and in 1996 the production was 3000 tonnes.

On the other hand, the mariculture industry of Hong Kong was criticised by the environmentalists for polluting the environment. In 1987 the government commissioned a study to assess the impact of the industry to the environment. The study found that the overall impact of mariculture on coastal waters was fairly localised and that using trash fish as feed was the major sources of pollution from the mariculture farms. The consultancy report recommended that improved feed with less polluting effects should be developed.

FEED DEVELOPMENT

In the late 70s and 80s, several feed companies had introduced various artificial feeds in the form of dry pellets to the fish farmers. However, none of them were successful and the fish farmers claimed that dry pellet were not easily accepted by the cultured fish and these feeds were more expensive than trash fish. In addition the growth of the fish fed on artificial feed was not as good as the fish fed on trash fish.

Chou and Wong(1985) showed that the growth rate and survival rate of fish fed on dry pellet made with 81.5% fishmeal are better than that of trash fish. Chen et. al(1978) indicated that artificial feed with a protein level of 45%(dry weight) could improved the growth of *Epinephelus salmonoides*. In Japan in the early 1980s moist pellet composed of minced raw fish formulated were developed to decrease the pollution of culture ground(Takeda 1985,Nagai1985).

In view of the above, efforts were made to develop a moist pellet using trash fish as a basic component with added components to improve nutritional value and reduce the polluting effect. After a desk top study, a moist pellet feed comprising of fish meal minced fish, vitamin mix and alpha starch was formulated. Detailed composition of the moist pellet was shown in Table 1.

The fish meal soaks up the fish juice in the minced trash fish, then mix with a binder and pelleted, thus leaching is greatly reduced. Nutritionally, with the incorporation of fish meal, protein level increases to double that of trash fish and the addition of vitamin mix makes up the loss of vitamin in trash fish.

Testing of palatability of moist pellet showed that the feed was accepted by groupers and seabream, common cultured species in Hong Kong. Culture trials were set out to assess the efficiency of the moist pellet and experiments were conducted to compare the leaching of nutrients of the moist pellet and trash fish. This paper reports the findings of the culture trials and the experiment on the leaching of the feed.

MATERIAL AND METHODS

Feed Efficiency

Culture trial of brown-spotted grouper(*Epinephelus aerolatus)*with moist pellet was conducted for a period of 6 months. The fry after acclimatization were randomly stocked in 4 netcages of 1.5mx1.5mx1.5m dimension at a stocking density of 300 per cage.

The composition of the moist pellet feed formulated according to Table 1 was analysed. The fish were fed to satiation. The amount of feed taken for each cage was recorded. Trash fish purchased from the Aberdeen Fish Market was used as a control diet.

Fish from each cage were sampled randomly and fish length and weight of 20 fish were recorded each month. The growth rates were compared. Any mortality of the fish during the period was recorded. The survival rate of fish in each cage was then calculated.

Leaching of Nutrients

An experiment was conducted to compare the leaching rate of nutrients from the following types of feed: moist pellet feed, chopped fish and minced fish.

A perspex tube with an outlet near the bottom was constructed. The tube was then filled with sea water up to the water mark(1m above the outlet). 50g of each type of feed being tested, the feed was allowed to travel from the surface to the bottom of the perpex tube. Water was drained off from the outlet of the tube 5 min afterwards and water samples were collected. The level of inorganic phosphate,nitrate,nitrite and ammonia were determined.

RESULTS

The proximate analysis of the moist pellet feed(wet weight) based on Table 1 indicated that moist pellet contains around 39% crude protein, 3.5% crude fat, 1.0%, crude fibre, 39.7% moisture content and 10% ash.

Results of the culture trial on feed efficiency was shown in table 2. Growth of fish fed with moist pellet was better than fish fed on trash fish.

Table 2 showed the feed conversion ratio and growth of the fish fed on moist pellet and trash fish. The feed conversion ratio was 2.34:1 and 2.56:1(replica) for fish fed on moist pellet. The feed conversation ratio was 10.13:1 and 5.38:1(replica) fish fed on trash fish on a wet weight basis.

The survival of the fish fed on pellet was better than fish fed on trash fish. The average survival rate for fish fed on trash fish was 59.17% and fish fed on pellet was 76.67%(Table3). Therefore the survival rate of fish fed on pellet was 17.5% better than fish fed on trash fish.

Leaching of phosphate nitrate and nitrite of moist pellet and chopped fish was similar, but minced fish showed the highest leaching rate for the above nutrients. The leaching of ammonia was highest in minced fish, followed by moist pellet and chopped fish.

DISCUSSION

The results shown that moist pellet is suitable for the common species cultured in Hong Kong and is more efficient than trash fish and achieving a faster growth and better survival.

It has been reported that the leaching of nutrients, about 38% could be reduced when moist pellet is used as daily ration(Wu and Lee,1989;OveAru and Partners,1991). It is due to the fact that during the growth cycle, minced fish was fed to the fish for a few months until the cultured fish reach to a certain size that the fish could feed on chopped fish. However, moist pellet could be pelleted to the size to suit the fish during the growth cycle. Furthermore, the moist pellet is uniform in shape and the size of pellet could be adjusted to suit different size of the fish and with good husbandry practice and careful feeding, feed wastage could be more or less eliminated. It is expected that the water quality in the fish culture zones will improve and the fish could grow faster and healthier and could withstand environmental stress such as cold spells.

The results showed that the fish can utilized and grow on the moist pellet. The use of moist pellet as the daily ration is labour saving as well as increasing the profits on mariculture operation. The price of the moist pellet is HK$6.50/kg while that of trash fish is about HK$2.00/kg. With a feed conversion ratio(FCR) of approximate 2.5:1 and 10:1 for moist pellet and trash fish respectively, the cost for production of 1 kg of fish using moist pellet is HK$16.25 and using trash fish is HK$20.00.Therefore it is obvious that it more economical to use moist pellet than trash fish.

Fish farmers who adopted moist pellet confirmed that seabream fed on moist pellet had a faster growth rate and could reach marketable size two months earlier than fish fed on trash fish. They also reported that the adverse effects of feeding on the water quality and the seabed had improved significantly after moist pellet was used at the site for a short period.

Table 1. Composition of the moist pellet

Composition of experimental diet	(%)
Fish meal, Peruvian	50.00
Trash fish	44.50
Vitamin mix	0.50
Alpha starch	5.00
Total	100.00

Table 2. The growth of brown-spotted grouper fed with moist pellet and trash fish and feed conversion ratio(FCR) of the two feeds.

Growth and feed efficiency	Moist pellet I	Moist pellet II	Trash fish I	Trash fish II
GROWTH				
Mean initial weight(g)	65.00	63.33	68.33	73.33
Mean initial length(cm)	15.18	15.00	15.67	15.92
Mean final weight(g)	231.25	175.00	135.71	200
Mean Final length(cm)	21.44	20.00	21.93	20.94
Mean weight gained(g)	166.25	111.67	67.38	126.67
Mean Weight gain/fish/day(g)	0.92	0.62	0.37	0.70
Feed Conversion(FCR)* FCR(as fed)	2.34:1	2.56:1	10.13:1	5.38:1
Mean FCR	Moist pellet		Trash fish	
	2.45:1		7.76:1	

*Feed conversation ratio(as fed)= Total feed intake/Total weight gained

Table 3. Table to show the survival rate of the fish.

Measurement	Moist pellet I	Moist pellet II	Trash fish I	Trash fish II
Nos of fish per cage(initially)	300	300	300	300
Nos of fish per cage(finally)	225	217	175	180
Survival rate (%)	75.00	72.33	58.33	60.00

Mean survival rate (%)	Moist pellet	Trash fish
	76.67	59.17

Table 4. The leaching rate of nutrients of different types of feed.

Parameter	Moist Pellet	Chopped Fish	Minced Fish	Sea water
Phosphate (ppm)	225.53	387.50	972.63	165.85
Nitrate (ppm)	38.53	37.67	54.48	34.27
Nitrite (ppm)	6.13	6.94	10.07	5.34
Ammonia (ppm)	138.00	84.50	251.000	38.0

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The Effects of Ultrasound in Killing Fish Bacterial Pathogens

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ABSTRACT

Ultrasound, as a kind of physical factors, can degrade organism, break cell into pieces and change structure and function of biomolecules such as DNA and protein. The pertinent intensity and frequency ultrasound can accelerate chemical reaction in solution, and can cooperatively accelerate enzymatic reaction because of its cavitation and mechanical oscillation.

In this paper, We studied the effects of the certain intensity and frequency ultrasound to several kinds of bacteria, which are separated from disease fishes . We also studied the cooperative bactericidal effects of ultrasound and drugs that can use to cure the fish disease. The results showed that ultrasound had obvious bactericidal effects. The ultrasound and drugs co-bactericidal ratio is higher than that by drugs and ultrasound , respectively.

After these bacteria were treated by ultrasound, we can see the transformation and fraction of cells, demolish of cell wall and ribosome, and the formation of cave in the bacteria cell with TEM. All of these can improve drug killing bacteria effectively.

The disease of fish and shrimp spread widely in resent years in our country, and have caught heavy losses. As a kind of physical factor, ultrasound can increase the effects of drugs efficiently. It will offer a new way to prevent and cure the diseases of fish and shrimp.

INTRODUCTION

As a physical factor, ultrasound is used widely in bio-medcine field. All these applications are related with the cavitation of ultrasound .Cavitation in fluids has been studied extensively and reviewed in many articles(e.g., Apdel 1981 a; Flynn 1964, Neppiras 1980). It is known that, as an ultrasound beam passes through a liquid, it can cause microbubbles to grow and oscillate within the varying pressure field. When these gas bubbles pulsate in response to the ultrasound they act on the surrounding media by unique forms of radiation pressure, forces and torque, causing shearing stresses, vibration of the cell boundaries and aggregation of particles. the collapse of a bubble can generate high local pressure and temperatures(Flynn, 1982).

At present, there are very few report(e.g.; Wu Miqun 1996; Han ling 1993) about the experiment of the ultrasound and drug co-bactericide. So this paper studied it.

MATERIALS

Ultrasound irradiation

The ultrasound irradiation was performed in an ultrasonic bath with a ultrasound at a frequency of 30KHz and a spatial average intensity of $2W/CM^2$.

Ultrasound system

Colorless small plastic cups, which bottom thickness is 0.4mm, were sterilized by alcohol and ultraviolet light. And 1cm bacterial suspension was injected into the cups, then covered a germfree culture dish.

Bacteria

1. *Vibrio vulnificus*
2. *Pseudomonas flurorescens*

Drug

1. Furozolidone
2. Methylene Blue
3. Oxytetracyclin
4. Copper (II) Sulfate
5. Potassium Permanganate
6. Terramycin

METHODS

1. Ultrasound cooperate with several drugs to kill the bacteria

Experiment is designed four groups: (The bacteria concentration is same in the every group)

0 group :Control group. The bacterial suspension isn t effected by ultrasound and drugs. then inpore 1ml suspension to alive-germ culture.

1 group : ultrasound group. The bacteria suspension is effected by only ultrasound. It is treated in different time by ultrasound, one is 5 minutes(1A), another is 10 minutes(1B).

2 group : drug group. The bacteria suspension is effected by only drug. It is treated in different time by drug, one is 5 minutes(2A), another is 10 minutes(2B).

3 group : ultrasound and drug group. The bacteria suspension is effected by ultrasound and drug together. It is treated in different time , one is 5 minutes(3A), another is 10 minutes(3B).

2. Treated bacteria is observed with TEM

The bacteria suspension is treated by 30khz ultrasound in 10 minutes, the depth is 1cm. The treated bacteria and control group both are observed with TEM.

Results

1.Ultrasound can cooperate with several drugs, which were used alone to cure fish diseases to kill the bacteria

The experiment results showed that the bactericidal ratio obtainable from the combination of ultrasound and drugs is higher than that by ultrasound or drugs alone. The ratio of killing *Vibrio vulnificus* is 100 percent under the 5 minutes radiation of ultrasound with 30khz frequency and 0.5ppm oxytetracycline, the ratio is 42.8 percent by using ultrasound independently, the ratio is 45.7 percent under 0.5ppm oxytetracycline only.

Table 1: Ultrasound with 30KHz and 0.5ppm Furozolidone effect on *vibrio vulnificus* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	680	0%
1	1A	only ultrasound 5mins	389	42.8%
	1B	only ultrasound 10mins	220	67.6%
2	2A	only drug 5mins	514	24.4%
	2B	only drug 10mins	387	43%
3	3A	ultrasound and drug together 5mins	315	53.6%
	3B	ultrasound and drug together 10mins	0	100%

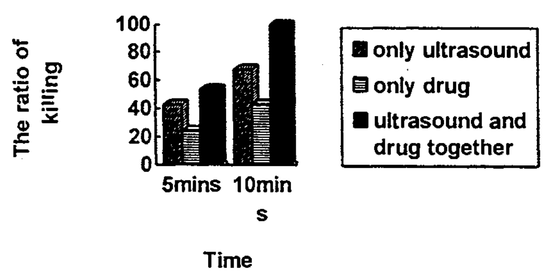

Figure 1: Ultrasound with 30KHz and 0.5ppm Furozolidone effect on *vibrio vulnificus* together

Table 2: Ultrasound with 30KHz and 1.5ppm Methylene Blue effect on *vibrio vulnificus* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	680	0%
1	1A	only ultrasound 5mins	389	42.8%
	1B	only ultrasound 10mins	220	67.6%
2	2A	only drug 5mins	331	52.7%
	2B	only drug 10mins	287	57.8%
3	3A	ultrasound and drug together 5mins	0	100%
	3B	ultrasound and drug together10mins	0	100%

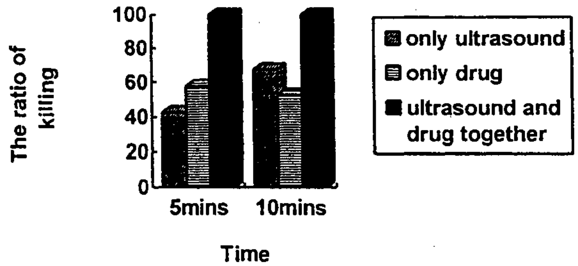

Figure 2. Ultrasound with 30KHz and 1.5ppm Methylene Blue effect on *vibrio vulnificus* together

Table 3: Ultrasound with 30KHz and 0.5ppm Oxytetracycline effect on *vibrio vulnificus* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	680	0%
1	1A	only ultrasound 5mins	389	42.8%
	1B	only ultrasound 10mins	220	67.6%
2	2A	only drug 5mins	369	45.7%
	2B	only drug 10mins	322	47.2%
3	3A	ultrasound and drug together 5mins	0	100%
	3B	ultrasound and drug together 10mins	0	100%

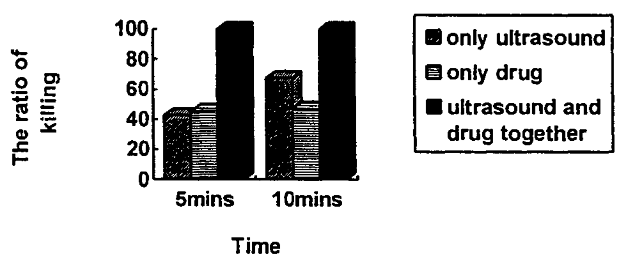

Figure 3: Ultrasound with 30KHz and 0.5ppm Oxytetracycline effect on *vibrio vulnificus* together

Table 4: Ultrasound with 30KHz and 0.5ppm Copper(II)Sulfate effect on *vibrio vulnificus* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	680	0%
1	1A	only ultrasound 5mins	389	42.8%
	1B	only ultrasound 10mins	220	67.6%
2	2A	only drug 5mins	398	41.5%
	2B	only drug 10mins	310	54.4%
3	3A	ultrasound and drug together 5mins	5	99.3%
	3B	ultrasound and drug together 10mins	0	100%

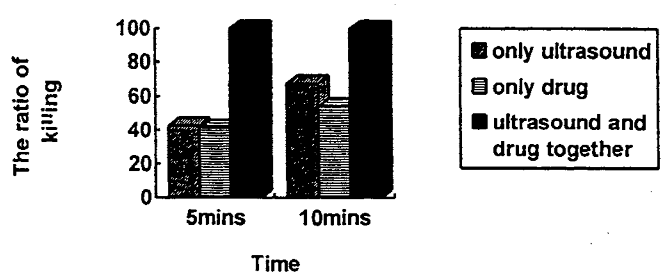

Figure 4: Ultrasound with 30KHz and 0.5ppm Copper(II)Sulfate effect on *vibrio vulnificus* together

Table 5: Ultrasound with 30KHz and 0.5ppm Potassium permanganate effect on *vibrio vulnificus* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	680	0%
1	1A	only ultrasound 5mins	389	42.8%
	1B	only ultrasound 10mins	220	67.6%
2	2A	only drug 5mins	417	38.7%
	2B	only drug 10mins	266	60.9%
3	3A	ultrasound and drug together 5mins	0	100%
	3B	ultrasound and drug together 10mins	0	100%

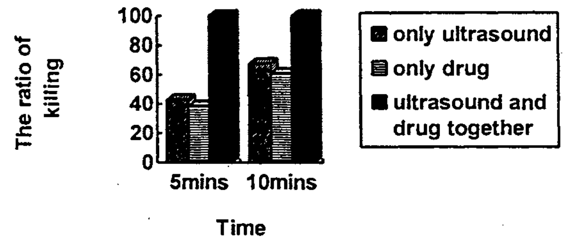

Figure 5: Ultrasound with 30KHz and 0.5ppm Potassium permanganate effect on *vibrio vulnificus* together

Table 6: Ultrasound with 30KHz and 1ppm Furozolidone effect on *Pseudomonas flurorescens* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	189	0%
1	1A	only ultrasound 5mins	112	40.7%
	1B	only ultrasound 10mins	30	84%
2	2A	only drug 5mins	157	17%
	2B	only drug 10mins	151	20%
3	3A	ultrasound and drug together 5mins	29	84.7%
	3B	ultrasound and drug together 10mins	0	100%

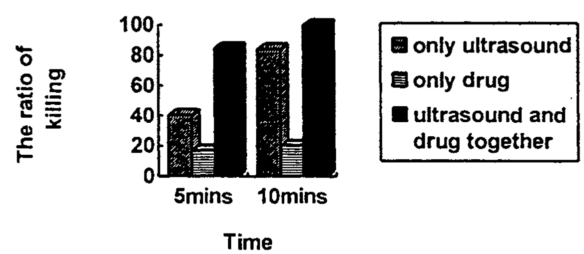

Figure 6: Ultrasound with 30KHz and 1ppm Furozolidone effect on *Pseudomonas flurorescens* together

Table 7: Ultrasound with 30KHz and 1ppm Mathyalend effect on *Pseudomonas flurorescens* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	189	0%
1	1A	only ultrasound 5mins	112	40.7%
	1B	only ultrasound 10mins	30	84%
2	2A	only drug 5mins	111	41%
	2B	only drug 10mins	96	51%
3	3A	ultrasound and drug together 5mins	0	100%
	3B	ultrasound and drug together 10mins	0	100%

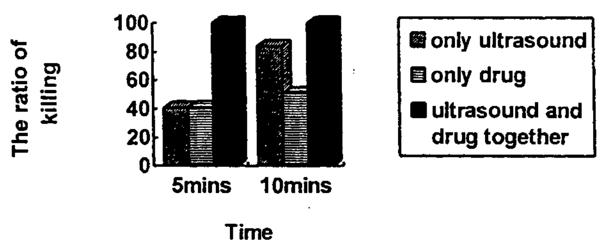

Figure 7: Ultrasound with 30KHz and 1ppm Mathyalene effect on *Pseudomonas flurorescens* together

Table 8: Ultrasound with 30KHz and 1ppm Terramycin effect on *Pseudomonas flurorescens* together

Date		content	alive bacteria (/ml)	the ratio of killing
0		no ultrasound and no drug	189	0%
1	1A	only ultrasound 5mins	112	40.7%
	1B	only ultrasound 10mins	30	84%
2	2A	only drug 5mins	150	21%
	2B	only drug 10mins	146	23%
3	3A	ultrasound and drug together 5mins	0	100%
	3B	ultrasound and drug together 10mins	0	100%

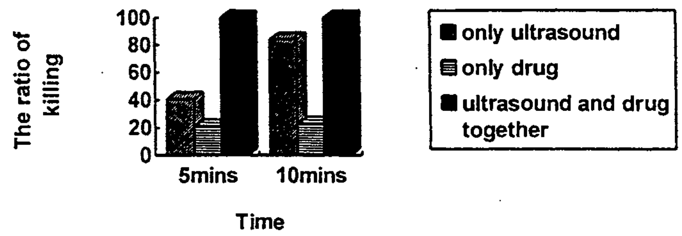

Figure 8: Ultrasound with 30KHz and 1ppm Terramycin effect on *Pseudomonas flurorescens* together

2. Treated bacteria is observed with TEM.

From the *Escherichia coli* s photo, we can find that , in the control bacterial(Fig. 9), plasma is homogeneous, and there are some ribosome in the cell, but in the treated bacterial cell(Fig. 10), plasma is not homogeneous, there are some air chamber in the plasma.

From *Pseudomonas flurorescens* , we can find that, in the control bacterial(Fig. 11), plasma is homogeneous, and some ribosome can be found, but in the treated bacterial cell(Fig. 12), the cell shape irregularity, plasma is not homogeneous, there are few ribosome and some air chamber.

DISCUSSION

Ultrasound bio-effect Ultrasound is a mechanical wave, which can spread in the organism by the form of energy wave, and interact with the tissue, then induce the changes of the structure and function of the organism system. These changes are the ultrasound bio-effect.

Ultrasound is a physical process, so it is very reasonable to expose and discuss the mechanism of the interaction between the ultrasound and the medium (bio-systerm) with the physical view .

Ultrasound energy causes several effects, such as cavitation, microstreaming, acoustic pressure, mechanical stresses and thermal effects(Bamber 1986)

Mechanical stresses When surface of medium is exposed to the ultrasound, there are the variations of sound stress along the spread direction. Now there is the force pressed on the surface. This is the mechanical stresses(Wan Minxi 1992). Thus pressure can accelerate the penetration rate of the cell membrane. So ultrasound can increase the drug concentration of the cell, and improve the bactericide rate. This is coincide with our experiment results.

Cavitation Cavitation has long been recognized as an important mechanism of ultrasound action. Cavitation involves the generation and oscillation of gas bubbles in a medium, and may be induced by the exposure to ultrasound . When gas bubbles pulsate in response to the ultrasound, they act on the surrounding media by unique forms of radiation pressure,, causing shearing stresses, vibration of the cell boundaries and aggregation of particles. The collapse of a bubble can generate high local pressure up to several MPa and temperatures up to several thousand degrees(Apfel 1981; Crum 1982; Mason and lorimer 1988; Neppiras 1980).

The bacterial cell wall can be damaged by the transient high local temperature and pressure generated from the collapse of the bubble in the cavitation process. The germ body can be made fragile by ultrasound cavitation. The cell membrane can be disformated by the cavitation , and cave into the cell to form the bubbles. So the more drugs can go into the bacteria body, and the effect of bactericide improved.

We think that the major co-action of germicide of the ultrasound and drugs is induced by the cavitation.Certainly, the bio-effect of the ultrasound is very complicated. The mechanism of the ultrasound is not clear, which needs the more deeply research.

From this study, we can get the conclusion that ultrasound can be used as a supplementary way to prevent and cure the fish disease.

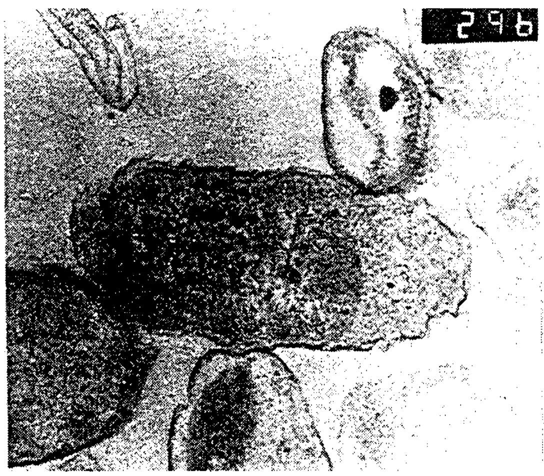

Fig. 9 The control *Escherichia coli*' s photo

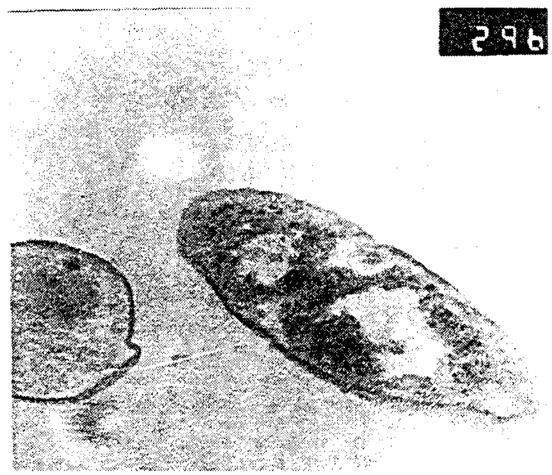

Fig.10 The treated *Escherichia coli*' s photo (it is treated by 30KHz ultrasound in 10 minutes, and depth of the bacteria suspension is)

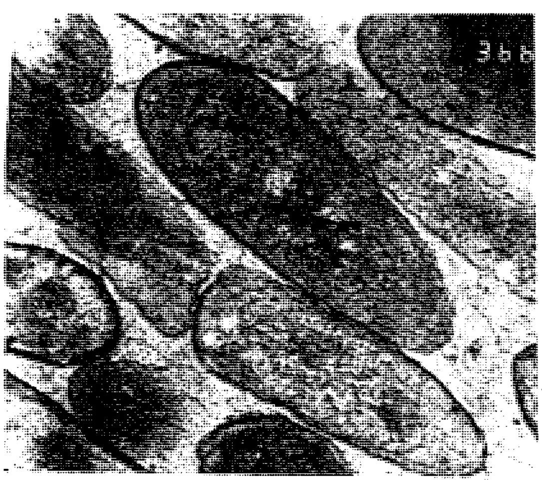

Fig.11 The control *Pseudomonas flurorescens* photo

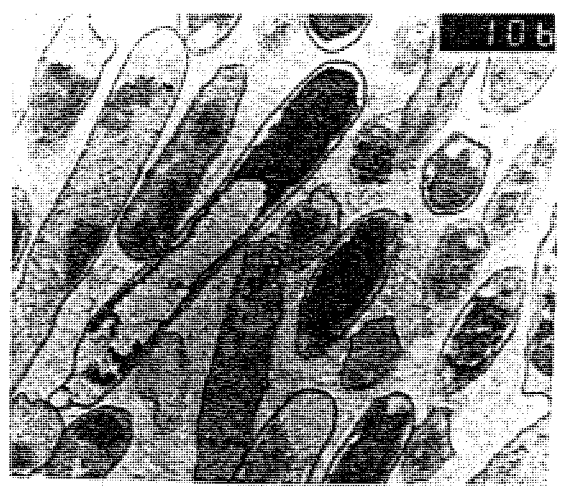

Fig.12 The treated *Pseudomonas flurorescens* photo (it is treated by 30KHz ultrasound in 10 minutes, and depth of the bacteria suspension is 1cm)

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EFFECTS OF EYESTALK ABLATION AND PROGESTERONE ON OVARIAN DEVELOPMENT OF PRAWN, *MACROBRACHIUM NIPPONENSE*

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ABSTRACT

The effects of eyestalk ablation and progesterone on the ovarian developments of the prawn, *Macrobrachium nipponense,* were investigated during the resting stage of the ovary development. On day 18 ablated female exhibited more advanced ovary developments than the unablated one did, and prawn treated with both ablation and dropping of the progesterone (0.8μg/g body weight) on the body surface under posterior carapace displayed the most advanced ovary stages of development. On day 25 the ovaries of 35.7% of the ablated prawn injected with progesterone (0.4μg/g body weight) and that of 30.7% of the destalked female dropped with progesterone (8μg/g body weight) became matured. However, only 20% of the animal destalked alone had mature ovary. The treatment of progesterone without ablation had no effects. The results indicate that eyestalk factor can regulate the effects of progesterone on the ovary development during the resting stage of the development.

INTRODUCTION

Estrogenic hormone was first reported by Donahue (1948) in a lobster eggs. Then, estrone and estradiol-17β were identified in the ovary of the shrimp, *Parapenacus fissurus* (Jeng *et al.* 1978),the changes in estradiol and progesterone concentration were investigated in tissues of the lobster, *Homarus americans* and it was found these changes to be in relation to the condition of ovarian development (Couch *et al.* 1987).

Experiments was conducted to research that if progesterone can stimulate shrimp ovary development. Kulkarni *et al.*(1979) was able to induce oogenesis in the prawn, *Parapenaeopsis hardwi* by injection of progesterone. Yano (1985) demonstrated that progesterone stimulated ovarian maturation and spawning in *Metapenaeus ensis.* Yu *et al* (1990) enhanced spawning rate of the prawn,*Macrobruchium nipponense* by injecting progesterone. *In vitro*, 17α-hydroxy-progesterone was found to stimulate Vg secretion (Yano,1987),and progesterone and estradiol were demostrated to be able to stimulate yolk synthesis in the shrimp,*Penasus vannamei* (Quckenbush,1992).

But until now,there is no any investigation that involves in studying that if progesterone effects are regulated by any other factor or hormone.The present study was undertaken to investigate the effects of progesterone on the ovary development of the prawn, *M.nipponense* the ovary of which was in the resting stage of development and the effects of eyestalk ablation on the effects of progesterone.

MATERIALS AND METHODS

Animals

Adult females *M.nipponense* were obtained from rural areas of Guangzhou City in November and December. Most of them were with stage I ovary. Females with body weight of 0.9—1.2g and stage I ovary were selected and divided into groups. Each group was raised in a 25 L aquarium. The water was aired and its temperature was 27±1℃. The photoperiod was natural. Animals were fed pelleted diets.

Progesterone

Prepared in pure ethanol as Yano (1985) and diluted in 0.7% Nacl solution (0.1μg/μl, 0.2μg /μl). Progesterone was injected once into the prawn as Yano(1985) or dropped once on body surface under posterior carapace.

Eyestalk ablation

Operated as Knowlton(1994).

Dividing of ovary development.

Divided as Damrongphol(1991) .

RESULTS AND DISCUSSION

Until day 29 none of the prawn treated with and without (Control group) progesterone spawned (Table 1) . The rate of ovary maturation (Stage III) in the group of the prawn injected with progesterone was equal to that of the control group. The average rate (12.9%)

Table 1 Effects of progesterone on ovray development of *M. nipponense* on day 29

Treatment	No. of prawn	No. of female in various stages of ovary development I	II	III	IV(Spawned)
Injected 0.1μg/g B.W.*	24	12 (75.1♦)	3 (18.7)	1 (6.2)	0
Injected 0.4μg/g B.W.	24	11 (78.0)	1 (7.1)	1 (7.1)	0
Dropped 0.16μg/g B.W.	24	7 (63.7)	4 (36.3)	0	0
Dropped 8μg/g B.W.	24	7 (66.7)	4 (33.3)	0	0
Control	24	13 (76.5)	3 (17.6)	1 (5.9)	0

* B.W. = Body Weight

♦ represents percent

Table 2 Effects of eyestalk ablation and ablation combined with progesterone on ovary development of *M. nipponense*

Treatment	No of prawn	No. of females in various stages of ovary development: On day 18: I	II	III	IV(Spawned)	On day 25: I and II	III	IV(Spawned)
Eyestalk ablation	23	2 (20♦)	8 (80)	0	0	8 (80)	1 (10)	1 (10)
Ablation +Injected 0.4 μg/g B.W.*	23	5 (29.4)	11 (64.7)	1 (2.9)	0	11 (64.8)	5 (29.9)	1 (5.8)
Ablation + Dropped 8 μg/g B.W.	23	0	12 (92.3)	1 (7.6)	0	9 (69.2)	3 (23.1)	1 (7.6)
Control	23	12 (70.6)	5 (29.4)	0	0	16 (94.2)	1 (5.8)	0

* ♦ means the same as in table 1.

of stageII ovary of the groups injected with progesterone was even less than that of the control one.In groups dropped wih progesterone,more prawns displayed stage II ovary,but there was no any prawn the ovaries of which were matured. The results showed that during the rest stage of ovary development progesterone was unable to induce ovary maturation. In the experiment (Yu ,*et al.* 1990) where the prawns used were in the developing stage of ovary, 52.9% of the prawn injected with the progesterone spawned, but only 16.7% of the control prawn did. The species of prawn and the progesterone dose used in his experiment were the same as we used.The injecting of progesterone induced ovary maturation of *M. ensis* in August(Yano,1985). The different effects of the progesterone should result from that our prawns had entered the rest stage of ovary development, the secretion of gonad-inhibiting hormone(GIH) from X-organ sinus gland complex is active, the hormone blocks the effects of progesterone on ovary development.

In the experiment of eyestalk ablation (Table 2) , all groups of the destalked prawns exhibited more advanced stages of ovarian development than the intact one on day 18 and day 25. This agrees with the point of view that eyestalk factor inhibits prawn ovary development.

Although there was one female spawned in each group that was eyestalk ablated , the destalked prawns that was also injected or dropped with progesterone spawned on day 19 and day 20 respectively, the female that was eyestalk extirpated alone did on day 25(Table 2). The rate of prawn that displayed stage III of ovary was higher in the groups that received progesterone than that of the group which did not received.These results seems show that the progesterone has better effects after eyestalk ablation, and this also supports the preceding dedution that eyestalk factor can regulate the effects of the progesterone on the ovary development. Further experiment is needed because the mortality of the destalked prawns was relatively high.

ACKNOWLEDGE

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Pathogenicity and characteristics of a *Vibrio harveyi*-like bacterium affecting hatchery-reared *Penaeus chinensis* Larvae

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ABSTRACT

From April to May in 1996, an epizootic occurred among *Penaeus chinensis* larvae, especially at the stage of zoeae, in some hatcheries located at Fengcheng, near Qingdao, Shandong Province, P. R. China. The typical clinical symptoms of the diseased larvae were poor swimming activity, anorexia and opacity of the head, followed by all the body becoming opaque white, twisting and settling to the bottom of the tank and then died. The mortalities were up to 80%.

A total of 38 strains of bacteria, which has been isolated or re-isolated from infected moribund larvae of *Penaeus chinensis*, had morphological, physiological and biochemical characteristics of the genus *Vibrio*. Among them, 26 strains seemingly belong to the same species, which were most related to *Vibrio harveyi* by comparison with the data of Bergey's Manual of Determinative Bacteriology (9th edition).

The present *Vibrio* isolates were proved to be pathogenic to larvae of *Penaeus chinensis* and were the causative agents for epizootic disease in larvae shrimp. Shrimp larvae challenged by immersion method showed significant mortalities in the nauplii, zoeae and early stages of mysis larvae, but not in the postlarvae. In the zoeal stages, the isolates caused severe infection with up to 10^3 cfu/ml of bacteria in the rearing seawater, which indicated that the causative agents were more virulent to zoeal larvae of *Penaeus chinensis* than other stages. This study is the first report of the pathogenicity of *Vibrio harveyi-like* bacterium in the larvae of *Penaeus chinensis*.

Keywords: *Penaeus chinensis*, larvae, vibriosis, *Vibrio*, *Vibrio harveyi- like* bacterium

INTRODUCTION

Vibriosis caused by *Vibrio spp*., has become the economically most important disease in wild and cultured finfish and shellfish, affecting a large number of species. *Vibrio* infection has often been reported to occur in penaeid shrimp (Lightner, 1983, 1988; Takahashi, et al., 1984, 1985; de la Peña et al., 1993; Mohney, et al., 1994; Sachul, 1994a). Several species of *Vibrio*, such as *V. alginolyticus*, *V. anguillarum* and *V. parahaemolyticus* (Lightner, 1983) , *V. fisheri* and *V. fluvialis* (Sakata & Tarune, 1987), *V. vulnificus* and *V. damsela* (Song, et al., 1990, 1993) and *V. harveyi* (Karunasagar, et al., 1994; Lavilla-Pitogo, et al., 1990) have been described as pathogens for cultured penaeid shrimp. Vibriosis is responsible for heavy losses in production of penaeid shrimp in mariculture.

Seed production has gained increasing importance for developing the shrimp culture industry worldwide and particularly in developing countries. Recently, serious infection of *Vibrio spp.* in larvae and postlarvae stages of penaeid shrimp have been reported in some countries in the Indo-Pacific (Sae-oui, et al, 1987; Sunaryanto & Mariam, 1986; Tansutapanit & Ruangpan, 1987; Lavilla-Pitogo, et al., 1990; Baticados, et al., 1991; Karunasagar, et al., 1994 and Sahul, et al., 1996). Most of these *Vibrio* species are part of the autochthonous flora of marine waters and therefore, the source of infection is suspected to be near-shore seawater (Lightner, et al. 1992).

Outbreaks of vibriosis have also been reported in cultured *Penaeus chinensis* in China (Meng & Yu 1982; Ye, et al., 1986), and the causative agents described as *V. cholerae* (non-o1) and *V. anguillarum* (Zheng, 1986a, 1986b, 1990), *V. alginolyticus* , *V. parahaemolyticus* and *V. campbellii* (Xu, et al., 1993) and *V. splendidus* (Cheng, et al., 1995). Most of these studies were focused on the grow-out penaeid shrimp and few on the larval shrimp. Recently, serious diseases mostly caused by *Vibrio sp.* often occurred in most hatcheries in North China, and has become the severe barrier to prevent the development of the shrimp aquaculture. In this study, we investigated the pathogenicity and characteristics of the causative agents and some relative factors associated with the health of hatchery-reared larval shrimp of *Penaeus chinensis*.

MATERIALS AND METHODS

Collection of samples

Samples of water and infected larvae of *Penaeus chinensis* were collected from various tanks during April and May in 1996, irregularly. The collected larvae were washed gently in sterile seawater for 3 times and transferred to a sterile screw-capped bottle containing sterile seawater. Water samples were collected by using sterile bottles (250 ml). All the samples were transferred to the laboratory and processed within 2 hours after collection.

Bacteriological analysis

About 50 infected larvae were randomly selected and placed in a sterile homogenizer with 1 ml of sterile 0.85% saline solution and homogenized. Then, 10-fold serial dilutions were made with 0.85% saline solution and 0.1 ml of diluted samples were inoculated onto TCBS plates by the spread plate technique. Water samples were added 5 μg/ml Tween-80 with violently shaking for 20 min. and then similarly diluted and inoculated onto 2216E plates.

After inoculation, plates were incubated at 28 °C for 2 - 4 days. Bacterial colonies were examined carefully and counted. Morphologically similar and dominant bacterial colonies were selected and streaked onto 2216 E plates for several times in order to obtain pure cultures. Purified cultures were maintained on 2216 E agar slants for further study. On the other hand, the bacterial number of the water samples were also investigated by the AODC method described previously (Xu, et al. 1993).

Bacterial isolates were characterized by various morphological, physiological and biochemical tests according the methods previously described (McFaddin, 1980 ; West & Colwell , 1984).

Experimental pathogenicity

Experimental infection of shrimp larvae to confirm the pathogenicity of the isolates were performed in another hatchery located at Tushan Town, Laizhou City, where no diseases occurred during the whole seed production season. Pathogenicity of one typical dominant isolate Z_3G_2 was studied for healthy nauplii, zoeae, mysis and postlarvae of *Penaeus chinensis* by immersion method. All the experiments were carried out in white plastic containers (11-liter) with aeration, and all the temperature of containers were maintained constant by placing them in water baths. Around 500-1,000 larvae were reared in each container and fed a progression of *Nannochlorpsis sp.*, *Rotifers*, *Artemia* larvae and egg yolk according to the different larval stages.

For the experimentally induced infection, the larvae and postlarvae were exposed to different concentrations of bacterial cells (2.5×10^3, 2.5×10^4, 2.5×10^5, 2.5×10^6 and 2.5×10^7 cfu/ml) in duplicate. The control consisted of larvae exposed to sea water only. In all the experiments, larvae were examined carefully for diseaes symptoms and the number of survivors in each container were counted to estimate the survival rate.

Confirmation of pathogenicity

The specific action of the representative bacterium of Z_3G_2 as a pathogen of *Penaeus chinensis* larvae was confirmed by re-isolating the bacterium from moribund larvae and re-infecting the healthy larvae to satisfy Koch's postulates. The re-isolated bacteria were identified according to the methods mentioned above.

RESULTS

Total bacteria number in the tank water and in the body of different larval stages were counted by the methods of AODC and plate counts. The results were shown in Table 1. During the natural epizootics, the viable bacterial counts in the rearing tank water ranged from 7.0×10^3 to 3.45×10^5 cfu/ml on ZoBell's 2216 E agar, and 6.94×10^6 to 6.865×10^7 counted by AODC. Correspondingly, the viable *Vibrio sp.* in larval body of different stages ranged from 6.0×10^3 to 4.7×10^6 cfu/ml on TCBS agar. The highest bacterial counts appeared in zoeal stages not only in the rearing tank water but also in the larvae bodies. Moreover, light microscopy also revealed densely packed short rod bacteria in the smear of homogenized suspension of infected moribund zoeal larvae. Primary isolation revealed that up to 95% of the colonies were dark-green and uniform in morphology on TCBS agar. On ZoBell's 2216 E agar, the isolates formed medium-sized (2-3 mm in diameter after 48 h at 28°C), low convex, smooth, entire, circular, cream-colored and semi-transparent colonies.

In total, 36 representative bacterial isolates were obtained from the natural infected nauplii, protozoea, mysis and postlarvae and 2 from experimental infected larvae. All of them were Gram-negative, short rods and motile by means of a single polar flagellum. Oxidase reaction , fermentation of glucose and sensitivity to the vibriostatic agent o/129 were positive. The bacteria produced acid without gas from glucose. These selected features placed the organisms in the genus of *Vibrio* according to West & Colwell (1984). Subsequently, characterization was concentrated on the 26 dominant isolates. All of the 26 isolates showed almost the same characteristics except for reaction in citrate and a few carbohydrates utilization tests, ONPG and sensitivity to o/129 (10 μg) (Table 2). All the results revealed that the present isolates exhibited most relatedness to *Vibrio harveyi* by comparison with the data of Bergey's Manual of Determinative Bacteriology (9th edition) (Table 2).

The pathogenicity tests were conducted by using a representative strain of Z_3G_2 at the concentration of 2.5×10^6 cfu/ml by immersion method. The total percentages of survival rates of nauplii, protozoea, mysis and postlarvae of *Penaeus chinensis* was shown in Table 3. The bacteria isolate caused significant mortality in nauplii, protozoea and early mysis larvae within 24 h. Our isolate caused 100% mortality in the zoeae-1 stage after 12 h exposure. In contrast, the isolate caused lower mortality in postlarvae at the same bacterial concentration by immersion.

Table 1 Bacterial counts in various samples

Samples	Water		Larvae
Bacterial No. / Stages	2216 E (cfu/ml)	AODC (cells/ml)	TCBS (cfu/ml)
Filter water	< 10	ND	ND
Egg	ND	6.94×10^6	ND
Nauplii	7.0×10^3	1.36×10^7	6.0×10^3
Zoea 1	1.51×10^5	4.225×10^7	3.4×10^5
Zoea 2	3.45×10^5	6.865×10^7	4.7×10^6
Zoea 3	1.07×10^5	6.12×10^7	2.1×10^6
Mysis 2-3	5.5×10^4	1.52×10^7	4.15×10^5
Postlarvae 5-6	1.84×10^4	4.53×10^7	2.26×10^5

Note: ND = no date

Table 3 Survival rate of larvae and postlarvae *Penaeus chinesis* exposure to *Vibrio harveyi*-like bacterium (%)

Dose (CFU/ml)	Nauplius	Zoea $_1$	Zoea $_2$	Zoea $_3$	Mysis $_{1-2}$	Mysis $_3$	Postlarvae $_{5-6}$
Control	57.03	54.70	47.08	52.08	59.03	60.20	73.4
2.5×10^6	10.41	0	3.33	3.88	16.77	44.80	61.50

Meanwhile, another challenge test was done by using the same isolate in $zoeae_2$ larvae with different bacterial concentration and the larval survival rates were determined at different times. As shown in Table 4, at a concentration of over 2.5×10^4 cfu/ml, the present isolate induced significant mortalities (> 80%) after 24 h exposure by immersion. An increase in inoculum of the bacteria will lead to more rapid development of disease.

Table 2 Characteristics of the bacterial isolates from infected larvae of *Penaeus chinensis* compared with reference strains

Properties	Isolates (n = 24)	Re-isolates (n = 2)	*Vibrio harveyi**
Gram stain	G^-	G^-	G^-
Bacterial shape	SR[a]	SR	SR
Colony color on TCBS	green	green	green/yellow
Motility	+	+	+
Swimming	-	-	-
Flagella	SP[b]	SP	SP
Luminescence	-	-	-
Growth at(°C): 4	-	-	-
10	d	d	ND
37	+	+	+
42	-	-	d
Growth in (% NaCl) 0	-	-	-
6	+	+	+
8	+	+	-
10	-	-	-
o/129 sensitivity 150 ug	+	+	+
10 ug	d	d	+
Catalase	+	+	+
Oxidase	+	+	+
O/F test	F	F	F
Citrate utilization	+	+	-
Nitration reduction	+	+	+
V-P reaction	-	-	-
MR reaction	+	+	+
Indole production	+	+	+
H_2S production	-	-	-
Thornley's arginine dihydrolase	-	-	-
Arginine decarboxylase	-	-	-
Lysine decarboxylase	+	+	+
Ornithine decarboxylase	+	+	+
Phenylalaninase	+	+	d
TDA	-	-	-
Gas from glucose	-	-	-
Acid from: Arabinose	-	-	-
Inositol	-	-	-
D-Mannose	+	+	+
D-Raffinose	-	-	-
Rhamnose	-	-	-

Sucrose	-	-	d
Mannitol	+	+	+
Lactose	+	+	-
Saincin	+	+	+
Sobitol	-	-	-
α- Glucosamine	+	+	ND
Amygdalin	+	+	ND
Melibiose	-	-	-
Propanol $_{cs}$	-	-	d
Cellobiose $_{cs}$	d	+	+
α- Citrulline $_{cs}$	+	+	d
Ethanol $_{cs}$	-	-	-
D- Gluconate $_{cs}$	+	+	+
L-Arabinose $_{cs}$	-	-	d
L- Glutamate $_{cs}$	+	+	+
L- Leucine $_{cs}$	-	-	-
Inositol $_{cs}$	-	-	ND
Sucrose $_{cs}$	-	-	d
Xylose $_{cs}$	-	-	-
α- Ketoglutarate $_{cs}$	d	+	+
Alginase	-	-	d
Amylase	+	+	+
Chitinase	+	+	+
Lipase	+	+	+
Gelatinase	+	+	+
Lecithnase	+	+	+
Caseinase	+	+	+
Urease	+	+	+
ONPG	d	+	-

Note : a: CR= curved rod ; b: SP = single polar ; c: ND = no data ; cs: carbon source
"+" = over 90% positive ; " - " = over 90% are negetive ; d = 11 -89 % positive
*Data from Beryer's Manual of Determanative Bacteriology (9th ed.) 1994

Table 4 Survival rate of larvae (Zoea $_2$) *Penaeus chinesis* at different times after exposure to different doses of a *Vibrio harveyi*-like bacterium (%)

Dose (CFU/ml) Time (h)	Control	2.5×10^3	2.5×10^4	2.5×10^5	2.5×10^6	2.5×10^7
0	100.00	100.00	100.00	100.00	100.00	100.00
2	98.80	86.80	87.90	80.90	76.30	84.20
4	94.30	82.20	74.30	68.00	57.40	73.70
8	92.00	79.00	56.80	58.50	46.50	54.90
12	80.15	56.42	46.06	41.90	30.81	24.06
24	69.83	41.35	13.09	9.80	1.50	0

The clinical signs observed in experimentally infected larvae were poor swimming activity, anorexia and opaqueness of body, loss of setae and bending, twisting and settling to the bottom of the tank. These symptoms were the same as those observed in natural epizootics. The infected nauplii and protozoea larvae settled to the bottom and moved only when disturbed. The infected mysis and postlarvae always ascended spirally in a vertical direction to the surface and then sank to the bottom. Moreover, over 90% similar green bacterial colonies were reisolated by the methods mentioned earlier from experimentally infected moribund larvae. Pure culture of 2 re-isolates were also identified as the same species as the initial isolates (Table 2). These results indicated that the isolates were the causative agent of this epizootics.

DISCUSSION

Vibrio spp. are the most common bacteria in coastal seawater, and some species have been reported as the pathogens of cultured *Penaeus chinensis*. Mortality of protozoea and mysis of *Penaeus chinensis* occurred regularly in the hatcheries in North China during the April and May in recent years and have caused serious losses. A total of 38 isolates were obtained from the infected larvae during the period of investigation. All the isolates examined were classified as being members of the genus of *Vibrio*. Twenty six of them seem to belong to the same species, because the morphological, physiological and biochemical characteristics of these strains agreed well with each other except for growth at 10 °C, sensitivity to vibriostatic agent o/129 (10 μg), ONPG, citrate and a few carbohydrate utilizations. The present isolate was closely related to *Vibrio harveyi* based on the morphological, physiological and biochemical characteristics examined in comparison with data in Bergey's Manual of Determinative Bacteriology (9th ed.). However, it differed from *V. harveyi* by growth in 8% NaCl, acid from lactose and citrate utilization. Meanwhile, all isolates have been classificated and identificated by using the Biolog system in Belgium. The classification of the isolates closely coincides with our results. In view of all these results, it can be concluded that the characteristics studied suggest the present isolate as a member of the genus *Vibrio*, with close resemblance to *Vibrio harveyi*.

The bacterium which has been initially isolated was confirmed to be the causative agent of epizootics in the hatchery-reared larvae of *Penaeus chinensis* based on the results of pathogenicity experiments by immersion method. The present isolate administered via bacteria-bath at a dose of 10^6 cfu/ml was found sufficient to establish infection in nauplii, protozoea and mysis$_{1-2}$ larvae, but failed to induce infection in mysis$_3$ and postlarvae. The mortality of the zoea$_2$ larvae exposed to different dosages (2.5×10^3 - 2.5×10^7 cfu/ml) of bacteria ranged from 100% to 40% within 24 h and the infection developed differently after different exposure time (2, 4, 8, 12 and 24 h). The mortality data showed that the pathogenicity of the present isolate depends on the dosage, period of exposure and age of the shrimp and also indicated that resistance to the present *Vibrio* isolate progressively increased as the larvae develop to the more advanced stages. Such variations in the level of mortality and susceptibility that correlate with age, dosage and time of exposure have been reported previously (Takahashi et al, 1984, 1985; Sahul Hameed et al. 1994, 1996).

In general, most of the isolates of *Vibrio sp.* from diseased or seemingly diseased larvae shrimp may not always produce experimental infection, except when massive doses are inoculated (Lightner, 1988). Up to now, standard about the infected time and dosage for determining a pathogen is not available. On the other hand, it is well known that natural disease outbreaks always occur under different stress conditions. It is therfore very difficult to determine whether an isolate is pathogenic to penaeid shrimp or not. However, our isolates were able to produce the disease at lower doses (2.5×10^4 - 2.5×10^6 cfu/ml) by immersion. It is the first report of the pathogenicity of *V. harveyi-like bacterium* to larvae of *Penaeus chinesis* in China.

Most of the *Vibrio spp.* are opportunistic pathogens of penaeid shrimp, and vibriosis mostly outbreaks under certain stress conditions. During the zoeal stages, an increase in bacterial count in the rearing tank water and a similar increase in *Vibrio spp.* in the larval body (Table 1) probably acted as the main stress factors to cause the onset of vibriosis in the hatchery-reared larvae of *Penaeus chinensis*. In another disease-free hatchery in Laizhou, the bacterial counts are much lower and the different *Vibrio sp.* developed yellow colored colonies on TCBS agar, not the greens as those in the infected hatchery. (Data not shown here). Stress which either lowers the resistance of the prawn or enhances the population and/or pathogenicity of the pathogen plays an important role in the disease process in prawns (Peña, et al., 1993). The results suggest that minimizing stress may act as a prophylactic measure against the outbreak of vibriosis in the hatchery-reared larvae of penaeid shrimps. (Lightner, 1988).

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NEW TECHNOLOGY FOR THE ACCELERATION OF REPRODUCTIVE MATURATION IN ECONOMICALLY IMPORTANT CRUSTACEANS

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ABSTRACT

Finding ways to stimulate gonadal maturation is a major need for successful culture of crustaceans. The sinus gland in the crustacean eyestalk is the release site of the gonad-inhibiting hormone whereas the brain and thoracic ganglia secrete the gonad-stimulating hormone. Eyestalk ablation, thereby removing the gonad-inhibiting hormone source, is routinely used to induce ovarian maturation. However, eyestalk ablation occasionally results in high mortality. In seeking a way to bypass this surgical technique the possible roles of neurotransmitters and their antagonists in controlling release of these hormones in the sand fiddler crab, *Uca pugilator*, and the red swamp crayfish, *Procambarus clarkii*, were investigated. 5-Hydroxytryptamine was found to stimulate testicular and ovarian maturation; but this action is indirect, 5-hydroxytryptamine triggering gonad-stimulating hormone release. Incubation of ovarian explants with 5-hydroxytryptamine alone has no effect on oocyte maturation. Naloxone, an opioid antagonist, induces ovarian maturation, whereas the opioid methionine enkephalin inhibits ovarian maturation. This action of methionine enkephalin may be due to its triggering gonad-inhibiting hormone release, inhibiting gonad-stimulating hormone release, or both actions. Both 5-hydroxytryptamine and methionine enkephalin are present in the crustacean nervous system. These experiments indicate that in crustaceans both an opioid peptide and a classical neurotransmitter have important roles in regulating gonadal maturation. Because both 5-hydroxytryptamine and naloxone stimulate ovarian maturation, supplementing the crustacean diet with either or both 5-hydroxytryptamine and naloxone may accelerate reproductive activity and thereby provide a new tool for crustacean culture.

INTRODUCTION

The search for new ways to facilitate the culture of economically important crustaceans has many facets. Inasmuch as maturation of the gonads in males and females is hormonally regulated, there are ongoing efforts world-wide to manipulate the endocrine system to induce more broods per year and a larger number of individuals per brood. Herein, first, the roles of the well-established hormones that regulate the reproductive systems of male and female decapod crustaceans will be reviewed. Next, the studies that have identified neurotransmitters which affect release of those hormones will be summarized. Then, the final section will discuss ways that this information about neurotransmitters might be adapted to enhance the culture of crustaceans such as shrimp and lobsters.

I. THE HORMONES THAT REGULATE THE REPRODUCTIVE SYSTEMS OF DECAPOD CRUSTACEANS

A multihormonal system of reproductive endocrines regulates the gonads of decapod crustaceans. The first incontrovertible evidence that hormones are involved in controlling crustacean gonads was provided by Panouse (1943, 1944). He used female prawns, *Palaemon serratus*, and showed that the sinus gland in the eyestalk has a gonad-inhibiting hormone (GIH). He found that removal of both eyestalks brings about precocious ovarian maturation, and sinus gland implants into eyestalkless individuals inhibit ovarian maturation. GIH is also present in the sinus glands of males, eyestalk ablation of a male resulting in early testicular maturation (Demeusy, 1953). Ōtsu (1960) and Gomez (1965) respectively showed that the thoracic ganglia and brain contain a gonad-stimulating hormone (GSH). In the years following these earlier studies the presence of GIH and GSH has been demonstrated in several decapods, including two species studied in this laboratory, the sand fiddler crab, *Uca pugilator*, by Eastman-Reks and Fingerman (1984) and the red swamp crayfish, *Procambarus clarkii*, by Kulkarni *et al.* (1991).

A major advance, made by Charniaux-Cotton (1954), was elucidation of the role of the androgenic glands. An androgenic gland is attached to each vas deferens in all decapods. The product of these glands, the androgenic gland hormone (AGH), acts not only to initiate differentiation of the male reproductive system, but also to induce spermatogenesis and ensure development of the male secondary sexual characteristics. Removal of the androgenic glands from an adult generally results in cessation of spermatogenesis (Charniaux-Cotton, 1964; Puckett, 1964; Nagamine *et al.*, 1980). In almost all decapods, spermatogenesis requires the continued presence of AGH, the intensity of spermatogenesis being directly related to the level of circulating AGH (Charniaux-Cotton and Payen, 1985). But, in some reptantians once spermatogenesis has begun under the action of AGH, spermatogenesis appears to be able to continue in the absence of this hormone (Payen and Amato, 1978). Crustacean testes do not produce any hormone. But in females the ovary produces a hormone that induces development of structures such as ovipositing setae and the brood chamber (Charniaux-Cotton, 1955; Nagamine and Knight, 1987).

In female decapods GIH and GSH directly affect the ovary (Adiyodi, 1985). In males, when both eyestalks are ablated, thereby removing the source of GIH, hypertrophy of the androgenic glands occurs, followed by precocious testicular maturation (Meusy, 1965; Demeusy, 1967; Payen *et al.*, 1971). In males GIH does not appear to affect the testes directly, but only indirectly by inhibiting the androgenic glands. GSH is required to activate the androgenic glands in order to initiate spermatogenesis (Juchault and Legrand, 1965), a process that Payen (1980) referred to as a positive control of the androgenic glands by a neurohormone. Adiyodi and Adiyodi (1970) have concluded that both GIH and GSH act indirectly on the testes, through the androgenic glands. Gupta *et al.* (1989) on the basis of their investigation of the crab, *Paratelphusa hydrodromus*, hypothesized that the inactive phase of the testes is due to an increase in the blood titer of GIH with accompanying decreases in the titers of GSH and AGH.

The mandibular organs, first described by Le Roux (1968), are the subject of continuing study. While Chang *et al.* (1993) continue to hold the view that the product of the glands, methyl farnesoate, has a role in molting, Laufer *et al.* (1993) have concluded that these glands regulate reproduction, including stimulation of vitellogenesis and the mating behavior of males.

II. ROLES OF NEUROTRANSMITTERS IN CONTROLLING RELEASE OF THE GONAD-STIMULATING AND GONAD-INHIBITING HORMONES

Both GSH and GIH are neurohormones, inasmuch as they are the products of secretory neurons. Their release depends upon input through synapses from connecting neurons that send signals that result in either release or inhibition of release of these hormones. In this laboratory for the past several years studies have been ongoing that were designed to identify the neurotransmitters that send such signals to these neuroendocrine cells. These studies have utilized both the red swamp crayfish, *Procambarus clarkii*, and the sand fiddler crab, *Uca pugilator*.

A. Ovaries

1. Uca pugilator

The initial study in this laboratory of the possible effect of a neurotransmitter on the reproductive system identified 5-hydroxytryptamine (5-HT, serotonin) as a candidate for such a role (Richardson *et al.*, 1991). Injection of 5-HT, which is present in the central nervous systems of this fiddler crab (Fingerman *et al.*, 1974) and *Procambarus clarkii* (Kulkarni and Fingerman, 1992a), brought about ovarian maturation. Furthermore, the 5-HT receptor blocker LY53857 inhibited ovarian maturation in crabs undergoing ovarian maturation during their normal reproductive season. It was suggested that this action of 5-HT on the ovaries was indirect, 5-HT triggering GSH release. In another study, the effects of two 5-HT agonists on the ovary were determined (Kulkarni and Fingerman, 1992b). The 5-HT releaser fenfluramine and the 5-HT potentiator fluoxetine, like 5-HT, stimulated ovarian maturation.

In a more recent study the opioid methionine enkephalin was found to inhibit ovarian maturation whereas a general opioid antagonist, naloxone, produced dose-dependent ovarian maturation (Sarojini *et al.*, 1995b). The hypothesis was presented that this enkephalin exerts this inhibitory action by (a) stimulating GIH release, (b) inhibiting GSH release or (c) both (a) and (b). By immunocytochemistry a methionine enkephalin-like substance was identified in the eyestalk of *Uca pugilator* by Fingerman *et al.* (1985). Since then, methionine enkephalin has been shown to be present in the nervous systems of other crabs by use of high performance liquid chromatography and sequence analysis (Leung *et al.*, 1987; Lüschen *et al.*, 1991).

2. Procambarus clarkii

For comparative purposes, our attention turned from the marine fiddler crab to the freshwater *Procambarus clarkii*. Females given injections of 5-HT exhibited more rapid ovarian maturation than did the control specimens (Kulkarni *et al.*, 1992). Also, when ovarian explants were incubated with ^{14}C-leucine significantly more labeled ovarian proteins were present in the explants from ovaries taken from crayfish that were injected with 5-HT than in the control explants. But when ovarian lobes from crayfish that had not been injected with 5-HT were incubated with only 5-HT added to the incubation medium, no significant change in the level of incorporation of ^{14}C-leucine into ovarian proteins was found. As with the fiddler crab, with the crayfish the 5-HT receptor blocker LY53857 retarded ovarian development *in vivo*, whereas crayfish injected with fenfluramine or fluoxetine showed rapid ovarian development. These results clearly support the hypothesis that 5-HT has an indirect action on the ovaries. This hypothesis was tested further. Ovarian explants were incubated with 5-HT and muscle, and with 5-HT in combination with brain or thoracic ganglia (Sarojini *et al.*, 1995c). As expected, 5-HT without brain or thoracic ganglia in the incubation medium had no significant effect on the ovarian explants. However, brain and thoracic ganglia alone induced ovarian maturation, indicating the presence of GSH in these tissues. But this stimulatory effect was greater when 5-HT was present in the incubation medium with brain or thoracic ganglia.

Dopamine (DA) is another neurotransmitter that is present in the crustacean central nervous system (Butler and Fingerman, 1983; Laxmyr, 1984). DA antagonizes the action of 5-HT *in vivo* (Sarojini *et al.*, 1995d). In a follow-up in vitro study with ovarian explants incubated with brain or thoracic ganglia DA inhibited the stimulatory action of 5-HT, just as it does *in vivo* (Sarojini *et al.*, 1996a). Inasmuch as GIH comes from the sinus gland in the eyestalks, this experiment showed that one likely action of DA is to inhibit GSH release from the brain and thoracic ganglia. However, it is possible that *in vivo* DA also triggers GIH release.

The red pigment-concentrating hormone (RPCH), an octapeptide that produces color changes of the integument of crustaceans, has long been known to be present not only in the sinus gland but also in all the major portions of the crustacean central nervous system (Brown, 1950; Fingerman, 1958). Furthermore, RPCH occurs in neurons that appear not to be neurosecretory as well as in neurosecretory cells (Mangerich *et al.*, 1986). This widespread distribution raised the question as to whether RPCH might have a role as a neurotransmitter in addition to that of a neurohormone. Then, Nusbaum and Marder (1988) showed that RPCH has such a nonendocrine role in the stomatogastric ganglion of the crab, *Cancer borealis*, increasing the frequency of the pyloric rhythm. Subsequently, the possibility that RPCH has a role in ovarian maturation was considered in this laboratory (Sarojini *et al.*, 1995e). When injected, RPCH stimulated ovarian maturation. However, *in vitro* RPCH did not affect ovarian explants when only RPCH, muscle and ovarian explants were used. But when RPCH, thoracic ganglia and ovarian explants were incubated together, ovarian maturation ensued, more than occurred with explants incubated with thoracic ganglia alone. The calcium ionophore A23187 mimics RPCH. Apparently RPCH acts here as a neurotransmitter like 5-HT to stimulate GSH release, with calcium acting as a second messenger for RPCH.

In another study methionine enkephalin was found to inhibit ovarian maturation in this crayfish (Sarojini *et al.*, 1996c), just as it does in the fiddler crab. Again, the general opioid antagonist naloxone produced dose-dependent ovarian maturation. Furthermore, a highly specific delta opioid receptor agonist, DADLE, also inhibited ovarian maturation, whereas a highly selective delta receptor antagonist, ICI-174,864, stimulated ovarian maturation. On the basis of these experiments, it was suggested that methionine enkephalin exerts its inhibitory action by acting through delta-type opioid receptors. In an even more recent study with this crayfish, Sarojini *et al.* (1997) found that ovarian explants exposed *in vitro* to methionine enkephalin and thoracic ganglia showed reduced development in a dose-dependent manner as compared to explants incubated with thoracic ganglia alone. As in our earlier studies, explants incubated with thoracic ganglia alone showed more development than did explants incubated with muscle alone. In contrast to methionine enkephalin, the opioid antagonist naloxone produced dose-dependent enhanced development of explants incubated with thoracic ganglia. These results show that in this crayfish methionine enkephalin, like DA, apparently exerts its inhibitory action on the ovary by at least inhibiting GSH release. Interestingly, Hanke *et al.* (1996, 1997) by using opioid receptor binding assays showed the presence of delta-type opioid receptors in the thoracic ganglia and eyestalks of the shore crab, *Carcinus maenas*. The fact that *in vitro* methionine enkephalin and naloxone affect ovarian maturation, the opioid inhibiting maturation and naloxone stimulating it, is consistent with the hypothesis that a functional endogenous opioid system is present in crustaceans and that this system modulates GSH release.

B. Testes

1. Uca pugilator

Studies have also been carried out to determine whether neurotransmitters that might be involved in regulating testicular maturation could be identified, particularly in view of the added complexity of males having androgenic glands. Sarojini *et al.* (1993) found that 5-HT injections do indeed produce testicular maturation. Furthermore, the 5-HT releaser fenfluramine and the 5-HT potentiator fluoxetine induced testicular maturation also, but the 5-HT receptor blocker LY53857 did not. Then, in another study DA and a dopaminergic agonist, ADTN, were found to inhibit testicular maturation whereas a dopaminergic antagonist, spiperone, induced maturation of the testes (Sarojini *et al.*, 1995a). Presumably, the inhibitory mechanism of action of DA on testicular maturation is the same as that suggested above for the effect of DA on ovarian maturation.

2. Procambarus clarkii

The possibility that 5-HT stimulates testicular maturation in the crayfish was also examined (Sarojini *et al.*, 1994). 5-HT and its agonists fenfluramine and fluoxetine not only induced testicular maturation but also development of the androgenic glands. In contrast, the 5-HT antagonists LY53857 and ketanserin had no stimulatory effect on the testes or androgenic glands. This stimulatory action of 5-HT in the male, as in the female, was hypothesized to be indirect, 5-HT stimulating release of GSH. Once released in the male, GSH would then in turn act on the androgenic glands inducing them to synthesize and release AGH, and AGH would then trigger testicular maturation, spermatogenesis, and development of the secondary sexual characteristics. In a subsequent study the effects of DA and dopaminergic agonists on testicular maturation in this crayfish were determined (Sarojini *et al.*, 1995f). As in the fiddler crab, DA inhibited testicular maturation and development of the androgenic glands. But when the dopaminergic receptor blockers spiperone and pimozide were injected the testes developed more rapidly and the androgenic glands were larger than in the control crayfish. When equimolar amounts of 5-HT and DA were co-injected, neither was as effective in combination than when injected alone, thereby showing their antagonistic nature to each other.

III. POSSIBLE FUTURE USES OF NEUROTRANSMITTERS, THEIR AGONISTS, AND THEIR ANTAGONISTS TO INDUCE GONADAL MATURATION ON A LARGE SCALE

The studies on the roles of neurotransmitters discussed above were done on a laboratory scale. Nevertheless, they suggest several avenues of attack on the problem of inducing gonadal maturation on a large scale, which would be necessary for a culture facility be an economically viable venture. Possible approaches to having eggs and sperm produced year-round would be to put into the food 5-HT, an agonist of 5-HT, or an antagonist of methionine enkephalin such as naloxone. A commonly used procedure to induce ovarian maturation is to remove one or both eyestalks, thereby depriving the crustacean of GIH. However, such a surgical procedure sometimes results in high mortality. Consequently, a nonsurgical pharmacological approach is more desirable. Manipulation of the endocrine system seems the better approach, and certainly should be tried in a commercial operation. By stimulating the reproductive maturation of both males and females, there is the strong likelihood that juveniles will become available throughout the year.

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RECOMBINANT MOLT-INHIBITING HORMONE-LIKE NEUROPEPTIDE PRODUCED IN THE YEAST *PICHIA PASTORIS*

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ABSTRACT

Molting is an essential process for somatic growth in crustaceans. Molt-inhibiting hormone is a primary regulator controlling growth and development. A cDNA encoding a molt-inhibiting hormone-like (MIH-like) neuropeptide from the white shrimp *Penaeus vannamei* has been cloned and sequenced in our laboratory. With information on the DNA sequence encoding the mature 72-amino-acid MIH-like peptide, a large quantity of the MIH-like peptide has been produced using the yeast *Pichia pastoris* expression system. The MIH-like expression vector, pPIC9-MIH-like, was constructed by modifying the MIH-like-cDNA by creating two flanking restriction sites, i.e. a SnaB1 at the 5' end and a Not1 at the 3' end using polymerase chain reaction. The modified MIH-like-cDNA was then sub-cloned into the unique SnaB1 and Not1 sites of the *P. pastoris* expression vector pPIC-9, resulting in the expression vector pPIC9-MIH-like. This expression vector contains the entire coding sequence of the mature MIH-like neuropeptide fused to the hybrid secretory preproleader sequence of the yeast vector.

Expression of the vector pPIC9-MIH-like in *P. pastoris* with defined growth medium yields two immunologically positive protein bands of 8 kd and 14 kd as revealed by Western blotting. The 8 kd band is the expected molecular size of the MIH-like peptide hormone. The 14 kd protein could be the result of glycosylation or disulfide bond aggregation of the MIH-like peptide. The recombinant MIH-like peptide secreted from the host cell is accumulated in the culture medium to approximately 130 mg per liter of growth medium as determined quantitatively by enzyme-linked immunosorbent assay (ELISA).

INTRODUCTION

In crustaceans, the molting process of periodic shedding of the exoskeleton is essential for development and maturation of the animals. This molting process is believed to be controlled and regulated by at least three structurally distinct hormones (Tamone and Chang 1993): ecdysteroids, the molting hormones, methyl farnesoate (MF), a sesquiterpenoid hormone and the molt-inhibiting hormone (MIH). Endocrine control of crustacean molting has been extensively reviewed by Kleinholz and Keller (1979), Quackenbush (1986), Lachaise *et al.*(1993) and Chang (1995). Ecdysteroids are secreted from the Y-organs, the molting glands in crustaceans. The secretion of the ecdysteroids from the Y-organs, in turn, is controlled by a molt-inhibiting hormone which is synthesized in the neurosecretory X-organ sinus gland (XOSG) complex in the eyestalks. *In vivo* and *in vitro* experiments have shown that MIH extract suppresses Y-organ function (Spaziani *et al.* 1989), and a putative molt-inhibiting hormone from the crab, *Carcinus maenas* (Webster and Keller, 1989) were found to have a profound effect on the inhibition of ecdysone secretion from the Y-organs.

Methyl farnesoate (MF), a juvenile hormone-like compound, synthesized in the mandibular organ (MO) and secreted into the hemolymph, is also considered a regulator of ecdysteroid secretion (Laufer *et al.* 1987). Recently, Tamone and Chang (1993) reported that MF stimulates secretion of ecdysteroids by Y-organs of the crab, *Cancer magister*, in vitro. Furthermore, the level of MF in the hemolymph was found to be higher in the eyestalk-ablated lobsters than in intact ones (Tsukimura and Borst, 1992), suggesting that the secretion of MF from the MO is under the control of a sinus gland neuropeptide. Therefore, MIH appears to be the primary regulator in the crustacean molting process. Yet, the regulatory role of MIH in the molting process remains unclear. The recent elucidations of the cDNA sequences of *Carcinus*-MIH (Klein *et al.*, 1993), *Callinectes*-MIH (Lee *et al.*, 1995) and *Penaeus*-MIH-like (Sun, 1994) place these neuropeptides in the crustacean hyperglycemic hormone (CHH) peptide family, a group of neuropeptides with diverse functions related to carbohydrate metabolism, reproduction and molting (Kegel *et al.* 1991; Keller 1992; Huberman *et al.*, 1995). The major hindrance of finding the precise role of MIH in molting process is because of the difficulty of obtaining pure and homogeneous biological material from the neuroendocrine XOSG complex in the eyestalk, and the lack of a specific and sensitive assay to detect and quantify the MIH.

This paper reports the production of recombinant MIH-like neuropeptide by expression of the MIH-like gene (Sun, 1994, 1995) in yeast cells using the *Pichia pastoris* protein expression system. This methylotrophic yeast *Pichia pastoris* system has been reported previously to produce high levels of heterologous proteins (Cregg *et al.*, 1993) including invertase (Tschopp *et al.*, 1989), tetanus toxin fragment C (Clare *et al.*, 1991a), mouse epidermal growth factor (Clare *et al.*, 1991b), aprotinin (Vedvick *et al.*, 1991), human serum albumin (Barr *et al.*, 1992), tick anticoagulant peptide (Laroche *et al.*, 1994) and rat high-mobility group protein (Mistry *et al.*, 1997). The *Pichia pastoris* system provides the ability to secrete high levels of recombinant protein in a well-defined medium.

MATERIALS AND METHODS

Construction of the pPIC9-MIH-like expression vector. A MIH-like expression vector was constructed by first modifying the MIH-like-cDNA by creating two restriction sites, a SnaB1 at 5' end and a Not1 at 3" end using polymerase chain reaction method (PCR). The modified MIH-like-cDNA was then sub-cloned into the expression vector pPIC9 (Invitrogen, California) which contains an alpha factor secretion signal derived from *Saccharomyces cerevisiae* and a HIS gene for selection of *Pichia* transformants.

Transformation of *P. pastoris* and selection of *His$^+$Mut^s* transformants. Approximately one µg of pPIC9-MIH-like DNA was digested with BglII to produced a linear DNA molecule with ends homologous to the 5' and 3' termini of the alcohol oxidase gene (AOX1), whose product is involved in the process of methanol metabolism. Integration into the host yeast cell AOX1 locus occurs by double crossover recombination resulting in the complete removal of the AOX1 coding region and, consequently, the loss of the ability to utilize methanol efficiently. The linearize DNA was used to transform the *P. pastoris* strain GS115 (*his4*) to the His$^+$ phenotype by electroporation method (Scorer *et al.*, 1994).

Electroporation was performed with cells pulsed in 0.2 cm electroporation cuvette at 1500 V, 150 Ohm and 50 µF, using an electroporator II (Invitrogen, California). One millimeter of cold 1 M sorbitol was added to the cuvettes immediately after pulsing, and 200-600 µl aliquots were spread on minimal dextrose plates (MD plates, containing 1.34% yeast nitrogen base, 4 x 10 $^{-5}$% biotin, 1% dextrose and 15 g agar per liter). His^{+}Mut^{s} transformants were screened by patching on minimal dextrose (MD) verus minimal methanol (MM) plates (same ingredients as in MD plates except that 1% dextrose is replaced by 0.5% methanol) as described in the manufacturer's instruction (Invitrogen). Six colonies showed slow growth on methanol were recovered and were grown in 10 ml YPD medium (1% yeast extract, 2% peptone, and 2% glucose) for 2 days at 30°C. Cells from each colony culture were collected by centrifugation at 1500 x g for 5 minutes at room temperature and were re-suspended in 2 ml of fresh SCED buffer (1 M sorbitol, 10 mM sodium citrate, pH 7.5, 10 mM EDTA, 10 mM DTT) and were used for genomic DNA isolation.

Isolation of genomic DNA from the selected six His^{+}Mut^{s} *Pichia* clones using Easy-DNA kit from Invitrogen Corporation (California) was performed and used as templates for PCR amplification to identify the MIH-like gene has integrated into the *Pichia* genome. PCR amplification was carried out on the Perkin-Elmer 9600 thermal cycler and a pair of 5' and 3' AOX1 primers (5'AOX1: 5' GGACTGGTTCCAATTGACAAGC 3'; 3'AOX1: 5' GCAAATGGCATTCTGACATCC 3') was used and a DNA band of about 711 bp will indicate the MIH-like gene has integrated into the *Pichia* genome.

Fermentation of *P. pastoris* strain GS115-MIH-like neuropeptide. Transformant #2 showed the highest yield of MIH-like peptide from mini-culture experiments (Figure 2) was chosen to use for large-scale fermentation. A 100-ml culture of GS115-MIH-like transformant #2 was grown in a 1000-ml baffled shake flasks at 30°C with shaking at 250-300 rpm for 20 hours (or O.D. = 6) on BMGY medium (1% yeast extract, 2% peptone, 100 mM potassium phosphate, pH 6.0, 1.34% yeast nitrogen base, 4 x 15 $^{-5}$% biotin and 1% glycerol). To induce expression, cells were harvested by centrifugation at 1500 x g for 5 min at room temperature and re-suspended in 1/5 of the original culture volume of BMMY medium (same as BMGY medium except that 1% glycerol was replaced by 0.5% methanol). The induction phase was maintained for 190 hours with 100% methanol added to a final concentration of 0.5% very 24 hours. One milliliter sample was withdrawn from the culture medium every 24 hours for protein expression analysis. Following centrifugation to remove the cell pellets from the culture medium, the supernatant from each sample was kept at -80 C until use.

Recombinant protein products analysis by SDS-polyacrylamide gel electrophoresis and Western blotting. Samples of the secreted expression from *P. pastoris* GS115 host strain in the culture supernatant were subjected to SDS-polyacryulamide gel electrophoresis (SDS-PAGE) and Western blot analysis. SDS-PAGE was performed based on the methods of Davis (1964) and Laemmli (1970), with a 15% separation gel and a 4% stacking gel. Polypeptides separated by SDS-polyacrylamide gels was fixed with methanol/glacial acetic acid and stained with Coomassie Brilliant Blue R250 (Sambrook *et al.*, 1989). Protein mass standards of Rainbow markers (Amersham, Illinois) was co-run in the gel electrophoresis.

For Western blotting, methods of Towbin *et al.* (1979) and burnett (1981) were used. Briefly, after gel electrophoresis, the separated proteins were transferred to a pure nitrocellulose immobilization membrane (Schleicher and Schuell, New Hampshire) with a pore size of 0.05 µm. The membrane was treated with anti-MIH-like polyclonal antiserum (Sedberry and Sun, 1997) followed by goat anti-rabbit IgG conjugated to horseradish peroxidase. The membrane was then developed with ECL reagents (Amersham, Illinois), and exposed to X-ray film (Fuji, Tokyo).

RESULTS

Construction of pPIC9-MIH-like expression vector. The plasmid pPIC9-MIH-like was constructed by modification of the MIH-like cDNA sequence which was then sub-cloned into the *Pichia* pPIC9 vector in frame with the alpha factor protein secretion signal of *S. cerevisiae.* The map of the pPIC9-MIH-like is shown in Figure 1. The expression vector also contains the *P. pastoris* HIS4 gene, a *P. pastoris* autonomous replicating sequence (PARS2). The vector was transformed into histidine-requiring auxotrophs (*his*4), GS115 which is wild type for alcohol oxidase. The pPIC9-MIH-like vector was integrated into the HIS4 or AOX1 gene of P. pastoris. .

Transformed clones were selected for their ability to grow in the absence of histidine and further screened for integration into the AOX1 locus by their inability to utilize methanol efficiently. The transformation efficiency to Mut^s was approximately 12%. In screening 208 clones, 25 clones were His^+Mut^s, and 6 of these 25 clones were chosen for further PCR analysis and subsequently DNA sequencing to confirm for correct integration of the vector in the *Pichia* genome.

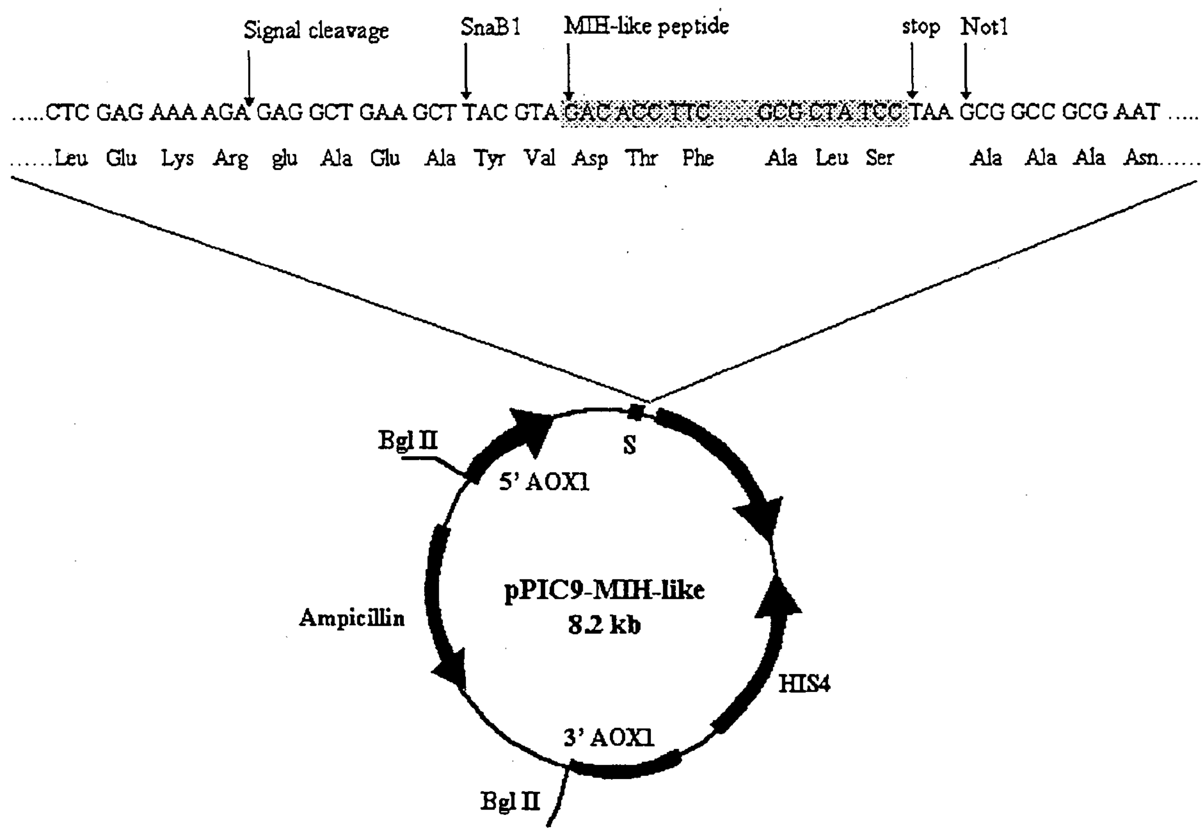


Figure 1. Map of pPIC9-MIH-like

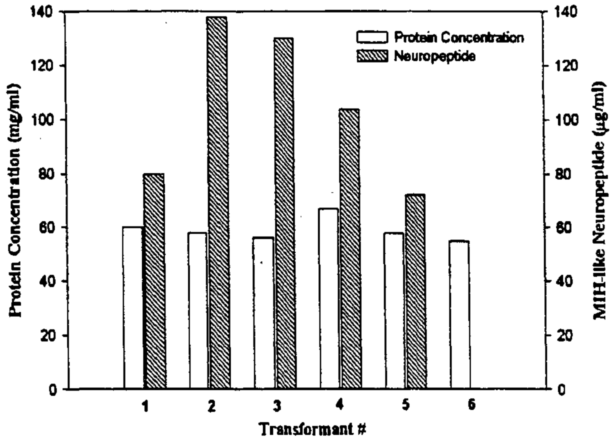


Figure 2. Expression level of pPIC9-MIH-like from six *Pichia* transformants. In the screening process, six positive transformants His$^+$ Mut^s, were grown in mini-culture medium for 190 hours with methanol induction starting at 22 hours after fermentation. Secretion of the MIH-like neuropeptide from the media was determined by ELISA. (Sedberry and Sun, 1997). Protein was determined by the methods of Bradford (1976).

PCR analysis of *Pichia* integrants. Genomic DNA isolated from six His$^+$Mut^s clones weere analyzed by PCR amplification using the 5' and 3' AOX1 primers. Figure 3 shows the PCR-DNA products revealed by ethidium-bromide-agarose gel electrophoresis. All clones (#1 - #5) except clone #6 gave expected correct size of about 710-bp DNA fragment which indicates that MIH-like gene has integrated into the *Pichia* genome. Figure 4 shows the partial nucleotide sequence of clone #2. This result demonstrates that the presence of complete nucleotide sequence encoding the mature MIH-like neuropeptide is in frame and is fused into the secret signal sequence of *S. cerevisiae.*

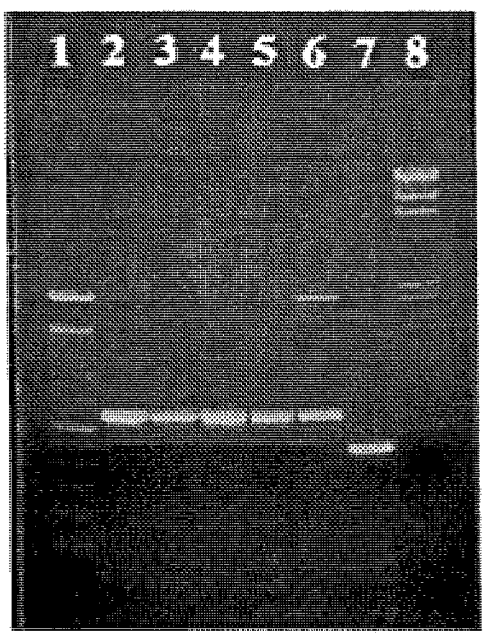


Figure 3. Size analysis of PCR products by agarose gel electrophoresis. Photo of a 1% agarose gel after electrophoretic separation of PCR products. DNA is visualized by ethidium bromide staining and illumination in UV. Lane 1 and lane 8 are molecular markers. Lane 2 to lane 7 are transformants #1 to #6. The PCR assay was performed with Perkin-Elmer 9600 system, and was programmed for 35 cycles at denaturation 1 minute at 95°C, annealing at 1 minute at 60°C and extension 30 seconds at 60°C; then a final extension for 1 cycle at 60°C for 7 minutes.

5' AOX1 Primer

5' .... CGA CTG GTT CCA ATT GAC AAG CTT TTG ATT TTA
ACG ACT TTT AAC GAC AAC TTG AGA AGA TCA AAA AAC AAC TAA TTA TTC GAA
GGA TCC AAA CG ATG AGA TTT CCT TCA ATT TTT ACT GCA GTT TTA TTC GCA
GCA TCC TCC GCA TTA GCT GCT CCA GTC AAC ACT ACA ACA GAA GAT GAA ACG
GCA CAA ATT CCG GCT GAA GCT GTC ATC GGT TAC TCA GAT TTA GAA GGG GAT
TTC GAT GTT GCT GTT TTG CCA TTT TCC AAC AGC ACA AAT AAC GGG TTA TTG
TTT ATA AAT ACT ACT ATT GCC AGC ATT GCT GCT AAA GAA GAA GGG GTA TCT
CTC GAG AAA AGA GAG GCT GAA GCT GAC ACC TTC GAC CAC TCC TGC
AAG GGC ATC TAC GAC CGG GAG CTC TTC AGA AAG CTG GAC CGC GTC TGT GAG
GAT TGC TAC AAC CTG TAC CGC AAG CCC TAC GTG GCC ACC GAG TGC AAG TCC
AAT TGC TTC GTG AAT AAG AGG TTC AAT GTC TGT GTG GCT GAT CTC AGA CAT
GAT GTC AGC CGC TTT CTG AAA ATG GCT AAT TCT GCG CTA TCC TAA
AAT TAA TTC GCC TTA GAC ATG ACT GTT CCT CAG TTC AAG TTG GGC ACT
TAC GAG AAG ACC GGT CTT GCT AGA TTC TAA TCA AGA GGA TGT CAG AAT GCC
ATT TGC .... 3'

3' AOX1 Primer

Figure 4. Partial pPIC9-MIH-like nucleotide sequences. After purification, the PCR-amplified DNA product was sequenced by the dideoxy-chain termination method (Sequenase system, version 2.0) and by the automatic sequencing method using the DyeDeoxy Terminator cycle sequencing kit (Applied Biosystems, Model 373A). The underlined sequences are those of primers used for PCR amplification. Lighter shaded sequences represent the mature MIH-like neuropeptide. Darker shaded sequences represent restriction enzymatic sites.

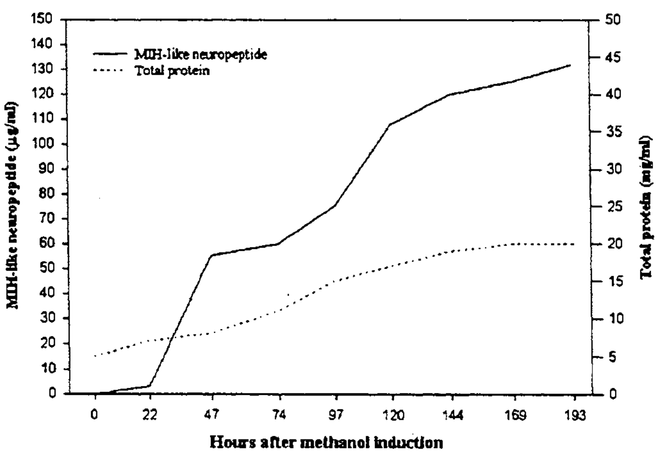
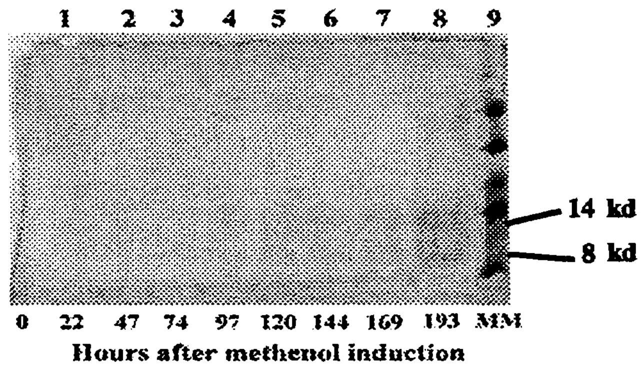


Figure 5. A time course study expression. ELISA quantitation of recombinant MIH-like neuropeptide secreted from culture medium. Procedures described in Sedberry and Sun (1997). Total protein was determined by the Bradford method (Bio-Rad Laboratories, California) and bovine serum albumin was used as the standard.

Expression and secretion of MIH-like neuropeptide in the host strain GS115. MIH-like neuropeptide was expressed and regulated by methanol. In the fermentation process of the host strain GS115-clone #2(GS115-2), it is found that the highest level of MIH-like peptide secretion from the culture medium were achieved after 190 hours following methanol induction (Figure 5). At 190 hours after induction, MIH-like peptide comprised to 130 mg per liter of growth medium while the total protein content remained fairly constant for the last five days of the fermentation process.

SDS-Polyacrylamide gel electrophoresis and Western blot analysis of MIH-like peptide produced in *P. pastoris*. Samples of *P. pastoris* GS115-2 culture supernatant were subjected to SDS-polyacrylamide gel electrophoresis. As shown in Figure 6, total proteins recovered from 4 µl of extract from culture medium is not significant and the anticipated protein band of about 8 Kd for MIH-like peptide is almost invisible. However, Western blot analysis of a similar gel as Figure 6, using polyclonal antiserum of MIH-like peptide, two strong immunologically positive protein bands of 8 kd and 14 kd were observed (Figure 7). The 8 kd band is the expected molecular size of the MIH-like hormone. The 14 kd protein, we speculate, could be the result of glycosylation or disulfide bond aggregation.



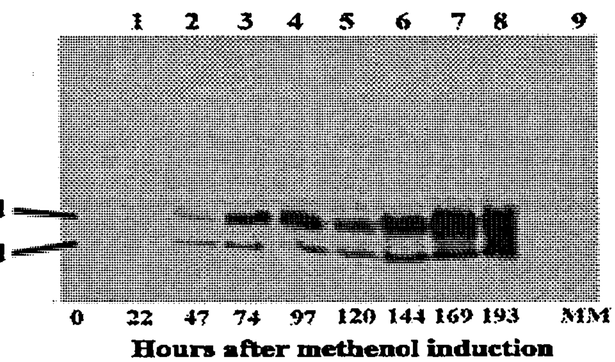


Figure 6. Coomassie blue-stained SDS-Polyacrylamide gel (15%) showing total protein secretion from culture medium. Lanes 1 to 8 each contains 4 µl of extract from culture medium withdrawn at indicated times and centrifuged at 10,000 g for 10 minutes. Lane 9 is the molecular marker (MM).

Figure 7. Western analysis of a similar gel as Figure 6. Protocols were used as described in material and method section.

DISCUSSION

In this paper we present the description of methanol-regulated expression of a crustacean molt-inhibiting hormone-like gene. A variation of expression level from several clones was observed and this phenomenon is probably due to different copy numbers and arrangement of the gene incorporated into the *Pichia* genome. In general, transformants with higher copy numbers of the inserted gene tend to produce more protein product than those with lower copy numbers. Scorer *et al.* (1994) developed a method of using G-148 resistance as a selection marker for screening high copy number transformants.

According to the construction of the expression plasmid pPIC9-MIH-like (Figure 1), the signal sequence of alpha factor was thought to be cleaved after the dibasic residues Lys-Arg by the KEX2 gene product (Brake *et al.*, 1984), and then Glu-Ala repeats may be further cleaved by dipeptidyl-amino-peptidase encoded by the STE 13 gene. Thus, the recombinant MIH-like peptide may have an extra two amino acid residues at the N-terminus in comparison with the deduced amino acid sequence from the MIH-Like-cDNA. However, N-terminal sequencing of purified recombinant MIH-like peptide will be performed to confirm the peptide sequence . In addition, further purification and biochemical analysis on both the 14 kd and 8 kd protein will be carried out to identify the structure of these proteins. According to the MIH-like-cDNA sequence there is no N-glycosylation site within the mature hormone structure, the speculated glycosylation product of the 14 kd protein may be from disulfide bond aggregation or a result from a gene product in a head-to-tail configuration. Further characterization of these proteins is required to identify its structure.

The data presented here demonstrate that *P. pastoris* is a powerful tool for large-scale production of recombinant crustacean MIH-like neuropeptide hormone. Further purification and characterization of the recombinant MIH-like peptide is in progress. Bioassay of the purified recombinant peptide will be performed to test its effectiveness in biological activities.

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STUDIES OF GENETIC VARIATIONS AND PHYLOGENETIC RELATIONSHIPS IN THIRTEEN MARINE SHRIMPS BY RAPD MARKERS

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ABSTRACT

Randomly amplified polymorphic DNA (RAPD) technique was applied to assess the genetic variations in 13 species of marine shrimps, *Penaeus chinensis, Penaeus japonicus, Penaeus monodon, Penaeus penicillatus, Penaeus merguiensis, Penaeus vannamei, Parapenaeopsis tenella, Parapenaeopsis hungerfordi, Metapenaeus joyneri, Metapenaeus affinis, Trachypenaeus curvirostris, Exopalaemon carinicauda, and Crangon affinis. Penaeus chinensis, Penaeus japonicus, Penaeus monodon, Penaeus penicillatus, Penaeus merguiensis, Penaeus vannamei, Parapenaeopsis tenella, Parapenaeopsis hungerfordi, Metapenaeus joyneri, Metapenaeus affinis, Trachypenaeus curvirostris, Exopalaemon carinicauda,* and *Crangon affinis.* The samples were collected from Qingdao, Guangzhou, Shanghai and Fujian. DNA from each five individuals for each species was extracted. Amplifications with 20 primers under predetermined optimal reaction conditions (samples were first heated at 94 ℃ for 5 min. and followed by 45 cycles of 1 min. at 94 ℃, 1 min. at 36 ℃, and 2 min. at 72 ℃, and then held at 72 ℃ for 10 min. after 45 cycles) gave 262 reproducible amplified fragments ranged from 230 to 2800bp. The amplified products were scored as present (1) or absent (0) for each DNA sample and an index of genetic similarity (F) was calculated by using Nei & Li's matching coefficient method. The value of (1-F) was used to evaluate genetic distances between species and construct a phylogenetic tree. The relationship indicated by the UPGMA and NJ method of cluster analysis on the values of the genetic distance is in good overall agreement with classical taxonomy. It suggests that randomly amplified polymorphic DNA (RAPD) approaches will be as useful in providing markers for marine animal genetics as they have been for other species.

INTRODUCTION

Despite the continuous accumulation of morphological and behavioural data, systematic and phylogenetic relationships among the most important economic marine shrimps are not yet completely understood. With the development of molecular biology, many DNA based techniques provide a powerful set of tools for the study of genetic variation and phylogenetic relationships. A molecular technique based on the polymerase chain reaction (PCR) provides an effective tool for the rapid identification of genetic markers known as Random Amplified Polymorphic DNA (RAPD) (Williams et al., 1990; Welsh & McClelland, 1990). Such markers, derived from priming sites randomly distributed throughout the genome, are inherited in a Mendelian fashion. These polymorphism allow the analysis of complex genomes without prior knowledge of DNA sequence (Hadrys et al., 1992). Potential uses of RAPD in phylogenetic studies and population genetics have been widely documented in a large variety of organisms.

The aim of the present study is first to investigate if RAPDs could discriminate between the family, genus, species of marine shrimps and secondly to ascertain whether phylogenetic relationships derived from RAPD data confirm or conflict with the existing classification of marine shrimps.

MATERIAL & METHOD

DNA isolation

100 mg biomass was ground with plastic pestles in microcentrifuge tube that contained 100mmol/L EDTA, 10 mmol/L Tris (pH 7.5), 1% SDS, and 50μg/ml Proteinase K. Samples were incubated at 55 ℃ for 2 h and extracted with phenol, phenol/chloroform (1:1), then chloroform/isoamyl alcohol (24:1). The resulting aqueous fractions were mixed with two volumes of ethanol and 1/10 volume 3 mol/L sodium acetate. Following centrifugation at 12,000 rpm for 10 min, the DNA pellet was vacuum dried and dissolved in water.

PCR amplification and electrophoresis

PCR reaction mixtures (25μl final volume) contained approximately 25 ng genomic DNA, dATP, dCTP, dGTP, dTTP each at 100μmol/L final concentration, 1 × standard Taq polymerase buffer, 0.2 μmol/L primer, 2 mmol/L $MgCl_2$, and 1 unit of Taq polymerase (S_{ABC}). The random sequence 10-mer primers used in this study were the products of Operon Technologies Inc.. Forty five cycles were run as follows: 1 min at 94 ℃, 1 min at 36 ℃ and 2 min at 72 ℃. After the finial cycle, samples were incubated for a further 3 min at 72 ℃ then held at 4 ℃ prior to analysis. Fragments generated by amplification were separated according to size on 1.5% agarose gels run in 1 × TBE (89 mmol/L Tris-HCl, pH 8.3, 89 mmol/L Boric acid, 5 mmol/L EDTA), stained with ethidium bromide and visualized with ultraviolet light.

Data analysis

Different fragments produced with each primer were numbered sequentially. Presence or absence of fragments in each sample was recorded in a binary matrix for each taxa as 1 (present) or 0 (absent). The matrix was analysed using the polymorphism parsimony method in the phylogenetic inference package PHYLIP (V3.5 phylogenetic inference software; Felsenstein,1993). The data were used to calculate Nei's similarity index: $S_{AB}=2N_{AB}/(N_A+N_B)$, where N_{AB} is the number of shared fragments, N_A the number of fragments from species A, and

N_B the number of fragments from specie B(Nei & li, 1979). The similarity index matrices were then transformed into distances (d) using the formula d=1-S (Swofford & Olsen, 1990). The distance matrices were subjected to cluster analysis using the program NEIGHBOR in PHYLIP with the UPGMA (unweighted pair group method with arithmetic mean) algorithm and NJ (neighbor joining). Phenograms were plotted with the program DRAWGRAM in PHYLIP.

RESULT

Amplification of DNA from shrimps

The amplifications were carried out twice independently using the same PCR machine (PE9600), obtaining reproducible results. Amplifications with 20 primers under predetermined optimal reaction conditions gave 262 reproducible amplified fragments ranged from 230 to 2800bp. The primers gave different species-specific patterns in terms of length and intensity of the amplification fragments (Fig. 1 shows, as examples, RAPDs obtained with primers OPL-07 and OPV-07).

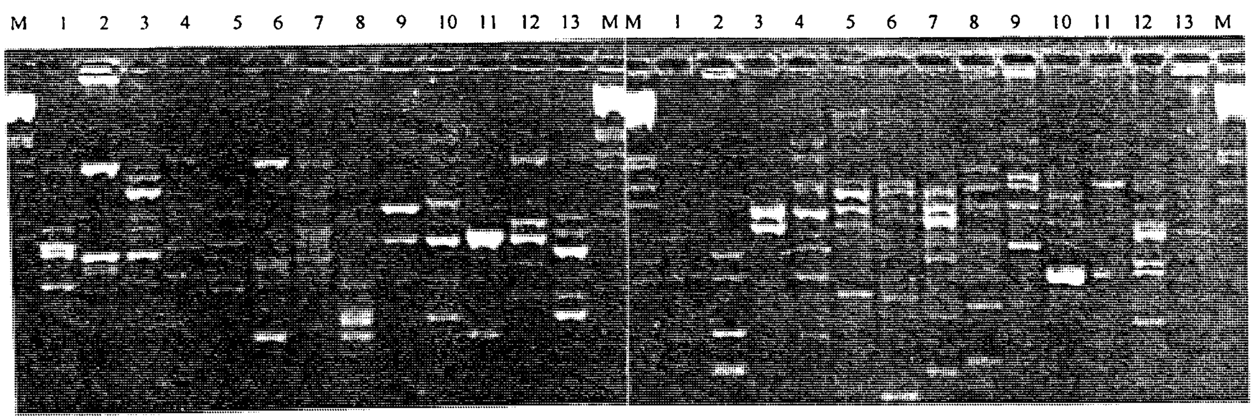

Figure 1. The electrophoresis patterns of RAPD from six species of shrimps in genus of *Penaeus* after random amplified with primers L-07, V-07.

1: *Parapenaeopsis hungerfordi;* 2: *Metapenaeus affinis*; 3: *Metapenaeus joyneri*; 4: *Parapenaeopsis tenella*; 5: *Trachypenaeus curvirostris*; 6: *Exopalaemon carinicauda*; 7: *Crangon affinis*; 8: *Penaeus chinensis*; 9: *Penaeus penicillatus*; 10: *Penaeus merguiensis*; 11: *Penaeus monodon*; 12: *Penaeus japonicus*; 13: *Penaeus vannamei*; M: λDNA Hind III/EcoR I

Analysis of RAPD data

The fragments in each sample were recorded in a binary matrix for each taxa as 1 (present) or 0 (absent), and the matrix was analysed using the polymorphism parsimony method in PHYLIP, giving the phylogenetic tree (Fig. 2). The data on band sharing were collected and analysed as discribed, generated similarity index matrices and distance matrices shown in table 1, in which values of S, the similarity index (also called the proportion of shared fragments) between the species, are shown to the right of the diagonal, and the values of d, the genetic distance, are shown to the left of the diagonal. Using the methods of UPGMA and NJ in the program NEIGHBOR in PHYLIP, the best trees for these data were generated and is shown in Fig. 3 and Fig. 4. They are in good agreement with the result in Fig. 2.

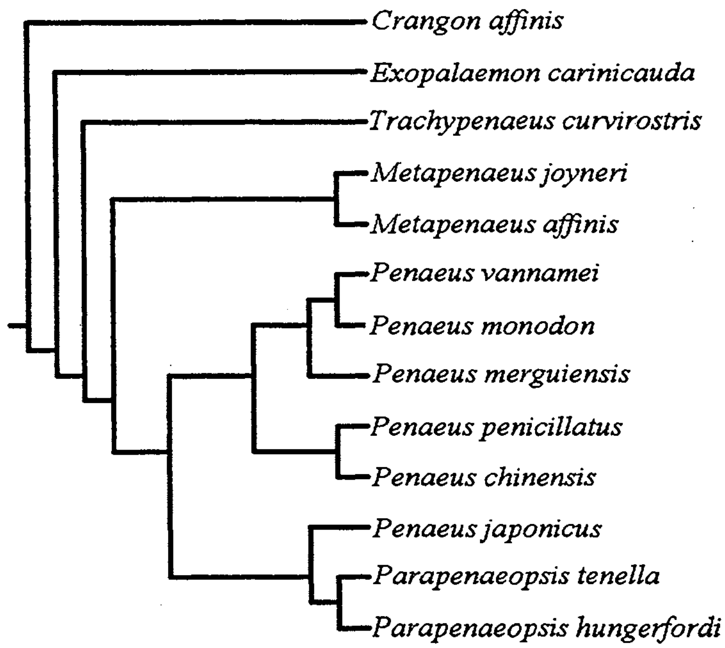

Figure 2. Parsimony tree based on 1000 bootstrap replicates with the present or absent of amplified polymorphic DNA fragments

Table 1. Matrix showing values of S (similarity index) to the right of the diagonal, and the values of d (the genetic distance) to the left of the diagonal

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	—	0.1875	0.1799	0.3582	0.0909	0.0896	0.1493	0.1644	0.1212	0.1067	0.1428	0.3056	0.1000
2	0.8125	—	0.3944	0.1408	0.2286	0.1972	0.1972	0.1558	0.0909	0.1333	0.1429	0.1944	0.0667
3	0.8201	0.6056	—	0.2500	0.1644	0.2432	0.3514	0.2500	0.1515	0.0800	0.1071	0.1772	0.1194
4	0.6418	0.8592	0.7500	—	0.2740	0.1622	0.1351	0.1250	0.2192	0.1463	0.1905	0.2532	0.1194
5	0.9091	0.7714	0.8356	0.7260	—	0.3836	0.2466	0.1013	0.1944	0.1975	0.1290	0.1539	0.1212
6	0.9104	0.8028	0.7568	0.8378	0.6164	—	0.4865	0.1500	0.1370	0.2195	0.1587	0.2025	0.1791
7	0.8507	0.8028	0.6486	0.8649	0.7534	0.5135	—	0.1500	0.1644	0.1951	0.1905	0.3038	0.3284
8	0.8356	0.8442	0.7500	0.8750	0.8987	0.8500	0.8500	—	0.4051	0.3182	0.2029	0.2118	0.1370
9	0.8788	0.9091	0.8485	0.7808	0.8056	0.8630	0.8356	0.5949	—	0.4196	0.2581	0.1539	0.1212
10	0.8933	0.8667	0.9200	0.8537	0.8025	0.7805	0.8049	0.6818	0.5804	—	0.3662	0.2299	0.1867
11	0.8572	0.8571	0.8929	0.8095	0.8710	0.8413	0.8095	0.7971	0.7419	0.6338	—	0.2647	0.2857
12	0.7522	0.8056	0.8228	0.8175	0.8461	0.7975	0.6962	0.7882	0.8461	0.7701	0.7353	—	0.2222
13	0.9000	0.9333	0.8806	0.8806	0.8788	0.8209	0.6716	0.8630	0.8788	0.8133	0.7143	0.7778	—

1: *Parapenaeopsis hungerfordi;* 2: *Metapenaeus affinis*; 3: *Metapenaeus joyneri*; 4:

Parapenaeopsis tenella; 5: *Trachypenaeus curvirostris*; 6: *Exopalaemon carinicauda*; 7: *Crangon affinis*; 8:*Penaeus chinensis*; 9: *Penaeus penicillatus*; 10: *Penaeus merguiensis*; 11: *Penaeus monodon*; 12: *Penaeus japonicus*; 13: *Penaeus vannamei.*

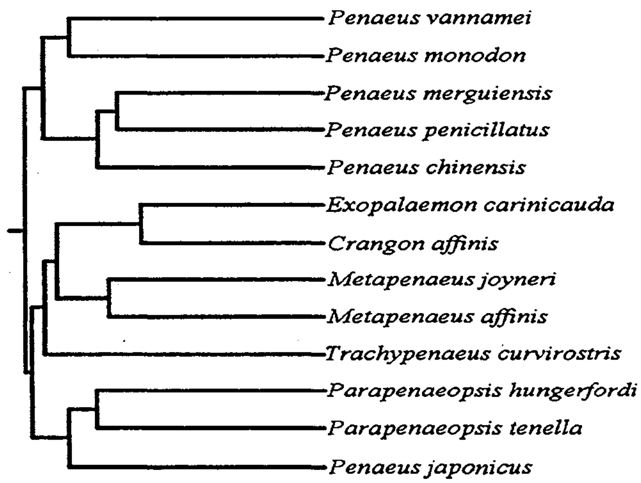

Figure 3. Phylogenetic tree based on the genetic distance matrices with the method of UPGMA

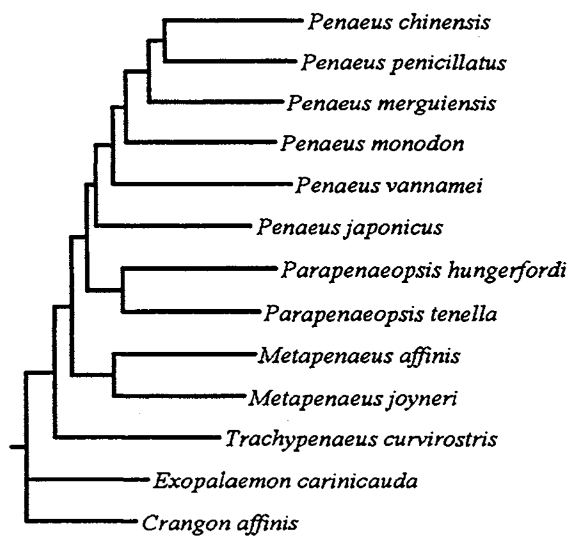

Figure 4. Phylogenetic tree based on the genetic distance matrices with the method of NJ

DISCUSSION

Advances in biochemical and molecular methods greatly improve our ability to observe variablity among individuals for specific gene products and genes themselves. Protein electrophgoresis was the first molecular method to have broad applications to acquaculture. Compared with other animals, decapod crustaceans have relatively low levels of genetically enzyme (isozyme) variation (Nelson and Hedgecock 1980; Hedgecock et al. 1982); both freashwater prawn (Hedgecock et al. 1979) and penaeid shrimp (Lester 1979; Mulley and Latter 1981 a,b; Lester 1983) fit in this general pattern. The few isozyme markers available in shrimp and prawns limit their usefulness in species identification, pedigree confirmation and analysis, and the study of genetic diversity. Newer methods for studying variation in DNA promise to reveal much more extensive variations. The analysis of nucleotide sequence variability has been revolutionized by the development of the polymerase chain reaction (PCR) (Saiki et al., 1988). Random amplified polymorphic DNA (RAPD) (Welsh and McCelland, 1990; Williams et al., 1990) is a PCR based method used for identification purposes. We applied the RAPD analysis to the study of the systematic relationships among marine shrimps. This technique is rapid and useful to detect large amounts of polymorphism. In essence, the RAPD assay utilises a novel feature of the PCR such that a single oligonucleotide primer of arbitrary nucleotide sequence and length (between 5-20 bases) is used to initiate DNA strand synthesis. This primer will anneal, under conditions of low stringency, to a number of complementary binding sites scattered throughout the target genome and ensuing thermal cycling often generates several amplification products within a single reaction. Considerable advantages of the teachnique are that no prior knowledge of the molecular biology of the investigated organisms is required and it is very cost-effective. Theoretically, the number of DNA polymorphisms that can be detected with RAPD analysis is greater than with traditional methods.

The thirteen species of marine shrimps used in the present study belong to Caridea in Pleocyemata and Penaeoidea in Dendrobranchiata respectively. *Exopalaemon carinicauda and Crangon affinis* belong to Palaemonidae and Crangonidae in Caridae respectively. The other 11 species belong to four genus in Peaeidae, Penaeoidea. The dendrogroms of fig. 2, 3, 4 clearly showed the phylogenetic relationships between the 13 species of shrimps. *Exopalaemon carinicauda*, *Crangon affinis* and the other 11 species of shrimp belong to different suborders, so they are separated by a relatively large distance in the phylograms. The shrimps in the family of Penaeoidea cluster together, and the species in similary genus cluster together first except *Penaeus japonicus* in the genues of *Penaeus* (Fig. 2, 3). We can find in Fig. 2,3,4 that *Parapenaeopsis hungerfordi* and *Parapenaeopsis tenella* cluster together; *Metapenaeus affinis* and *Metapenaeus joyneri* cluster together; *Penaeus chinensis*, *Penaeus penicillatus*, *Penaeus merguiensis*, *Penaeus monodon and Penaeus vannamei* cluster toghter. In the genues of *Penaeu*, there is a high level of genetic variations; species similar in morphological characters share a higher similarity on genomic DNA, on the contrary, the similarity is lower. For example, *Penaeus chinensis*, *Penaeus penicillatus* and *Penaeus merguiensis* are very similar in morphology. In fact, it is very difficult to identify them during the period of larva, so they cluster together first, while *Penaeus vannamei*, distributed in eastern Pacific region and seperated from the other species in a large distance, shares a low similarity with the other *Penaeus* spp..

The taxonomy in the genus of *Penaeus* containing only 28 species has been disputed for a long time. Burkenroad (1934) observed that numbers of the genus fell into two groups or divisions, in one of which the adrostral carinae and sulci reach to the posterior border of the carapace and a gastrofrontal carina is present, whereas in the other group the adrostral carinae and sulci do not reach to the posterior borber and there are no gastrofrontal sulci. The former division has other characteristic facies and its members are known in many parts of the world as "grooved shrimp" (or prawns).

Kubo (1949) divided the second group into two additional divisions, mainly on the basis of the presence or absence of an hepatic carina. Perez Farfante (1969) further separeated the open thelycum American *Penaeus*spp. and raised these four groups to subgeneric status: *Penaeus* (*Penaeus*), *P. monodon* group (with an hepatic carina); *Penaeus* (*Fenneropenaeus*), *P indicus* group (without an hepatic carina); *Penaeus* (*Litopenaeus*), open thelycum types; *Penaeus* (*Melicertus*), grooved prawns. Subsequent authors have separated the American grooved prawns into *Penaeus* (Farfantepenaeus). Tirmizi (1971) observed that the thelycum of *Penaeus japonicus* was seminal receptacle pouch-like, open crosswise in the front, which was unique in the genus of *Penaeus*, and different from the thelycums of other species, which were disc-like and open longitudinally. Thus, he separated *Penaeus japonicus* into *Penaeus* (*Marsupanaeus*). The cluster results in the present study are in agreement with the conclusion mentioned above, *Penaeus japonicus* culster together with the other 5 species in *Penaeus* genus finally (Fig. 4), and even cluster together with the 2 species in *Parapenaeopsis* genus (Fig. 2, 3).

The data suggest that RAPDs can clearly show differences between suborders, families, genus, and species in marine shrimps, and can provide an efficient and sensitive method to dectect the variability, and to estimate the status of organisms of controversial systematics.

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CORAL TRANSPLANTATION AS A REEF CONSERVATION TOOL - THE SINGAPORE EXPERIENCE

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ABSTRACT

Corals transplanted to Sentosa, an island south of the main island of Singapore, from a reef due for reclamation, were monitored and assessed one year after completion of a massive two-year transplantation exercise. This transplantation exercise was conducted by the Marine Conservation Group of the Nature Society (Singapore). Assessment of the 3m x 3m permanent quadrat showed that 24.29% of transplants remained healthy, while 57.14% were impacted or dying and the remaining 18.57% completely dead. The broad scale belt transect survey showed that 35.27% of the translocated corals were healthy, while 43.04% were impacted or dying and 21.69% completely dead. The low survival rate could be attributed to 2 main factors : improper securing techniques and unfavourable site conditions. The results also indicated that certain coral growthforms (mushroom, encrusting and massive) and genera (*Fungia, Herpolitha, Favia, Platygyra, Favites, Goniopora* and *Turbinaria*) were more suitable transplants than others.

INTRODUCTION

Coral transplantation as a means to aid reef rehabilitation, promote reef development, increase juvenile coral recruitment or save corals threatened by development has been carried out in many parts of the world with varying success (Birkeland *et al.*, 1979; Buchon *et al.*, 1981; Alcala *et al.*, 1982; Auberson, 1982; Plucer-Rosario & Randall, 1987; Harriott and Fisk, 1988a, Yap *et al.* 1992; Clark & Edwards, 1995). A brief description of various coral transplantation techniques is discussed in Harriot and Fisk (1988b) while Yap *et al.* (1992) highlights various considerations that should be considered in planning a coral transplantation exercise.

In 1991, the Marine Conservation Group (MCG) of the Nature Society (Singapore), embarked on a coral transplantation exercise dubbed Reef Rescue 1 (RR1). RR1 involved transplantation of 10m^2 to 12m^2 of corals and other reef organisms from Buran Darat to Sentosa (The Straits Times, 1993). The MCG claimed survival rates of between 70% to 90% (Nature News, 1992, 1993; The Straits Times, 1992), and embarked on a second transplantation exercise - Reef Rescue 2 (RR2), which involved transplantation of corals and other reef organisms from another island destined for reclamation to a second site at Sentosa. Undertaken on a larger scale, 450 volunteers spent over 10,000 man-hours to transplant approximately 500m^2 of corals from Pulau Ayer Chawan to Sentosa between July 1993 to June 1995, at a cost of S$50,000 (Nature Watch, 1995). The Reef Ecology Study Team (REST), of the School of Biological Sciences, National University of Singapore, was requested to monitor the health and survival of the transplanted corals.

MATERIALS AND METHODS

Collection and Transplantation

The first trip under RR2 started in July 1993, and continued once every week (Sunday), for two years. As the transplants were not to be anchored to the site by cement, ropes or any other means except to be wedged between existing granite boulders, only large colonies of corals and other reef invertebrates were selected. Once removed, transplants were placed in plastic baskets (some with draining slots), brought to the surface, and transferred onto boats where they were placed in large plastic tubs filled with aerated seawater. Each collection trip averaged between 1hr to 1.5hrs, with an additional 1.5hrs taken to get to Sentosa, the transplantation site. At Sentosa, the transplants were transferred to dry containers, floated by divers or snorkellers to the transplantation sites, and then sunk (Nature News, 1993).

Monitoring

The Reef Ecology Study Team (REST) was not involved in the planning and execution of RR2, and had to design a monitoring programme based on work done by the MCG. The transplantation area outside the lagoon mouth was not specifically defined or mapped out, and thus, there was no defined area to confine the monitoring programme to. In addition, background information on the number of corals, their growthform, genera or species, their sizes, the depths they were collected from, their condition, and the characteristic/s of the substrata at the time of transplantation were not recorded by the MCG.

The establishment of a 3m x 3m permanent quadrat towards the end of RR2 allowed the monitoring and assessment of a definite number of transplanted corals over time. However, a single permanent quadrat to assess the condition of the translocated corals was deemed insufficient to represent the entire population of transplanted corals and a belt transect was included covering a larger area.

The 3m x 3m permanent quadrat was surveyed twice; once in early 1995, soon after corals were transplanted to it, and again in June 1996. Visual mapping was made using 1m x 1m frames. In the first survey, transplants within quadrat were identified, mapped and tagged with waterproof drafting film. In the second survey, transplants were monitored for growth and survival.

Before belt transects were laid out, an initial visual census was conducted to identify the general area of the transplants. It was estimated that the transplants were randomly placed within an area spanning approximately 150m x 30m, or 4500m^2 and that belt transects totalling 500m^2 (or about 10% of the total transplantation area) was a sufficient representation. Within these transects, growthform, genera, size, % colony survival and colony condition were recorded.

Data analysis

The map of the permanent quadrat was redrawn onto a 30cm x 30cm sheet of drafting film and then scanned using a Microtek flatbed scanner. The scanned image was then transferred to an image processing software (SigmaScan/Image 1.20.09), scaled appropriately, before calculating the area of each coral within the permanent quadrat. Field data of the belt transects were keyed into a database (created using Microsoft Access 7.0 for Windows 95) and the area of individual transplants were estimated by taking the product of their length and width measurements.

For both the permanent quadrat and belt transect surveys, the percentage of individual transplant surface that was visibly alive was estimated and recorded as percentage colony survival (ColS). These estimations made it possible to group the corals into three "survival" categories as follows:

Healthy	ColS=100%
Impacted	0%<ColS<100%
Dead	ColS=0%

The size of the transplants (ColSz) were also grouped into three general guilds as follows :

Small	$0m^2$<ColSz<$0.01m^2$ ($100cm^2$)
Medium	$0.01m^2$≤ColSz<$0.05m^2$ ($500cm^2$)
Large	ColSz≥$0.05m^2$

RESULTS

Permanent Quadrat

A total of 114 transplants from 28 genera representing five growthform types were mapped in the 1995 survey (Fig. 1a, Table 1). Of these, 112 were hard corals, with one sea anemone (*Heteractis magnifica*) and one sponge (*Petrosia* sp.) making up the remaining two. All transplants were in the Healthy category. Massive and foliose corals were the dominant growthforms transplanted, accounting for 35.96% (41 corals) and 39.47% (46 corals) of the total number of corals. About 1/3 of the transplanted corals were small colonies (39; 34.21%), while just over 1/2 of them were medium-sized colonies (63; 54.39%) and the remaining 10.53% (12 corals) were large colonies. Some genera were represented by one or two individuals, while others had more than ten. The genus *Pectinia* was most abundant with 26 corals (22.81%) transplanted, followed by *Favia* with 17 corals (14.91%) and *Plerogyra* with 12 (10.53%).

One year after the first survey, the transplants within the permanent quadrat showed varying degrees of impact (Fig. 1b, Table 2). Seventy transplants left, representing 24 genera from 5 growthforms. This translates to a 38.6% decrease in the number of transplants. A total of 13 (18.57% of the total) transplants were dead, with 40 (57.14%) impacted and 17 (24.29%) still healthy. The number of large colonies did not change but the number of small and medium sized colonies decreased by 1/2 and 1/3 respectively. Of the transplants 68 were hard corals and 2 were sponges. The single sea anemone recorded in 1995 was not present.

Both the number of foliose and massive corals decreased by almost 1/2, while mushroom corals decreased by 3/4. Submassive corals showed the lowest decrease in number.

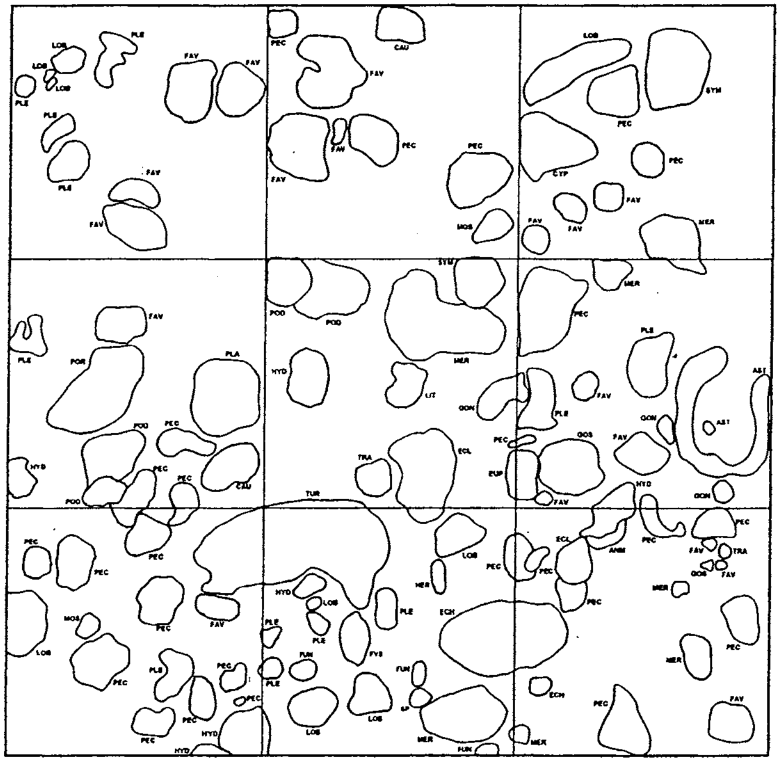

Figure 1a. Map of permanent quadrat for 1995.

Number of corals within quadrat - 114
Number of healthy corals - 114
Number of corals with partial mortality - 0
Number of corals completely dead - 0

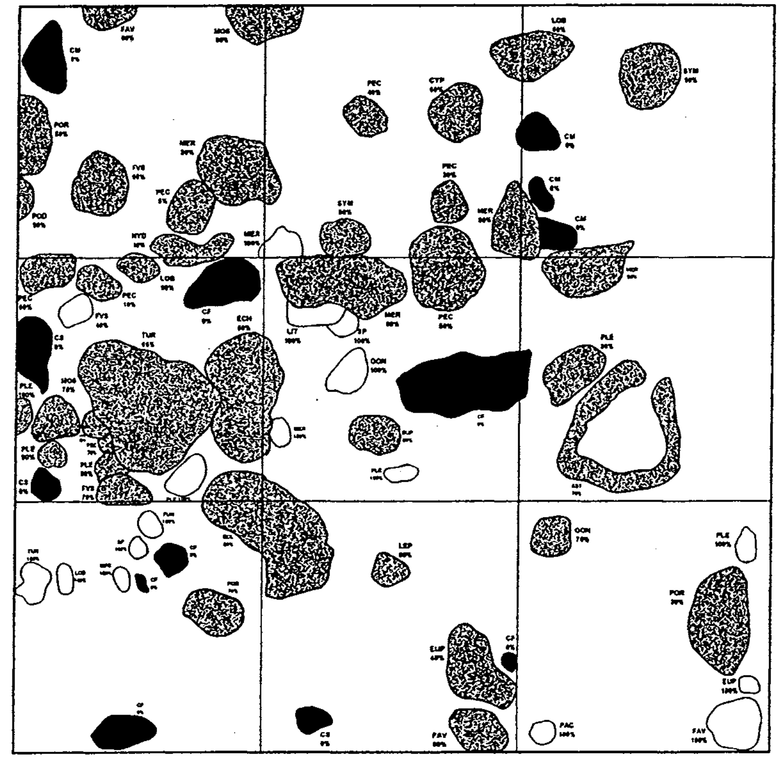

Figure 1b. Map of permanent quadrat for 1996.

Number of corals within quadrat - 70
Number of healthy corals - 17 (white)
Number of corals with partial mortality - 40 (grey)
Number of corals completely dead - 13 (black)

Codes used for coral genera :
AST - *Astreopora*; CYP - *Cyphastrea*; ECH - *Echinopora*; ECL - *Echinophyllia*; EUP - *Euphyllia*; FAV - *Favia*; FUN - *Fungia*; FVS - *Favites*; GON - *Goniopora*; HYD - *Hydnophora*; LEP - *Leptoria*; LIT - *Lithophyllon*; LOB - *Lobophyllia*; MER - *Merulina*; MOS - *Montastrea*; PAC - *Pachyseris*; PAV - *Pavona*; PEC - *Pectinia*; PLE - *Plerogyra*; POD - *Podabacia*; POR - *Porites*; PET - *Petrosia* (sponge); SYM - *Symphyllia*; TUR - *Turbinaria*; XXX - unidentified coral genera.

Table 1. First survey (1995) of the permanent quadrat; (a) Growthform distribution; (b) Size distribution.

(a)

GROWTH-FORM (GF)	ColS = 100 (HEALTHY)		% OF TOTAL
	NO OF CORALS	% OF GF	
CF	41	100	35.96
CM	46	100	39.47
CMR	4	100	3.51
CS	21	100	19.30
OT	2	100	1.75
TOTAL	114		100.00

CF=Foliose coral; CM=Massive coral; CMR=Mushroom coral;
CS=Submassive coral; SC=Soft coral;
OT=Other fauna (e.g., sponge, sea anemone)
ColS = Colony Survival (% of coral colony alive)

(b)

SIZE GUILD (ColSz)	ColSz = 100 (HEALTHY)		% OF TOTAL
	NO OF CORALS	% OF SIZE	
SMALL	39	100	34.21
MEDIUM	63	100	55.26
LARGE	12	100	10.53
	114		100.00

Small $0m^2<ColSz<0.01m^2$ ($100cm^2$)
Medium $0.01m^2\leq ColSz<0.05m^2$ ($500cm^2$)
Large $ColSz\geq 0.05m^2$
ColSz = Colony Size

Table 2. Second survey (1996) of the permanent quadrat; (a) Growthform distribution; (b) Size distribution.

(a)

GROWTH-FORM (GF)	ColS = 0 (DEAD)		25 < ColS <100 (IMPACTED)		ColS = 100 (HEALTHY)		TOTAL NO OF CORALS	% OF TOTAL
	NO OF CORALS	% OF GF	NO OF CORALS	% OF GF	NO OF CORALS	% OF GF		
CF	6	23.08	14	53.85	6	23.08	26	37.14
CM	4	16.67	18	75.00	2	8.33	24	34.29
CMR					1	100.00	1	1.43
CS	3	17.65	8	47.06	6	35.29	17	24.29
OT					2	100.00	2	2.86
TOTAL	13		40		17		70	100.00

CF=Foliose coral; CM=Massive coral; CMR=Mushroom coral; CS=Submassive coral; SC=Soft coral; OT=Other fauna (e.g., sponge, sea anemone). ColS = Colony Survival (% of coral colony alive).

(b)

SIZE GUILD (ColSz)	ColS = 0 (DEAD)		25 < ColS <100 (IMPACTED)		ColS = 100 (HEALTHY)		TOTAL NO OF CORALS	% OF TOTAL
	NO OF CORALS	% OF SIZE	NO OF CORALS	% OF SIZE	NO OF CORALS	% OF SIZE		
SMALL	3	16.67	2	27.78	10	55.56	18	25.71
MEDIUM	9	22.50	26	65.00	5	12.50	40	57.12
LARGE	1	8.33	9	75.00	2	16.67	12	17.14
TOTAL	13		40		17		70	100.00

Small $0m^2<ColSz<0.01m^2$ ($100cm^2$)
Medium $0.01m^2\leq ColSz<0.05m^2$ ($500cm^2$)
Large $ColSz\geq 0.05m^2$
ColSz = Colony Size

Table 3. Results of the belt transect survey conducted in 1996; (a) Growthform distribution; (b) Size distribution.

(a)

GROWTH-FORM (GF)	ColS = 0 (DEAD)		25 < ColS <100 (IMPACTED)		ColS = 100 (HEALTHY)		TOTAL NO OF CORALS	% OF TOTAL
	NO OF CORALS	% OF GF	NO OF CORALS	% OF GF	NO OF CORALS	% OF GF		
ACB			2	100.00			2	0.23
CB	3	30.00	6	60.00	1	10.00	10	1.14
CE	1	5.88	4	23.53	12	70.59	17	1.94
CF	47	20.80	128	56.64	51	22.57	226	25.80
CM	23	10.45	117	53.18	80	36.36	220	15.11
CMR	17	16.50	10	9.71	76	73.79	103	11.76
CS	36	17.48	109	52.91	61	29.61	206	23.52
OT			1	2.56	19	61.29	31	3.54
SC					9	100.00	9	1.03
XXX	63	100.00					63	7.19
TOTAL	**190**		**377**		**309**		**876**	**100.00**

ACB =Branching *Acropora*; CB=Branching coral; CE=Encrusting coral; CF=Foliose coral; CM=Massive coral; CMR=Mushroom coral; CS=Submassive coral; SC=Soft coral; OT=Other fauna (e.g., sponge, sea anemone); XXX=Unidentified dead coral. ColS = Colony Survival (% of coral colony alive).

(b)

SIZE GUILD (ColSz)	ColS = 0 (DEAD)		25 < ColS <100 (IMPACTED)		ColS = 100 (HEALTHY)		TOTAL NO OF CORALS	% OF TOTAL
	NO OF CORALS	% OF SIZE	NO OF CORALS	% OF SIZE	NO OF CORALS	% OF SIZE		
SMALL	8	18.60	5	11.63	30	69.77	43	4.91
MEDIUM	95	20.83	182	39.91	179	39.25	456	52.05
LARGE	87	23.08	190	50.40	100	26.53	377	43.04
TOTAL	**190**		**337**		**309**		**876**	**100.00**

Small $0m^2<ColSz<0.01m^2$ ($100cm^2$)
Medium $0.01m^2 \leq ColSz<0.05m^2$ ($500cm^2$)
Large $ColSz \geq 0.05m^2$
ColSz = Colony Size

Majority of corals within the three major growthform guilds were impacted. Although both foliose and submassive corals had the highest number of healthy corals (6 each) in 1996, overall the submassive corals showed better survival rates when compared to the numbers present in 1995. The total number of dead corals were only 13, but this number does not account for the 38.6% missing from the original group of transplants. If the missing transplants are assumed to be dead, then the percent dead corals would increase to 50% of the original 114 transplants. Of the three size guilds, small corals, despite decreasing by almost half the number, showed the greatest survival.

The most abundant genera encountered were *Plerogyra* and *Merulina* with seven colonies each (10% of total), followed by *Pectinia* with six colonies (8.57%). The remaining 21 genera were represented by between one to three colonies only.

The PQ maps of 1995 and 1996 (Figures 1a & 1b) show marked differences in the size, position and to a smaller extent, generic composition of the transplants. A year after the first survey, a large number of small and medium sized transplants were missing from the quadrat. This was due to the transplants being swept out of the quadrat. There also appeared to be a shift in the overall positions of the remaining transplants, suggesting that the area was exposed to strong wave action.

Belt Transect

Tables 3a and 3b list the results of the belt transect survey conducted in 1996. A total of 876 transplants representing 40 genera from eight growthform types were recorded within the 500m^2 survey area, giving it a density of 1.75 colonies/m^2. The substratum cover consisted of rock boulders (58.17%), sand (19.01%), silt (9.1%), live coral (6.4%), algal assemblage (5.14%) and dead coral (1.83%). Almost all substrata, with the exception of live coral and algal assemblage, was covered with a thin layer of filamentous algae. Of the 876 transplants, 309 (35.26%) were healthy, 377 (43.01%) impacted and 154 (21.69%) dead. Hard corals made up the bulk of transplants with 693 live and 154 dead individuals. A total of 14 anemones (*Heteractis magnifica*), 9 soft corals (*Sinularia* sp.) and 6 sponges (*Petrosia* sp.) were also encountered. Foliose, massive and submassive corals were the most abundant growthforms transplanted, accounting for 25.8% (226 colonies), 25.11% (220 colonies) and 23.52% (206 colonies) of the total number of corals. Mushroom corals accounted for 103 colonies (11.76%) while the remaining growthforms were represented by fewer than 40 colonies each. The 63 dead colonies were not recognisable even to growthform level, and were given a code of XXX.

Only 4.91% of the transplants encountered were small, while medium and large transplants made up 52.05% and 42.04% of the total respectively. The percentage of dead transplants for each size guild was similar (between 18.6% and 23.08%). Small transplants survived well with almost 70% within the size guild healthy, but since the total number of small transplants was low to begin with (43 out of 876), the high percentage of healthy transplants does not necessarily reflect better survivorship over the medium or larger transplants. Visual observations during the survey indicated that many small dead transplants were overlooked as they were either broken into fragments or completely covered with a thick algal mat and were not taken into account. For all growthforms, the percentage of dead colonies did not exceed 30%. Instead, majority of the growthforms had colonies which were impacted. Encrusting and mushroom corals registered the greatest number of colonies in the healthy category.

The genus *Plerogyra* was the most abundant with 91 colonies (10.39% of the total). Other common genera were *Fungia* (84 colonies; 9.59%), *Pectinia* (72 colonies, 8.22%) and *Favia* (51 colonies, 5.82%). Half the number of coral genera (22, 55%) were represented by fewer than 10 colonies each. Based on percentage healthy transplants per genera, several genera showed better survival. Non-hard coral reef invertebrates survived the transplantation better; between 83% and 100% of the sea anemones, sponges and soft corals were healthy. Free living mushroom corals (*Fungia* sp. and *Herpolitha* sp.) survived well with over 75% individuals still healthy. Other genera with good to moderate survival include submassive *Goniopora* sp. (63%), foliose *Turbinaria* sp. (51%), massive *Favia* sp. (51%), *Platygyra* sp. (45%) and *Favites* sp. (40%).

DISCUSSION

Studies on transplantation (almost exclusively on hard coral) have been conducted by various researchers as early as the 1970's, and these studies have shown that even with controlled and carefully planned experiments, survivorship of transplants are not high. Harriott and Fisk (1988b) gave a comprehensive summary of published results of experiments testing coral transplantation by various researchers. Results of both the permanent quadrat and belt transect surveys indicated that generally, the survivorship of transplants one year after transplantation is comparable with other published results (example, see Alcala *et al.*, 1982, Plucer-Rosario & Randall, 1987 and Harriott & Fisk, 1988a). The transplants however, did not show potential long term survivorship.

A major reason for the low survivorship of the transplanted corals was the unsuitability of the site. Coral were transplanted beyond the opening of a man-made lagoon, at depths of between 3m to 4m (at mean spring tide). The entire southwestern coastline of Sentosa is subjected to constant surges caused by high speed ferry boats plying daily, and since the transplants were not secured firmly to the substratum, they were subjected to the full force of the surges. During the survey, it was noted that many of the colonies were either overturned or on their sides. The transplantation site was subjected to sediment stress. In addition, reclamation works along the eastern coastline of Sentosa added to the sediment load of the water. Algal growth at the site was also intense such that many transplants were completely overgrown by macroaglae and had little chance of survival.

Clark and Edwards (1995) discussed survivorship of various coral species based on transplant studies conducted by them and others. The fact that a large number of transplants from 40 genera and eight growthform types provided an opportunity to assess the survivorship of a great variety of transplants. Certain coral growthforms and genera fared better than others. Mushroom, massive and encrusting growthforms showed the highest survivorship, as did the genera *Fungia* and *Herpolitha* (mushroom), *Favia*, *Platygyra* and *Favites* (massive), *Goniopora* (submassive) and *Turbinaria* (foliose). In addition, several non-coral reef invertebrates also showed high survivorship. These included the sea anemone *Heteractis magnifica*, the soft coral *Sinularia* sp. and the neptune's cup sponge *Petrosia* sp.

The deployment of proper transplantation techniques such as extraction, handling, positioning and securing of transplants are essential for their long-term survival. Many reef invertebrates, especially corals, are easily stressed and therefore, need to be handled carefully. Yap *et al.* (1990) gave a brief yet detailed summary on proper transplantation techniques.

Although care was taken by the MCG to ensure that proper transplantation techniques were used as much as possible, they did not manage to properly secure transplants onto the substratum. Wedging transplants between granite boulders did not prevent the consistent wave and surge action from tossing them about.

Several general conclusions can be derived from this study:

1) Favourable recipient site conditions are essential for long term survivorship of transplants. Ideally, recipient site should possess similar environmental characteristics as the donor site, and with minimal anthropogenic impacts. In Singapore's coastal waters, the growth and

proliferation of macroalgae is intense along reef-flats and reef-crests, but diminishes rapidly down the reef slope. Thus, securing a recipient site between the depths of 3m to 6m may increase the survivorship of transplants in Singapore waters.

2) Transplants should be properly secured to the substratum to withstand wave action. The use of cement is highly recommenced, and where necessary, masonry nails to secure larger coral colonies.

3) Certain coral growthforms and genera fared better than others. Mushroom, massive and encrusting growthforms showed the highest survivorship, as did the genera *Fungia* and *Herpolitha* (mushroom), *Favia*, *Platygyra* and *Favites* (massive), *Goniopora* (submassive) and *Turbinaria* (foliose).

4) Several non-coral reef invertebrates survival well, such as the sea anemone *Heteractis magnifica*, the soft coral *Sinularia* sp. and the neptune's cup sponge *Petrosia* sp.

5) The number of transplants, the density and position in relation to each other are important considerations. Inter- and intra-specific competition between transplants should be minimised as much as possible, and to achieve this, a good scientific knowledge on the biology and ecology of the transplants is essential.

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INTEGRATED COASTAL ZONE MANAGEMENT: THE PHILIPPINE EXPERIENCE

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ABSTRACT

The concept of integrated coastal zone management (ICZM) is relatively new in the Philippines although initial efforts were made on it in the mid-70s. The approaches of community-based management and co-management of coastal resources have been advocated in the country since the late 1980s.

The three major programs on ICZM discussed are the Central Visayas Regional Project, the Fisheries Sector Program and Coastal Environment Program. The experiences from these show the need for active community participation, integration of multisectoral efforts and strong institutional support in the ICZM process.

INTRODUCTION

The concept of integrated coastal zone management (ICZM) is believed to have been developed in the United States with the United States Coastal Zone Management Act of 1977. The coastal zone is defined as the area between the seaward margin of the continental shelves to a depth of about 200 m and the inland limits of the coastal plains to an altitude of about 200 m. ICZM involves the process of combining all aspects of the physical, biological and human components of the coastal zone within a single management framework (Pernetta and Elder, 1993).

The United Nations Conference on Environment and Development of 1992 emphasized the need for sustainable development of oceans and coastal areas by coastal and island states through ICZM.

The Philippines is an archipelagic state with over 7,000 islands and a discontinuous coastline of 18,000 km. Eighty percent of the country's present population of about 70 million live within 50 km of the coast. The country has a total marine area of 1,666,380 km^2, 16% of which are coastal waters.

Like most developing coastal states, the Philippines has its share of problems concerning the management of the coastal zone. With population growth and increasing human impacts on the environment, depletion of coastal resources such as mangroves and coral reefs has occurred. Overexploitation of the marine fisheries and extensive degradation of coastal habitats are much evident. The poverty of coastal communities throughout the country is also pervasive.

There have been efforts made in the Philippines to address the need for sound management of the coastal zone since the mid-70s. The Silliman University, a private institution in Central Visayas, Philippines, established the first protected marine area in Sumilon Island in 1974 (Russ and Alcala, 1994). From the previous centralized management of coastal resources by the national government in the 70s, there was a shift to the community-based management strategy in the 80s, and finally to the multisectoral co-management approach in the 90s.

This paper shall discuss the three major programs on integrated coastal zone management conducted in the Philippines, namely, the Central Visayas Regional Project, the Fisheries Sector Program and the current Coastal Environment Program.

MAJOR PHILIPPINE ICZM PROGRAMS

Central Visayas Regional Project (CVRP)

The CVRP was implemented in 1984 in Central Visayas, Philippines with support from the World Bank. The project was designed to stabilize and improve the coastal resource base through community-based resource management. Recognizing fisherfolk as the "day-to-day managers" of the coastal resources the project stressed the development of local capabilities for coastal resources management (Bojos, 1996).

With five sites, the project activities included family-managed artificial reef clusters, protection and management of coral reefs, mariculture on protected and managed reefs, and local control of illegal and destructive fishing methods.

The six-year project was considered a success in that it demonstrated the importance of community-organizing and the involvement of the community, local government, government line agencies and non-government organizations in the protection and sustainable development of coastal resources (Vande Vusse, 1991).

Fisheries Sector Program (FSP)

The FSP of 1990-1995 had a coastal resources management component which focused on 12 priority bays, 17 provinces and 146 coastal municipalities. In one of the priority bays (San Miguel Bay in the Bicol Region), the integrated coastal fisheries management was adopted. A coastal environment profile, technical report detailing the status of the fisheries and an integrated fisheries management plan were prepared within a two-year period.

The San Miguel Bay experience showed the importance of stakeholder participation at key stages of research planning and management process, the usefulness of decision methods in structuring research planning and associated debates, and the efficacy of research cum planning efforts in ensuring research utilization and relevance and the scientific basis of management planning (Silvestre, 1996).

Coastal Environment Program (CEP)

The Philippine Department of Environment and Natural Resources established the CEP in 1993 guided by the principles of equitable and sustainable resource management. The program has adopted the strategies of community-organizing, involvement of communities in the protection and management in coastal ecosystems, mobilization of financial and administrative resources from the public and private sectors, and the use of contingent approaches in identifying issues, problems and opportunities for human and environmental welfare (Ganapin, 1997).

To date, the program has 62 projects covering 849,848 has of coastal areas in 44 provinces and 104 municipalities. Ten protected areas and 23 model sites have so far been proclaimed.

ICMZ LESSONS LEARNED IN THE PHILIPPINES

The management of common resources requires the control of access to the resources, conservation of the resources, sustainable use of the resources, and local level management of the resources (Berkes, 1987).

The experiences in the Philippines have shown the effectiveness of the community-based management and co-management approaches for ICZM. Ferrer (1992) considered community-organizing as the critical first step to community-based coastal resources management. He defined community-organizing as "a problem-solving approach whereby the community is empowered with the knowledge and skills to identify and prioritize its needs and problems harness and mobilize its human and material resources to deal with these problems, and take action collectively."

While community-organizing is vital to the ICZM process, there are also other indispensable needs that should be provided and in place. Such needs include technical and socioeconomic inputs in a multisectoral and integrated support system, and institutional networking. In sum, the effective management of coastal resources requires the participation of the local community, the integration of multilevel and multisectoral efforts, and the efficient implementation of technical experts and government in a co-management approach (Aliño and Juinio-Meñez, 1996).

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ON A ROBUST MANAGEMENT MODEL FOR SUSTAINABLE COASTAL DEVELOPMENT

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ABSTRACT

A robust management model, which is able to analyse data and provide management decisions, is required for sustainable coastal development. Here, "robust" means that the principle of sustainable development will be observed, even if some mistakes or errors in the background information occur within the data base of the management model. Technically, the GIS and data base techniques can be used to store and analyse the various data sets, in the form of legislation documents, regional plans for social and economic development, and scientific information (on the natural environment and human activities). Based upon these data sets, some maximum capacity criteria for sustainable development can be established. Using the data representing the necessary conditions specified in the application for any proposed development project as the input, the model can examine the feasibility of the project through an internal consistency test. Thus, whether or not the proposed project should be approved will be determined by the management system itself. It is the time now to develop such a model, because of the rapid advancement in the computer science.

INTRODUCTION

Today's human society faces a crisis of population explosion, exhausting natural resources and environment degeneration. The crisis is perhaps more serious in the coastal zone than other land regions. In China, human activities in the coastal zone have exerted huge pressure and have caused serious conflicts between the various parties of the society (Yu, 1994). Hence, the issue of sustainable development in the coastal zone has become more urgent than ever. Sustainable development means that the standard of living for the people should be improved in response to economic growth, and, on the same time, our natural environment must be protected (Cicin-Sain, 1993). This task is not easy, since the coastal zone lies in such a narrow space within which the human activities are highly concentrated.

A solution to this problem may be to establish an effective, integrated management system (Cicin-Sain, 1993). Many theoretical and technical issues must be considered for such a system. In some countries, legislation documents and regional development plans for social and economic developments have been formulated to reduce unfavourable human activities (in the USA, the law *Coastal Management Act* was effective since as early as 1972). However, although such measures are *necessary* for the sustainable development, they do not represent *sufficient* conditions. This is partly because of our insufficient understanding of the natural environment and its evolution: the coastal zone is characterised by active sediment transport and deposition, rapid geomorphological evolution and continuous changes in ecosystems.

Another technique within the frame of the present day management system is to collect and store scientific information using, for instance, a data base software. The computer will provide the data sets when they are needed for management purposes. Such computer softwares are known as management tools. These tools may be helpful to the management official (hence, studies on the relationships between the scientific data and the management tools are required (Healey and Hennessey, 1994)), but they cannot guarantee that the data are used correctly by the official.

Some scientists of coastal researches have suggested that, because our scientific studies are insufficient, a real management model for decision making may not be possible at this stage. They state that more scientific investigations (i.e. more grants for research) must be done. It is not incorrect to argue that continuous support for scientific research is required, but we cannot wait until our scientific understanding is good enough and our scientific data are sufficient. The reasons are that probably the time when we achieve those goals will never come, and the degeneration of the environment is too rapid for us to wait for the scientific progress. As pointed out by M. Elliott (1994), management measures must be taken on the basis of what we have obtained, even if the data are not sufficient.

In order to overcome these difficulties or shortcomings, the way of constructing the management model on the basis of the concept of sustainable development must be considered. In the present contribution, the possibility of establishing one of such models, which is referred to as a "robust" management model, is explored. In particular, the basic framework of the model, including the relationship between scientific data and the management, is described.

CONCEPT AND DEFINITION

For a definition of a robust management model, let us first of all explain what we mean by *management model* and *robust*. Here a management model refers to a computer software which is able to evaluate any human activities within the coastal zone according to the principle of sustainable development; on the basis of this, the model provides the decision of approval or disapproval of any proposed development schemes or projects. By *robust* we mean that the management model will implement the principle for sustainable development, even under the condition that there are mistakes in the input data. As far as the management of coastal areas is concerned, there exist various sources of errors. For instance, the data sets defining the natural processes may contain some errors (because of insufficient scientific research). Such errors may cause inappropriate decisions made by the management system. However, if the management model is able to identify the errors within a short period of time and make corrections so that the sustainability for development is not affected, then it is called a robust model. Hence, a robust management model is a software package which faithfully implement the strategies of sustainable development and provide management decisions on a daily basis for human activities associated with the coastal areas.

Such a model possesses a number of characteristics. Firstly, it does not depend upon a thorough understanding of the science or the natural environment. Secondly, it is highly dynamic i.e. it can be improved continuously in response to changes in the natural environment, modifications of the legislation documents and regional plans, and the progress in scientific research. If some new scientific investigations have been undertaken for a coastal area, then the model for the area will be modified immediately in response to the addition of the new data sets. Thirdly, the reality of development (i.e. the need of continuous changes in development patterns) is taken into account in this model. Under a given development pattern, there exists a limit for economic and social developments, beyond which the environment will be damaged. The environmental damage will, in tern, reduce the efficiency of development. Therefore, to achieve sustainability, the space of the coastal areas originally occupied by some enterprises must be transferred to other new enterprises (Healey and Ilbery, 1990). Finally, this model provides management decisions, rather than scientific knowledge alone.

Human errors may be rarer in a robust management model than in existing management systems. Since the model takes into account all the scientific data available, any management decisions thus produced should represent the best option. In contrast, in the traditional decision-making process, the human being as a manager may have to analyse the huge amount of data which include the natural conditions and the land use or development patterns of the coastal zone; technically, it is almost impossible for the manager to have a good grasp of the data sets, even if the data base techniques are used. Thus, it is easy for the manager to make undesirable mistakes. Economically, the cost of running a computer management system is, in a long run, lower than using a team of management officials. At the beginning of the establishment of the computer system, the monetary input may be relatively high, but the cost of normal operation (including the renewal of data sets and maintenance of the computer system) will be kept at a low level. Furthermore, the time required for the computer management system to work out a decision is extremely short; however, in the case of the human-based management system, a large team of officials may have to be involved in making the same decision, because of the complexity of the coastal management problems.

TECHNICAL FEASIBILITY

Structure of the Management Model

The management system outlined above can work according to the following procedures. First, the model is run to derive a number of rules or regulations for sustainable development, from the data consisting of legislation documents, plans for regional social and economic development, scientific data of the natural environment, and the existing land use patterns. Second, the necessary conditions of for the proposed development scheme are used as the input data for the management model. Finally, a consistency test is undertaken to examine if there are any contradictions between the rules and the necessary conditions for the scheme. If no conflict is identified, then the proposed scheme is approved; otherwise, the implementation of the scheme is not recommended and suggestions for modifications of the scheme are provided. Moreover, environmental impact assessment, which is required for any development schemes (Glasson et al., 1994; Kenchington, 1990) can be carried out within the frame of the management model, because the same data sets are used in the assessment.

From the viewpoint of computer techniques, the key issues of the management model include: (i) the determination of the rules for sustainable development; (ii) quantification of the conditions for the development scheme; (iii) the derivation of the management decision and its output format; and (iv) the up-dating of the model. The advancement of the computer technology (i.e. data base, geographical information system (GIS) and other software engineering techniques) has enabled us to provide solutions to these problems. One of the possible solutions is now described below.

Criteria of Sustainability

The data representing the laws or legislation documents, plans for regional social and economic development, and scientific data are dynamic in character: they are subjected to continuous modification and adjustment (the scientific data, including information on hydrodynamics, sedimentology, geomorphology, biology and chemistry of the coastal zone, are up-dated more rapidly than other data sets). Nevertheless, as far as the management practice is concerned, these data sets can be used to define maximum spatial, temporal, category and environmental capacities which can be used as the rules for sustainable development.

The spatial capacity can be defined as the maximum space or area and the locations which are available for development within a given region. This quantity can be derived using the data specified by the regional plans, in combination with the legislation documents and existing land use patterns. For instance, suppose that, according to the development plan, 100 km of the coastline in the eastern part of an area can be used for marine aquaculture. If 40 km of the coastline have been already used, then the spatial capacity will be the remaining 60 km.

By the temporal capacity we mean a maximum time span when a piece of land or a sea area in the coastal zone can be occupied for a particular utilisation. Such a criterion is necessary because any sustainable development depends upon a continuous change in the manner of development. If the enterprises which no longer fit into the general frame of the economic growth are allowed to occupy the coastal area permanently or for an excessively long period of time, then the spatial (land) resources will not be available for future development; this is not sustainable.

In terms of the robustness, the spatial and temporal issues for the development are crucial. Because the scientific data (together with the legislation system and regional plans) cannot be perfect in both quality and quantity, management errors (i.e. a development plan which is not sustainable is mistakingly considered as a sustainable one) may occur. In this case, the management model can control the whole situation using the spatial and temporal capacity rules. For any development application document, the length of time and the range of the space should be specified explicitly. Thus, even if the approval of a project itself is a mistake, this can be corrected at a later stage; since only a limited time span and space (location) is allowed, the general pattern of sustainable development will not be affected significantly.

The type capacity refers to the difference between the magnitude or scale of the existing enterprises and that specified by the regional development plan. The use of this rule benefits a healthy social and economic development. The health of the development depends upon not only a market economy, but it is determined also by a good guidance provided by the regional plan for social and economic development. Otherwise, destruction of the economic order and damage to the sustainability is likely to occur.

Associated with any given pattern of development, a coastal area can support only a limited human activities. Thus, the scale of the society, economy and population must be a function of the natural resources and the development pattern. If the scale is not right, then excessive modifications to the natural and ecological environment may occur. The difference between such a scale, which is theoretical in character, and the existing scale is referred to as the environmental capacity. This parameter can be calculated using the data sets with regard to the natural environment and the development method. It should be noted here that scientific monitoring of, and investigations into, the coastal zone should be undertaken regularly to obtain up-dated environmental capacity data.

For any proposed development scheme, if more resources are required than those which can be potentially provided according to the capacities, then it is not feasible. Therefore, the spatial, temporal, type and environmental capacities form the rules for sustainability.

Identification of Necessary Conditions for Development Schemes

Since the necessary conditions for a proposed project serve as the input data for the management model, such conditions must be clearly and completely listed within the application document. It is important to define the necessary conditions properly. Such conditions differ from sufficient conditions (Gao and Collins, 1995). The former are those without which the scheme cannot be implemented, whilst the latter means a set of conditions which guarantee the realisation of the scheme. In any proposed scheme, if the sufficient conditions are used, then it is likely to cause waste of the resources. However, if it is requested that only necessary conditions are used, then the resources can be used reasonably and, at the same time, the scheme itself can be implemented successfully since the sum of all the necessary conditions represents a sufficient condition. For example, suppose that a section of the coastline is allocated for the construction of a power plant according to the regional development plan, and the amount of power supply is also specified; if a proposal says that this coastal section is required to provide only a third of the power supply requested, then the management system will identify the contradiction between the plan and the proposal and make a decision of rejecting the proposed development project.

Such conditions are expressed in the from of digitised data, because the computer can only deal with quantified data, rather than qualitative information. If, for example, in an application document a condition is that "a piece of land is required within the intertidal zone, then this proposal cannot be approved. The quantification can be realised by an appropriate design of the application form (e.g. the spatial range required can be specified by the longitude and latitude figures). Qualitative information (e.g. the type of the development) can be represented using a coding technique. Generally, the quantitative and qualitative information needed by the model include the nature of the development scheme, the location and spatial range of the project, the length of time for occupation, the amount of investment and output, raw material and disposed waste (type and quantity). If there is a lack of any of these data, then the running of the management model will result in the decision of reject of the proposal.

Internal Consistency Test and Decision Made by the Model

In order to provide a management decision, an internal consistency test is performed by the management model. This means that the necessary conditions required by the proposed scheme are compared with the capacities. If the capacity rules can be observed in the implementation of the proposed project, then it is said that the development scheme has an internal consistency. Otherwise, it is not internally consistent with the capacities of the coastal region. The main point of this test is to make it sure that the proposed project must not be contradictive to the existing legislation, regional plans and scientific data.

If the internal consistency test is passed, then the application of the project will be approved by the management model. If, on the other hand, the test is a failure, which means that the necessary conditions required by the proposal are against the capacity rules for sustainable development, then the project will be rejected by the management model. The computer can provide a list of the errors in the propoosal.

Data Up-dating

Immediately after the approval of an application, the model itself should be up-dated. The implementation of the new project will modify the existing environment and land use patterns. Hence, the new data must be added to the data base of the management system when construction of the proposed project is carried out. Moreover, changes in the legislation, regional plans and new scientific data must be up-dated within the computer system whenever such changes occur, to achieve an effective dynamic management. This implies that there must be continuous interactions between the government officials and scientists; it is unlikely to be feasible that the scientist makes a management model and the official uses it for ever. Successful management depends upon the joint effort by the government and the scientists.

CONCLUSIONS

In order to implement effectively the strategies of sustainable development in coastal regions, a robust management model is required. Such a model provides management decisions (rather than a scientific basis for decision making) for any proposed development projects, using the most up-dated data. It observes a number of capacity rules to guarantee the sustainability, even if there are errors or shortcomings in the input data.

Technically, the establishment of the model depends upon the definition of the capacities for sustainable development and the identification of the necessary conditions for the proposed project, include the temporal, spatial, type and environmental capacities. An internal consistency test can be performed to determine if the project should be approved or disapproved.

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THE INDONESIAN COASTAL RESOURCES MANAGEMENT PROJECT (CRMP): A TWO TRACK APPROACH

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ABSTRACT

Indonesia is the world's largest archipelagic state, with some 17,500 islands, an 81,000 kilometre coastline and an Exclusive Economic Zone (EEZ) covering some 5.8 million square kilometres. In the past decade, coastal and marine resource management has become a strategic priority in national development planning. Currently, numerous projects are underway which collectively seek to better understand and manage Indonesia's vast marine and coastal estate.

One of the most recent Integrated Coastal Management (ICM) projects to commence in Indonesia is the USAID supported Coastal Resources Management Project (CRMP). The CRMP involves a partnership between a range of government, academic, industry and community organisations with technical guidance provided by the Coastal Resources Center (CRC) of the University of Rhode Island working with the Centre for Coastal and Marine Resources Studies (CCMRS) at Bogor Agricultural University (IPB).

The project commenced with a design study in 1995 and is now being implemented for a seven year period in a two track mode. The first track emphasises testing and learning from field programs, initially in the Province of North Sulawesi, with additional Provincial locations to be added in 1998. The second track integrates lessons from the field site program with institutional capacity building at Provincial and National levels to promote improved co-ordination and policy making and thus facilitates replication of local lessons in non CRMP Provinces.

The CRMP is an innovative and timely complement to other integrated coastal zone planning and management initiatives in Indonesia. It is one of the first coastal management project to begin to work specifically at the local scale outside non protected areas, although it is designed to complement protected area management initiatives such as the USAID supported Bunaken Marine Park project. Most importantly, the project is geared towards developing 'models' and principles for better coastal management which can then be applied in other areas of the archipelago with the support and participation of communities, governments and other stakeholders.

INTRODUCTION

Coastal areas are the dynamic interface between land and sea. They contain diverse and productive ecosystems, particularly in tropical regions such as the Indonesian archipelago. Because of their location, productivity and diversity, coastal areas are a key focus for human activity. In the Asia-Pacific region (home to some 55% of the world's population) some 75% of the population live within 60 kms of the coastline (Hotta and Dutton, 1995). While the majority of that population live in rural areas, there has been a rapid growth in coastal urban populations; 13 of the world's 21 largest cities are now located in coastal areas of Asia.

Rapid economic development and population growth in the Asia-Pacific region has placed unprecedented strains on coastal resources and ecosystems. The consequences of often unplanned and/or sectorally-focused development planning are now being manifested in loss of habitats, species and environmental quality. Equally importantly, they are resulting in increased competition and conflict between resource users and increased production costs.

Response to these trends and issues has been varied, although increasingly, nations of the region are implementing integrated coastal management approaches (Clark, 1992; Sorensen, 1993; Hotta and Dutton, 1995). GESAMP (1996) define ICM as... *a process that unites government and the community, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal ecosystems and resources. The overall goal of ICM is to improve the quality of life of human communities who depend on coastal resources while maintaining the biological diversity and productivity of coastal ecosystems.*

Olsen and Hale (1997) observe that the appeal of ICM approaches to countries like Indonesia stems from the convergence of need (for integration of development efforts) and the utility of ICM principles in providing balance in development planning. Dahuri (1996) argues that such balance will be essential if Indonesia is to achieve the ideals of sustainable resource utilization which are now embodied in National Development Plans and to properly address issues as diverse and pervasive as poverty (he notes that some 15% of Indonesian live in poverty - many of these live in coastal villages) and resource degradation (e.g. pollution of coastal waters).

Kusumaatmadja (1996) noted that specific provision for improved management of coastal and marine resources in Indonesia was formally introduced in the 1993 State Policy Guidelines (GBHN), although various ICM-related initiatives had been underway in the previous decade (Sloan and Sugandhy, 1994). Since the formal recognition of marine and coastal sectors in national development planning, numerous initiatives have been launched to implement ICM in Indonesia. Foremost amongst these is the ADB funded Marine Resources Evaluation and Planning Project, a multi-component, multi-institution loan project which seeks to strengthen institutional capacity to collect, apply and analyse data relevant to coastal and marine resources planning, especially at the Provincial level. A further major initiative currently being planned is the COREMAP (Coral Reef

Rehabilitation and Management) project which may be supported by various loan and donor agencies. Various NGO, community and donor sponsored resource management and community development projects in coastal locations have also commenced in recent years (Malik, 1997).

Very few of the macro/national ICM or local scale ICM initiatives in Indonesia have, as yet, begun to coalesce into a coherent and mature ICM program. This is not surprising in view of the relatively recent adoption of ICM approaches, the geographic scale of coastal resources management and the complexity of issues which need to be addressed (Dutton, 1996). The USAID supported Coastal Resources Management Project occupies a strategically important niche in facilitating the development of local approaches to ICM which contribute to national ICM capacity-building and which enable testing of the applicability of globally-derived ICM principles in the Indonesian context. The CRMP thus has considerable potential to support, complement and direct other ICM initiatives.

COASTAL RESOURCES MANAGEMENT PROJECT

Project Context

The Coastal Resource Management Project (CRMP) is one of four interwoven components of the USAID-BAPPENAS Natural Resources Management II Program currently being implemented in Indonesia. The strategic objective of the NRM II program is ... *decentralizing and strengthening natural resources management* (USAID/BAPPENAS, 1996). This objective has been adapted as the Vision for the CRMP (Proyek Pesisir, 1997). It also forms the pinnacle outcome for annual workplans (see, for example, Proyek Pesisir, 1997) and an elaborate and comprehensive NRM II performance monitoring plan in which progress towards realization of the strategic objective is measured in annual project reviews, as shown in the Figure below.

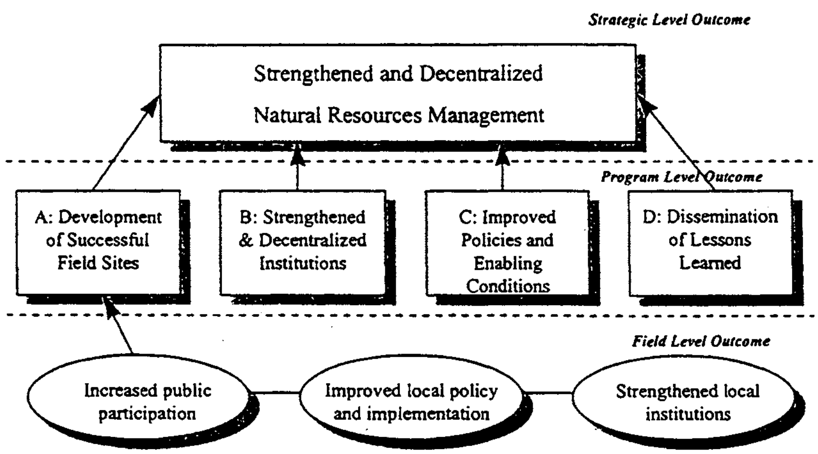

Figure 1: NRM II/CRMP Results Framework

Project Organization

The CRMP is implemented via a Co-operative Agreement between the Coastal Resources Center (CRC) of the University of Rhode Island, USAID Washington and USAID, Indonesia and as such forms a central part of the CRC-USAID Coastal Resources Management II global program. CRC has more than 25 years experience in the development and application of ICM approaches and has been extensively involved in the development of much of the theory which underpins contemporary ICM practice.

The CRMP team works closely with resource users, local, provincial and national authorities, industry, community groups NGOs and academics. The close relationship between these groups was forged during the initial design of the NRM II program and CRMP project in 1995 and 1996. During this process, extensive customer surveys and partner consultations were undertaken (USAID/BAPPENAS, 1996) resulting in careful definition of issues and opportunities to be addressed. Following that research and further consultation with CRMP partners, a project organization structure has been developed which reflects the purposeful integration of government and non-government stakeholders in ICM and the need for integration of different scales of management accounting for local, provincial and national interests. The general project organization is shown in Figure 2 below.

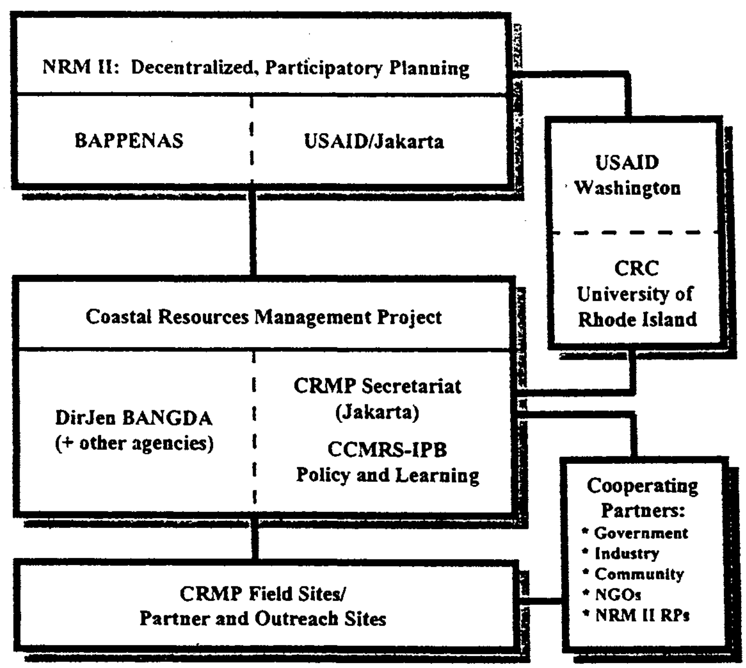

Figure 2: CRMP Organization

The Two Track Approach

Within Indonesia, the CRMP (known locally as Proyek Pesisir, literally meaning 'coastal project') is being implemented via a 'two track' approach. As Olsen and Hale (1997) point out, a key requirement of ICM is the need to integrate "top-down" and bottom-up" approaches to resource management and policy reform. A "top-down" approach focuses on central government, its procedures and structures, and the need for national policy reform. A "bottom-up" approach works to enable change at the community and local government level with the hope that success at this level can be transferred across society.

The two track strategy combines both approaches by simultaneously and incrementally building capacity both within central government (national and provincial) and at selected community sites. This approach creates unique, locally-focused opportunities for policy dialogue, information sharing and evaluation as well as promoting a sense of shared purpose. Clark (1992) notes such co-ordination is an essential feature of ICM programs, particularly when there are geographic or institutional barriers to collaboration between those who need to be involved in ICM programs.

The initial emphasis of the CRMP has been on rapid development of local track activities so as to enable early definition of management needs which can be used to guide later program design and to articulate requirements for national track involvement. To facilitate integration of both tracks a range of background studies have been initiated and mechanisms for 'cross track' information sharing established. Key activities within the first year workplan of the CRMP (1997-98) include:

- Field Program Commencement (establishment of offices, staffing, site studies, establishment of partnerships, awareness raising, identification of options for early intervention at site level, etc.)
- Initial Strengthening of National and Provincial Institutions (training/skills development, role reviews, infrastructure supplementation, encouragement of linkages with external organizations, etc.)
- Development of Understanding of ICM Policy Contexts (review of policy mechanisms, establishment of forums and mechanisms for policy input, development of baselines/methodologies for evaluation, provision of initial advice and resources to decision-makers, etc.)
- Establishment of Communication Strategies (development of educational materials, media reviews, conduct of meetings and seminars, local and global outreach activities, etc.) (Proyek Pesisir, 1997)

CRMP LOCAL TRACK DEVELOPMENT

The initial 'local track' focus of the CRMP is on the province of North Sulawesi, located adjacent to the Philippines. Up to two additional Provinces (from a total of 27 in Indonesia) will be selected by a team of CRMP partners in late 1997. The North Sulawesi field program will, however, remain the primary focus of the CRMP over the life of the NRM II Program and will thus be a key centre for learning and for transfer of lessons and information to other areas of Indonesia.

Following consultation with authorities and other stakeholders in the coastal resources of North Sulawesi, it was agreed that the project would be implemented initially within the Regency of Minahasa. Minahasa Regency (see Figure 3) covers a land area of 4,200 sq. kms and had a population of some 735,000 in 1995 ((Pollnac, Rotinsulu and Soemodinoto, 1997). The length of coastline of Minahasa is approximately 350 kms and there are approximately 110 villages along this coastline.

Under the guidance of a Provincial working group, comprising representatives of some ten provincial and local level agencies and the main provincial university (UNSRAT), a rapid assessment of 20 villages along the coast of Minahasa was completed (Pollnac, Rotinsulu and Soemodinoto, 1997). The assessment indicated that:

- coastal resources of Minahasa are generally in good condition (unlike much of Indonesia - see Dahuri, et al. 1996),
- marine biodiversity is high (the region lies within the global epicentre of marine biodiversity and thus has extremely high conservation values),
- coastal resource-based activities contribute significantly to the incomes of village residents, although most residents have multiple income sources, and
- the key management issues in the region are diverse, but widespread (small scale coral mining, rapid tourism development, seaweed farming, coastal erosion, access to potable water supplies, sanitation, mangrove utilization, unsustainable/destructive fishing methods, sedimentation of coral reefs from land-based activities, capture of endangered species and watershed deforestation).

From that assessment, the working group applied the following criteria to enable selection of three sites for initial implementation of CRMP local track activities:

- dependence of coastal residents on resources,
- coastal resource potential,
- commitment of village leader and community to project ideals,
- relevance of site within regional context and capacity to act as a centre for information transfer/outreach (to neighbouring villages and regencies),
- scale of site and level of external influence,
- accessibility,
- local context (informal leadership, role of women, contribution of local government to project, level of existing development, etc.)

From this review (which included additional site visits and consultation with community leaders and residents), three villages have been selected for development as CRMP field sites: Bentenan-Tumbak (two adjacent villages which share a common 'suite' of coastal resources), Talise and Blongko. The location and strategic significance of these sites is shown in Figure 3.

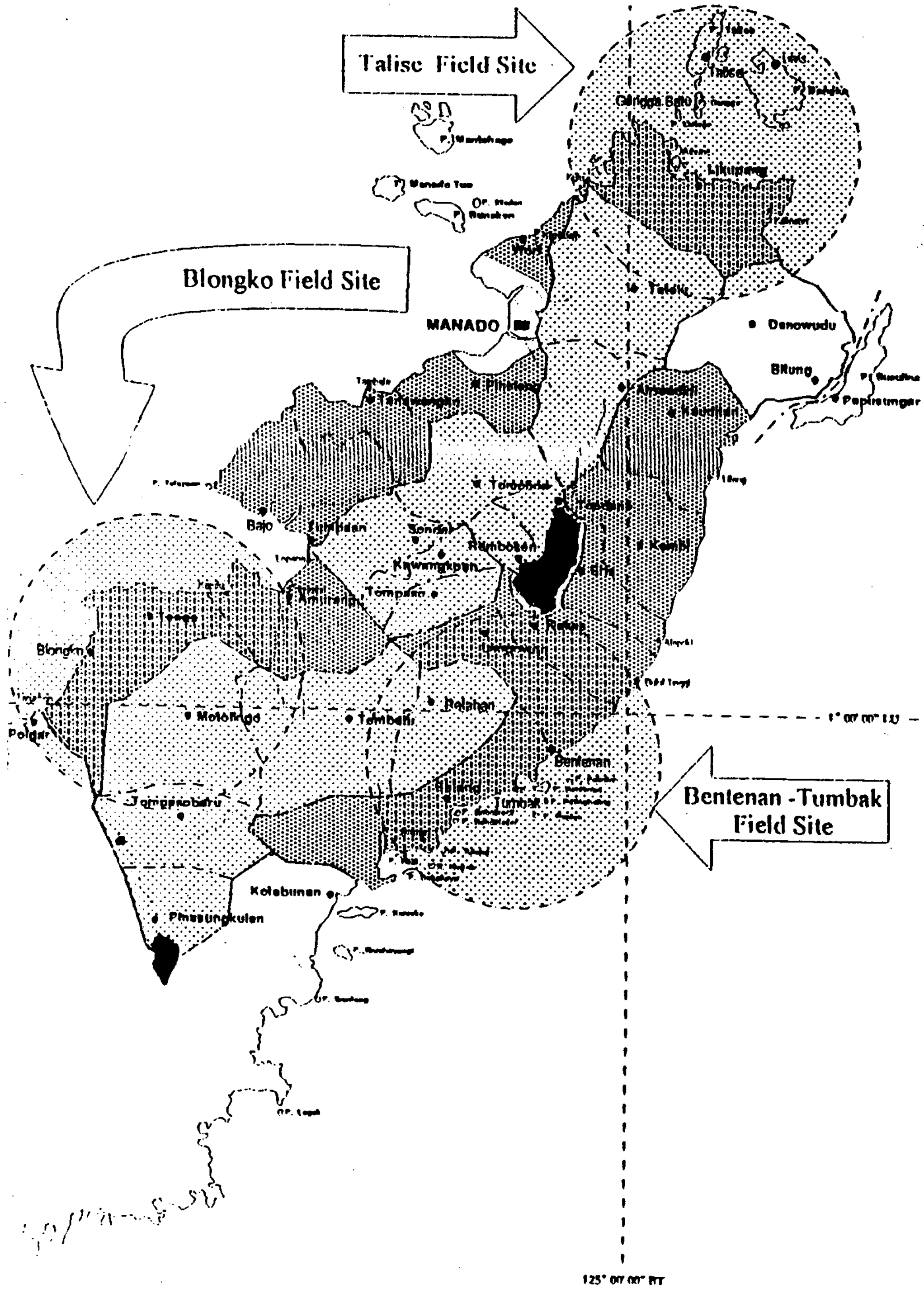

Figure 3: Initial CRMP Field Sites in North Sulawesi

Over the remainder of 1997, detailed profiles of these sites will be prepared by CRMP staff, consultants and partners (including village residents). These profiles will form a key input to site management plans and an input to baselines which are being established to monitor the impacts and outcomes of the CRMP.

CRMP DEVELOPMENT: NATIONAL TRACK

The initial 'local track' experience of the CRMP has been extremely positive. The project has received outstanding and unparalleled support from provincial and local governments, research and community groups and is now actively engaging a wider range of local stakeholders so as to develop the broad base of support and commitment necessary to progress to the next stages of the ICM process.

However, as Olsen and Hale (1997) suggest, success at the local level is not sufficient to ensure the development of a mature and comprehensive national approach to ICM. At the same time as 'local track' activities are being implemented, the CRMP is thus establishing the framework for 'national track' activity. The Centre for Coastal and Marine Resources Studies (CCMRS) at IPB is playing a key in this respect, as indicated in Figure 2. CCMRS will be responsible for facilitating and promoting the integration of local track with national track activities in coming years of the CRMP - the initial lessons from North Sulawesi will thus play a pivotal role in the process of developing models and lessons to be tested in other coastal locations of Indonesia and in the development of improved national ICM policy.

Much of the initial emphasis of national track activities lies in developing the institutional awareness, understanding and capacity necessary to improve coastal resources governance and in defining governance options which are workable and sustainable. Considerable attention has been given to acquiring and sharing information of relevance to central government agencies and in encouraging links (both formal and informal) between government and non government stakeholders in coastal resources so as to ensure that they have a common perception of issues and access to information relevant to addressing those issues.

As noted by Butarbutar (1997) unless these agencies (and other stakeholders) have a common perception and motivation, then it is unlikely that a truly integrated approach to coastal resources management will be attainable. This demanding task (in view of the myriad of agencies involved) will be supported by development of a CRMP Communications and Outreach Strategy, by continually working closely with stakeholders and will be reinforced by the production of locally relevant and immediately useable reference materials (there is a dearth of suitable information which has been 'tailored' for Indonesian audiences).

CONCLUSION

The Indonesian Coastal Resources Management Project is a timely and innovative complement to the initiatives of the Government of Indonesia in seeking to improve management of the vast marine and coastal resources of the Indonesian archipelago. By implementing a two track approach, the project is hopeful of developing robust management systems which are capable of addressing ICM needs across sectors and at various scales of decision-making.

Equally significantly, the strong emphasis given to stakeholder consultation and involvement in all stages and aspects of the project is contributing to improved awareness and understanding amongst stakeholders in ICM. The resultant partnerships are likely to provide a firm foundation for implementing sustainable coastal resource use practices.

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DIFFERENTIAL SEDIMENTATION BETWEEN TWO SIDES OF THE PEARL RIVER ESTUARY AND ITS INFLUENCE ON URBAN AND INFRASTRUCTURE PLANNING IN HONG KONG

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ABSTRACT The sharp contrast of the geomorphologic features between the two sides of the Pearl River estuary is mainly the results of differential deposition. It has a profound influence on the urban and infrastructure planning in Hong Kong. A brief investigation on the history of ocean cities reveals that there are commonly three phases in the evolution of city-harbor relation. The overlap of the functional systems operating for the city and the seaport in an extremely limited space in Hong Kong originated many urban problems. According to this primary study and the scenario analysis conducted, the author points out that the PADS program carried out by Hong Kong government may have serious strategic defect. The North-eastern Lantau Island is proposed for future metro area expansion.
Key words urban planning, scenario analysis, Hong Kong, Pearl River

THE DIFFERENTIAL SEDIMENTATION ALONG TWO SIDES OF LINGDINGYANG ESTUARY

The coastal morphology and modern sedimentation processes on the two sides of Lingdingyang estuary display a sharp comparison. The coastline of Hong Kong, on the east side of the estuary, is partially submerged, dissected upland rising to over 900m in height(Su, 1986). With numerous bays, headlands, projecting peninsulas and offshore islands, the coastline is highly crenulated and dominated by a ria form often associated with sharp underwater slope. Owning to the strong erosion and lack of material supply, the beaches often did not fully developed. On the other side of the estuary including Macau, Zhuhai and Zhongshan areas, due to abundant sediment supply and deposition, the muddy coast is the dominated morphology. The coastline is smooth and with very gentle underwater slope. The striking contrast owns its origin to the differential sedimentation between the two sides of the Lingdingyang estuary in the last five thousand years.

In the last glacial period (18ka BP), the global sea level was some 130m below the present level. Sea level had reached the present level approximately five thousand years ago. During the maximum transgression (5ka BP) the numerous hills and terraces in the west side of Lingdingyang estuary were offshore islands, as well as the islands in Hong Kong coast. Since the RSL changes have been the same on both sides of the estuary, the differential sedimentation has been caused by the different sedimentary dynamics, which is in turn the result of geographical setting and sediment supply.

1.1 Evolution of the West Lingdingyang Estuary

The evolution of the coastline along the west side of the estuary has been associated with the development of the Pearl River Delta. The delta plain was progressively emerged from the shallow sea as a result of the river-sea interaction since the last glacial period. Approximately 15000 BP at the end of the last regression, the sea level was 70-110m below the present level in the south China coast. The late Pleistocene delta plain formed during the last transgression was weathered, dissected and eroded. The coastline of the delta was some 200 km to the south of the present coast. The present islands such as Sanzao, Hengqin, Lantau and Hong Kong were rocky hills standing on the late Pleistocene fluvial plain. Since 12000 BP, RSL raised at a rate of 10-18 mm/yr. Approximately 7000-8000 BP the back water along the river reached the present estuary. A fining-upward sequence was deposited in the drowned valley. It has been widely found beneath the present channel network (Huang et al,.1982;Li et al, 1991)

When transgression reached the maximum in 5000 BP, the sea level was not much different from the modern sea level. The old delta was submerged and the new delta started to develop. Several sets of typical wave-cut caves with well preserved wave-cut platform and forehead in Qixing Hill (Seven Star Hill), 40-50 km from the nearest present coast, were found and identified (Wu, 1937). They are important indication of the sea once reaching Guangzhou City. In this period, the isolate hills mentioned previously were submerged and became offshore islands. They acted as nucleus for deposition of sediment carried by the rivers. Compared to the other coastal plain estuaries this special evolution process in the Pearl River has left many imprints on the formation of deltaic estuaries and made them unique in many aspects.

The coastlines of the Pearl River delta in different periods in the last five thousand years migrated from north to south in general (Figure 1). Thousands of square kilometers of productive land has been emerged from the shallow sea. At the mean time, with the infilling of bays and tidal inlets, most of the potential deep water harbors disappeared with the progress of the delta front (Li et al, 1991; Zhao, 1990).

1.2 Development of the Hong Kong Coastline

Compared to the coast on the west of the estuary, the Hong Kong coast underwent a completely evolution. While the thousands of square kms of delta plain emerged from the west of Lingdingyang estuary, the Hong Kong coast did not experienced substantial changes. Each year approximately 80 million tons of suspended sediment is brought into coastal sea by the Pearl River through its eight outlets. Because of the geographical setting and Coriolis force most of the sediments are transported and deposited along the western side of the estuary including Macao, Zhuhai and Zhongshan. Very few suspended sediment from the river reaches Hong Kong coast crossing the Lingdingyang estuary. The most significant changes has been the result of the reclamation along the waterfront of Victoria Harbor in the last 150 years.

THE EVOLUTION OF CITY-SEAPORT RELATION IN HONG KONG

A brief investigation on the history of major seaports in the world reveals some marked common characteristics.

2.1 General Trend of the Relation of City and Its Harbor

2.1.1 Case Study

Singapore Singapore river has played an important role in the development of Singapore City. In 1819 Sir Stamfort Raffles landed on Singapore River and declared Singapore a free port. Singapore estuary soon became an important trading centre. The rubber trade was born nearby. Gold, spices, iron, guns and opium, all flowed across the river to the world. Singapore River is a small river, with the increase of ship size and the booming of trading activities, its place as a seaport was soon replaced by other harbors in the Singapore Strait, such as Jurong Harbor. However, the city continuously developed and expanded as a trading and commercial center and became an important international city (SURA,1992).

Hamburg Hamburg Harbor celebrated its 800th anniversary not long ago. The harbor plays an important role in the development of the Hamburg city ever since it was built. The process began in the 8th century, Charlemagne built a missionary castle the 'Hammaburg' on the north bank of the River Elbe. Adolf III founded a 'New Town' as a port and trading post on the upper Nikolai fleet (downtown area now) in 1188 (HTB,1979). This harbor was the seed from which the international port was later to grow. In the 17th century, the City of Hamburg extended and strengthened. Its functional systems of fortification, religion, commerce and residence had been developed. The seaport was situated in the downtown area of the city. Since then, the City expanded to the north on the right bank of North Elbe while the harbor developed to the left bank of the river. The city proper has been gradually separating from the harbor area.

Rotterdam Rotterdam is situated where the North Sea meets the estuaries of the rivers Rhine and Meuse. In approximately 1328 the first port activities began with the construction of the Old Harbor. Around 1850, the port started to develop to the southern bank of the river, still virtually virgin territory by building bridges and so emerged a new city: Rotterdam South. The former fishermen's hamlet grew to an international city of trade, transport, industry and distribution. Rotterdam has been probably the most typical example representing a highly mixing of city and harbor function systems. Quays and streets developed side by side in the city. This will be changed in the coming years. An ambitious program called 'the New Rotterdam' has been developed. This plan contains among others a new Rotterdam airport, a completely new residential area, recreational facilities, town parks and new industrial zone. The south bank of the river, the old harbor area, will turn into a commercial and residential area. The main seaport has been migrating further down along the estuary. A major issue of the scheme is the separation of city and harbor.

Guangzhou The history of Guangzhou city can trace back to more than two thousand years ago. The Po Hill in downtown area was once a small ferry on the north bank of the Pearl River in Jin Dynasty(Zeng, 1991). After entering the delta area the Pearl River bifurcates continuously and forms a complicate channel network, many harbors and ports developed with the towns and cities. The separation of Guangzhou city and its major seaport took place in an early stage. The Fuxu Port (outer port) nearby Bolo Miao (Pineapple Temple) where the Front Channel and the Back Channel meet became a commercial port for foreign trading no later than Tang Dynasty (1300BP). A poem by Du fu says, 'Hundreds of foreign ships were mooring in the river'.

2.1.2 Three Phases in the City-Seaport Evolution The cities in the case study have different social, economic and cultural background, different geographic setting and history. However the development of the relation and general layout of the city and its seaport can be summarized into three stages or phases.

Phase 1: It is the initial stage of the development of a city and its harbor. The history is often started from a small fishing community with hundreds of inhabitants. The city or town has only several streets constructed along the quays or by the harbor. Both the city and the harbor are in their infancy(Figure 2).

Phase 2: With the evolution of the city and the harbor, the city functional systems of administration, fortification, religion, commerce and residence are continue to develop and improve. One of the characteristics of this stage is that the city and its harbor share the same traffic and other functional systems. Hamburg City in 1660 was in this stage when the city had extended and strengthened but the seaport was still situated in the downtown area. The diversity of these systems for the city and for the harbor may lead to the spatial separation to certain extend.The transition of this stage varies from case to case. It lasted a rather short period of time in the case of Singapore and Guangzhou. In the case of Rotterdam this stage lasted several hundred years. If a highly developed modern city and its full scale seaport remain in this stage, it may induce some common city problems.

Phase 3: The city and its harbor will further separate. Hamburg, Singapore, Guangzhou and many well known cities and seaports are in this stage. In this stage the seaport is highly developed and plays an important role in the city economy. Solutions to problems of urban sparrow — over-populated residential and commercial development, road traffic congestion, environmental and ecological pollution, all point to further separation of city and the seaport. The 'New Rotterdam Program' and PADS (Port and Airport Development Strategy) project are ambitious city reconstruction plans. The planning of city and seaport of long-term perspective and sustainable development is the key issue.

2.2 The Relation of City and Harbor in Hong Kong

2.2.1 Hong Kong and Victoria Harbor Hong Kong was a small fishing community before the Opium War. Its population was 4350 according to the first census carried out in 1941. The population grew to over 6.31 million in 1996. With the limited amount and difficult nature of available land and a large and vigorous population growth, land use has been an extremely important issue in Hong Kong. From the early stage, development of Hong Kong City has centered on Victoria Harbor (Peng, 1992). Since the Territory became established, throughout the process of city expansion, no significant migration of population and separation of city and seaport happened except the development of the 'new town' project in the 70's. Victoria Harbor has been important to Hong Kong in two ways: First, the Harbor has been the mainstay of Hong Kong economy. In the 80's the volume of waterborne cargo accounts for 90-95 percent of the total cargo transported. In the 90's, road and railroad transport grew rapidly, the volume of waterborne cargo transported reduced to approximately 85 percent of the total. Secondly reclamation of land from the sea, mostly along the waterfronts of Victoria Harbor, has play an important part in the development of Hong Kong. Over a quarter of population in Hong Kong lives in reclaimed land. Figure (3) shows a general relation of the City and the Harbor. The harbor has affiliated with almost all aspects of the City's daily economic and social activities, which owns its origin from two facts:

(1)Victoria harbor is one of the best deep water seaport in the world. From its establishment until not long ago, the harbor satisfied all commercial and trading demands. There has been expansion but no migration.

(2)Hong Kong has an area of 1095 km^2, but only 16% of the area is low-lying flat land. From the early stage of Hong Kong's development, encroachment of the sea has been going hand in hand with the encroachment of the slope (So, 1986). Since 1841, approximately 60 km^2 of land has been reclaimed, accounting for a quarter of total urban area. Most of them was gained by infilling the frontshores of the Victoria Harbor.

2.2.2 The Crucial Issue from the Interlocking of City and Harbor Hong Kong is an international city and important financial centre. Victoria Harbor is a highly developed full scale seaport. In the last two decades, Hong Kong economy and harbor activities grew rapidly. Many city problems originated from the shortcoming of the interlocking of the City and the Harbor emerged and getting worse. When a highly developed modern city with a full scale seaport remain in the second stage of evolution, the common city problems will be more severe. The extremely limited amount and difficult nature of the land available in Hong Kong makes the corporate layout of land use a crucial issue. Other than the administering ability, working efficiency and citizen involvement, what is needed to offset the problems from disjointed, improvident and solely economic driven planning is an integrated, foresighted and rational approach to land use, especially the layout of Metro area and seaport.

A SCENARIO ANALYSIS FOR SUSTAINABLE DEVELOPMENT OF HONG KONG CITY

In the recent years, it seems that the Hong Kong government has realized the serious nature of the problems resulted from both the general layout of city-harbor relation and restriction of natural resources. From the 80's a series of consultant studies (SSDS, for example) were carried out aiming to tackle the urban environmental problems and reduce the pressure from cumulative, long-term effect of some disjointed planning decisions on urban fabric. Among which PADS (Port and Airport Development Strategy) Studies is one of the most ambitious and costly program in Hong Kong's history. It is actually a corporate strategy for the future development of Hong Kong City and its most important infrastructures. There is no doubt that the program should be integrated and have vision of long-term consequences of the action proposed.

For urban planning scenario analysis has been a useful tool. It provides possible perspectives under different external environment scenarios and strategies with richer information than single point forecasting.

3.1 Future Layout of City-Seaport Development — A Scenario Analysis

A brief scenario analysis is conducted on the urban planning in regard to the general layout and siting of Metro area expansion and harbor migration. The consequent scenarios then are discussed.

3.1.1 Problem Description In the last two decades, to some extent benefited from the open policy and economic reform of inland China, Hong Kong experienced a rapid economic development and population growth as well. In the recent years, new urban development projects have been proposed and some of them carried out including seaport expansion, construction of new transport systems (road and railroad), older district reconstruction, expansion of commercial and financial areas, building new facilities for tourism and recreation, environment projects and new airport relocation etc. During this process it has become more evident that many urban problems in Hong Kong have been originated, directly and indirectly, from not only the resource restriction, but also the general layout of city and harbor. The issue for scenario analysis can be defined as: what will be the proper perspectives judged by certain criteria under the external environment scenarios and strategy proposed.

3.1.2 External Environment Scenarios The two external environmental factors considered are population growth and seaport expansion:

Population According to the 1996 population by-census, Hong Kong's population was 6.31 million. The population growth was much faster in the second half than the first half of the 1987-1996 ten year period. The annual growth rate averaged 1.8 per cent over the period 1991-1996, but only 0.6 per cent over the period 1986-1990. It is worth to note that the annual growth rate was 2.0 and 2.5 per cent in 1995 and 1996 respectively. Since World War II the natural growth rate (NGR) has been steadily declining. In 1961 NGR was 28.9 ‰. It was 4.9 ‰ in 1996. The mechanic growth rate (MGR) showed more complicate patterns. In the 80's MGR decreased to less than 10% of the total population increase. However it was 2.2 and 2.9 times higher than NGR in 1995 and 1996.

Based on a growth rate 1.0% which is lower than the average over the last 10-year period, Hong Kong's population will be 6.57,8.85 and 10.8 million people in 2001, 2030 and 2050 respectively. Table (1) is the population forecasting under different growth rates.

Table 1 Population Forecasting under Different Growth Rates(thousand)

Growth Rate / Year	0.5%	0.8%	1.0%	1.5%	2.0%
2001	6470	6568	6633	6799	6968
2010	6767	7056	7254	7774	8327
2030	7476	8275	8852	10470	12374
2050	8261	9204	10801	14101	18387

The 'New Territory Program' started from the 70's has significantly reduced the growth rate in the Metro area. While the trend of decentralizing from the Metro area continues, the population in some of the older districts declines, but population in the Metro area as a whole still grows. According to the 1996 by-census, the percentage of the population living in the Metro area will decrease to 56% of the total by the year 2011, or accordingly 4.13 million people, which exceeds the 'fully developed population' proposed by Hong Kong government by almost a million.

Seaport With a cargo-handling capacity of 182 million tons of goods of all kinds (1996), it is one of the most significant cargo handling center in the world. In container traffic, which continue to climb steadily in last decade, Hong Kong ranks number one in the world with 13.3 millions TEUs in 1996. According to PADS, with a 8.2% annual growth rate, the cargo-handling volume for Hong Kong Harbor will reach 450 million tons and container traffic of 30 million TEUs by the year 2011. This is likely an over-estimate. In the 80's the annual growth rate was two digits for cargo handling and from 1983-1993 the annual growth rate averaged 17.0% for containers. But because the rapid development of ports for both cargo and containers in the Pearl River delta area, the quick growth in Hong Kong has been slow down substancialy in recent years.

Table 2 Scenarios for Population and Seaport Growth:

xternal environment	*Scenario I (Trend)*	*Scenario II (Accelerated))*
pulation Growth	1.0%	1.5%
port Expansion		
Cargo (Million Ton)	6.0%	8.2%
Container(Million TEU)	5.0%	8.2%

Scenarios The average population growth rate was 2.1% based on the four census and by-census carried out in the period 1981-1996. The following changes have been assumed under the 'Trend' and 'Accelerated' scenarios for population and seaport growth (Table 2).

3.1.3 Strategies for Siting of Metro Area Expansion and Harbor Relocation The choice of strategy for the layout of Metro area expansion and seaport relocation has been restricted within a rather narrow limits due to the lack of natural resources, especially the available land.

Siting of Metro Area Expansion The population density has exceeded 165,000 people per square km^2 in some most densely districts. In spite of the decentralizing trend, many functions of the Metro area cannot be replaced and substituted by the 'new towns'. Metro area of Hong Kong needs substantial expansion for ① population growth, ② economic development ③ reconstruction of older districts and improvement of urban environment. Where is the land for Hong Kong's Metro area to expand? Due to the geologic and geographical setting the choice is limited to two possible alternatives: (1)remaining where it is and to continue the reclamation of the waterfronts of Victoria Harbor, (2) expanding to north-east Lantau Island(Figure 4A,4B).

Alternative 1 (HKV) The Metro area will mainly remain in the present area. Hong Kong City has been developed along the Harbor in the last 150 years. Reclamation of the waterfronts along the Harbor will continue according to this alternative.

Alternative 2 (HKL) The Metro area will expand to north-east Lantau Island. Lantau Island is the second largest island in Hong Kong's territory. It is only 3 km to Tsing Yi Island and some 8 km across the bay to Hong Kong Island. When the Metro area expands to Lantau Island, the City will face a calm and scenic bay semi-enclosed by Hong Kong Island, Kowloon Peninsula, Tsing Yi and Lantau Islands with easy transportation.

Seaport Relocation The Victoria Harbor grew with Hong Kong City for the last 150 yeas. Due to the rapid growth of harbor business and the demands for improvement of urban environment, the migration of Victoria Harbor has been inevitable and imperative. Several sites were proposed and studied for the future main seaport of Hong Kong. These include north-east Lantau Island (PADS, 1992), Tun Men[1] and Tolo Harbor(Zhu et al, 1986). Three alternatives are included in the scenario analysis.

Alternative 1 (HBV) The main seaport and activities remain in the Victoria Harbor. Since the migration has been inevitable, this alternative is listed only for comparison.

Alternative 2 (HBL) The main port will move to North Lantau. Because the inner harbor expands westwards to north-east Lantau Island area, it will provide a much larger water fetch for substantial development of the future outer port. The urban environment and traffic congestion in the central business district will be improved with the diminishing of inner harbor activities for the time being. This alternative conflicts with alternative HKL for city expansion.

Alternative 3 (HBO) Tuen Mun is a semi enclosed deep water bay sheltered by Qing M and Lantau Island.Tuen Mun has been a well known anchorage since Tang Dynasty. 'There is no gale for days in Tuen Mun, only the calm sea with tides up and down' are few verses from a poem by Liu Yuxi (Tang Dynasty). Tolo Harbor also a well sheltered port with sluggish tidal current. Both sites has been proposed as the main outer seaport. What this study concerns are the long-term effects of the general layout of city-harbor relation. Comparisons of proposed siting for future seaports in detail are out of the scope of this study. All seaports proposed are included in alternative HBO.

3.1.4 Evaluation and Criteria The long-term effects of the combined strategy alternatives and external environment scenarios are evaluated by four criteria.

Population density (PD) - A good strategy will reduce the population density in the Metro area.

Traffic condition (TR) - A good alternative will release the road traffic congestion.

Environment (EV) - A good strategy will minimize the environment pollution(water, air, noise etc.) caused by harbor activities to Metro area.

City image (CI) - A good alternative will provide more space for Metro area development, a better urban ecological environment for the inhabitants and will improve the image of Hong Kong as a scenic ocean city.

Four grades for evaluation used are:

+ — improving	0 — no substantial changes
- — situation getting worse	■ — deteriorating to an unacceptable level

3.5 Results and Discussion

Four combined strategic alternatives and two external scenarios are considered in the scenario analysis. Due to the conflicts between alternatives and reality some of the alternatives have been excluded from the scenarios. Table 3-5 list the results of the scenario analysis for the years 2011,2030 and 2050

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[1] Lo,Z.R.,1994,An analysis on reclamation in Hong Kong, in 《Research on Infrastructures and Environment in Hong Kong》,Center for Economic Development and Management of the Pearl River Delta Area (Ed.)

respectively.

Strategic Alternatives HKV/HBV The Metro area's expansion will be limited to the Victoria Harbor area and the seaport will not be relocated. Should these alternatives be chosen, all aspects of evaluation will be rapidly worsening before 2011 judged by the criteria. After 2030 the population in Metro area will exceed the 'fully developed population' and the scenario becomes 'unacceptable'. Over-reclamation of the Victoria Harbor frontshore will be forced to take place.

Strategic Alternatives HKV/HBL and HKV/HBO According to this strategy, the Metro area will remain in the present boundary and the seaport will be relocated to Lantau Island (HBL) or other locations (HBO). Because the Metro area will separate from the seaport, all the aspects evaluated will improve to certain extent for the time being. However the land made available and the harbor frontshore can provide only very limited space for Metro expansion. After 2030 under the 'accelerated' scenario for population growth the population density in Metro area has become 'unacceptable'. Environment may

Table 3 Scenario Analysis for Layout of City and Harbor(Year 2001)

Strategic Alternatives	External Scenarios	Evaluation			
		PD	TR	EV	CI
HKV/HBV	T/A	—/—	—/—	—/—	—/—
HKV/HBL	T/A	+/+	+/0	+/+	+/+
HKV/HBO	T/A	+/+	+/0	+/+	+/+
HKL/HBO	T/A	+/+	+/+	+/+	+/+

Table 4 Scenario Analysis for Layout of City and Harbor(Year 2030)

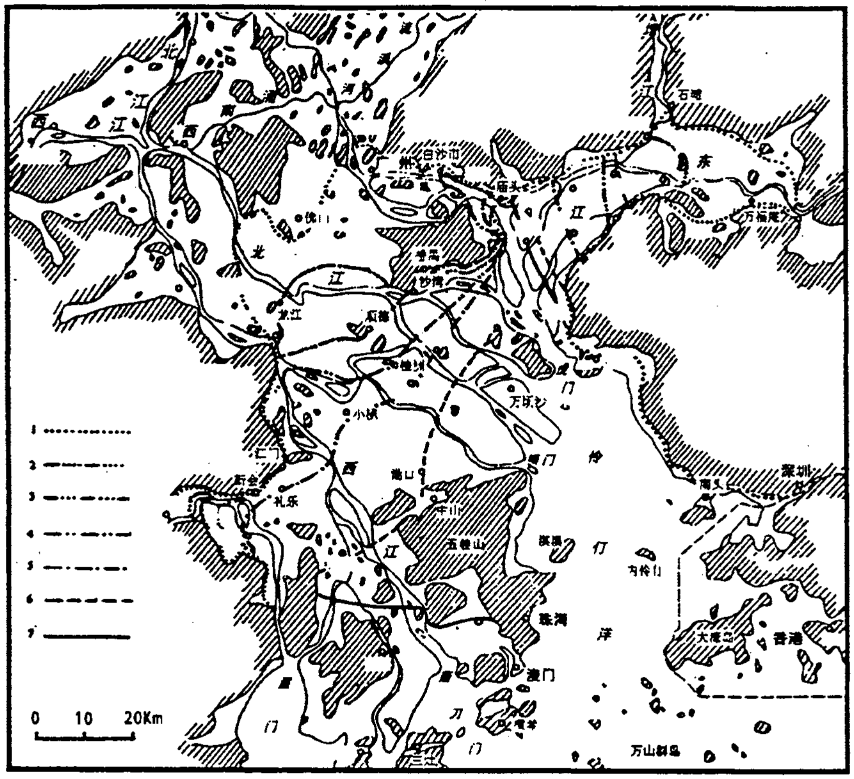
Strategic Alternatives	External Scenarios	Evaluation			
		PD	TR	EV	CI
HKV/HBV	T/A	—/■	—/—	—/—	—/—
HKV/HBL	T/A	—/■	—/—	+/0	—/—
HKV/HBO	T/A	—/■	—/—	+/0	—/—
HKL/HBO	T/A	+/+	+/+	+/+	+/+

Table 5 Scenario Analysis for Layout of City and Harbor(Year 2050)

Strategic Alternatives	External Scenarios	Evaluation			
		PD	TR	EV	CI
HKV/HBV	T/A	■/■	—/—	—/—	—/—
HKV/HBL	T/A	■/■	—/—	—/—	—/—
HKV/HBO	T/A	■/■	—/—	+/0	—/—
HKL/HBO	T/A	+/+	+/+	+/+	+/+

continue to improve by 2030 due to separation of city and harbor. The other two aspects are also worsening. To the year 2050, all aspects will deteriorate except 'Environment'.

Strategic Alternatives HKL/HBO According to these strategic alternatives, the future Metro area will gradually expands westwards to North Lantau and the outer harbor will be relocated to the proposed site. This strategy will not only direct to the separation of city and harbor, but alsoprovide a space and scenic environment for the Metro area expansion in the next century. All scenarios evaluated improve for all the time considered. This is a sensible strategy for sustainable development of Hong Kong in the next 50 years.



1. 6000 BP
2. 4000 BP
3. Han dynasty (2200 BP)
4. Tang dynasty (1400 BP)
5. Song dynasty (1000 BP)
6. Ming dynasty (700 BP)
7. Qing dynasty (300-400 BP)

Figure 1 Shoreline evolution of the Pearl River delta in the last 6000 years

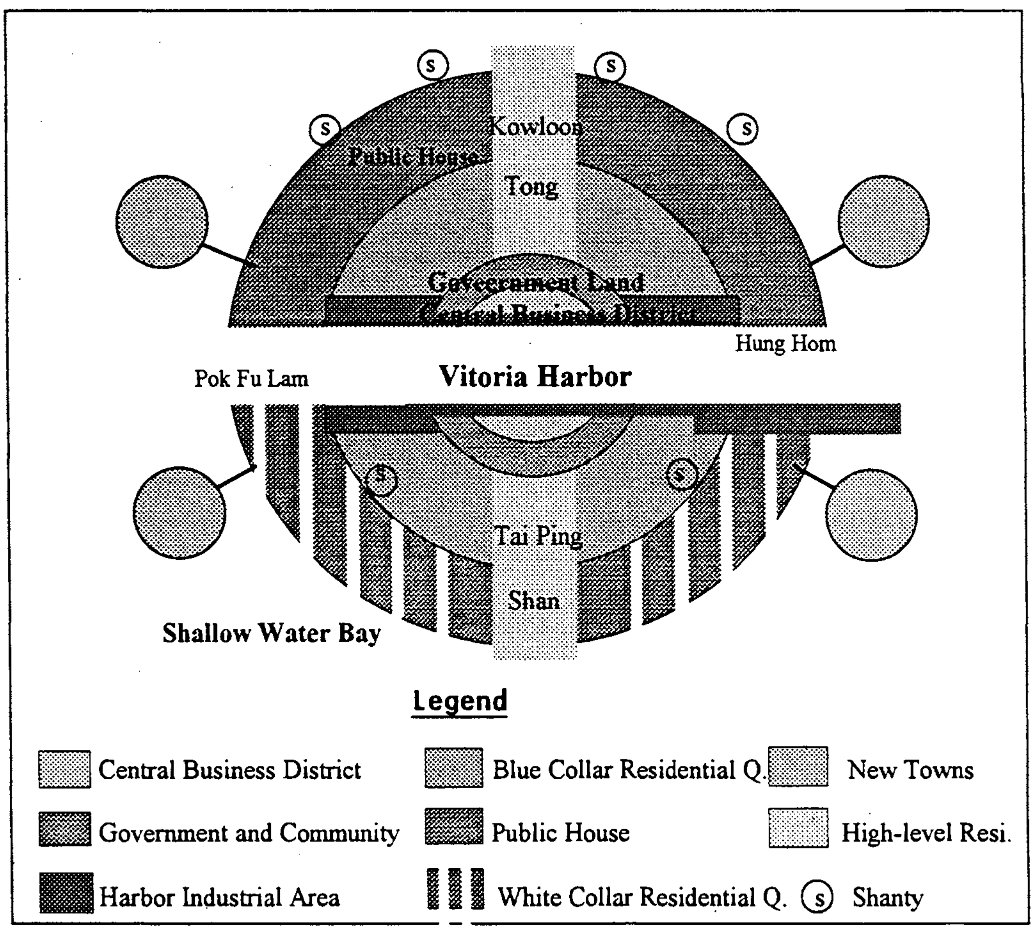


Figure 3 A sckech map to show the relation of Metro area and the Harbor

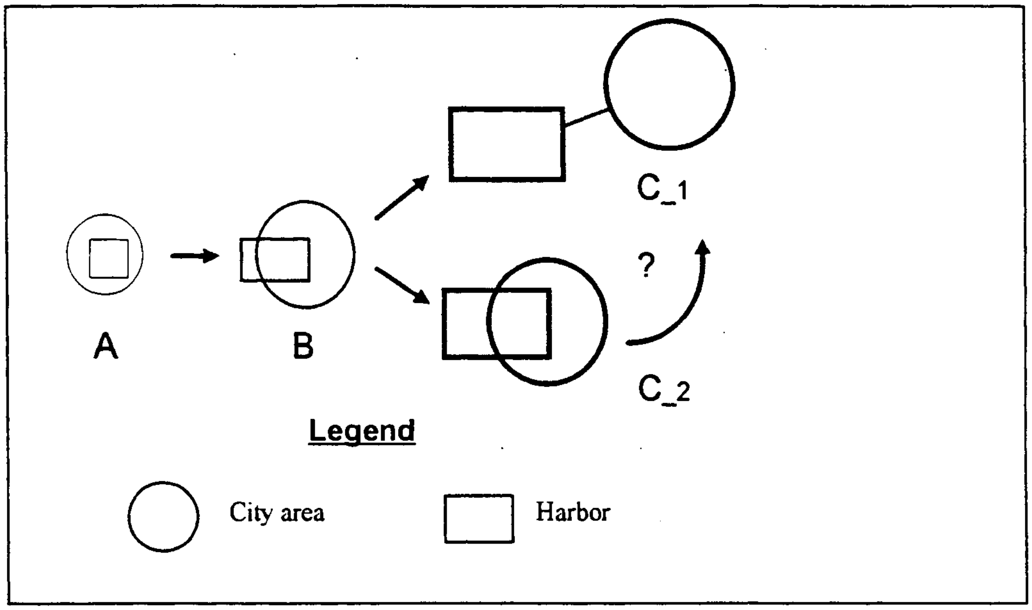


Figure 2 A skech map showing the evolution of city-harbor relation

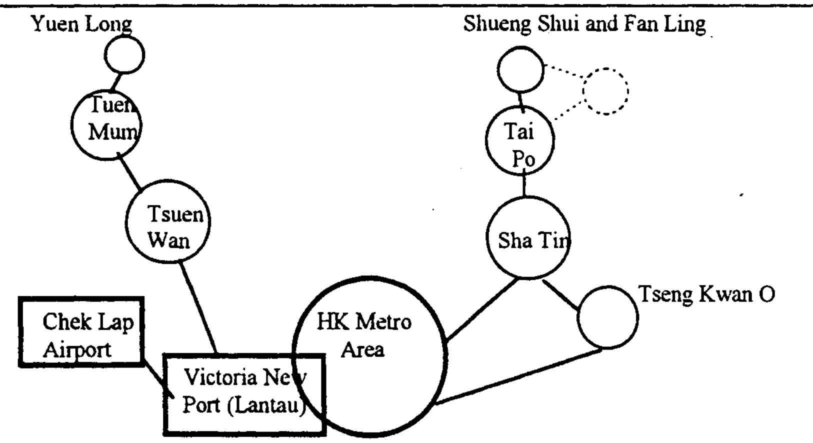


Figure 4A Scenario Analysis of city-seaportlayout,alternative (HKV/HBL)

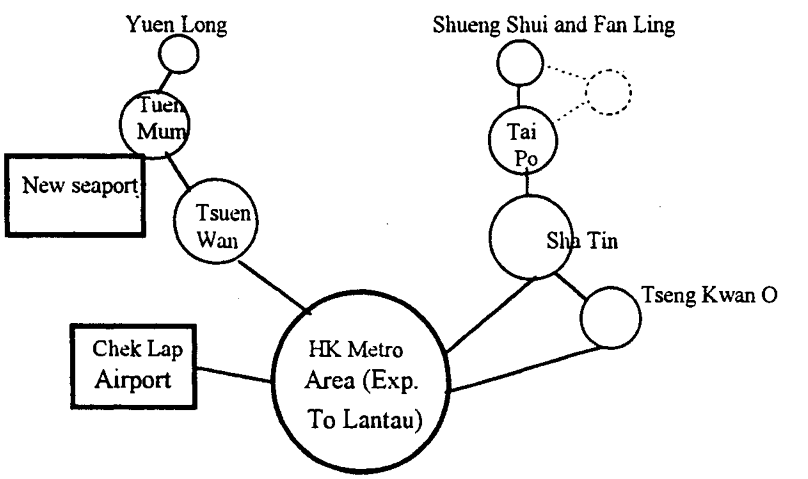


Figure 4B Scenario Analysis of city-seaportlayout,alternative (HKL/HBO)

CONCLUSIONS

(1)The sharp contrast on the geomorphologic features between the two sides of the Pearl River estuary is mainly the results of differential deposition. With the continuously growth of the delta in the west of the estuary, all the deep water bays were filled up by rapid sedimentation in the last 5000 years. In the mean time Hong Kong coast remains dominated by a ria form with numerous potential port sites. This has a profound influence on the urban and infrastructure planning.

(2)A brief investigation on the history of Singapore, Hamburg, Rotterdam and Guangzhou reveals that there are commonly three phases in the evolution of the city-harbor relation. The general trend of this relation is towards the separation of metro area and harbor. Hong Kong is a highly developed international city and Victoria Harbor is a full scale seaport. Many of the functional systems operating for the Metro area and the seaport overlap and interlock in an extremely limited space, which is responsible for many urban developing problems in Hong Kong.

(3)The expansion of Metro area and relocation of the outer seaport are very important step and one of the few turning points in Hong Kong's urban development. There are several alternatives proposed for the future seaport, including North Lantau, Tuen Mum and Tolo Harbor. However due to the geologic and geographical setting, North Lantau Island is essentially the only rational alternative and territory left for Metro area expansion in the next century. PADS may have serious strategic defect on the planning of general layout of city and seaport in view of sustainable development.

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SIZE-FRACTIONATED CHLOROPHYLL *A* AND PRODUCTIVITY OF PHYTOPLANKTON IN THE BEIBU GULF

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ABSTRACT

The distribution of the abundance of phytoplankton, chlorophyll *a* concentration and primary productivity in the Beibu Gulf were observed from May 23 to June 4, 1994. The results showed that there were marked features of spatial zonation in the surveyed area due to the differences between the geographic environment and the hydrological conditions. Chlorophyll *a* and primary productivity were higher in the inshore than in the middle area and higher in the north than in the south of the Beibu Gulf. The average concentration of chlorophyll *a*, primary productivity and the abundance of phytoplankton were $0.94\pm0.45\mu g/dm^3$, 351 ± 172 $mgC/(m^2 \cdot d)$ and 0.97×10^4~10050×10^4 Ind./m^3 in the surveyed area, respectively. There were 176 species belonging to 4 phyla and 56 genera based on microscope identification. The results of the size-fractionation showed that the contribution of nanoplankton with picoplankton to total chlorophyll *a* was 77%, to total primary productivity was 91% , which proved their importance in phytoplankton community of the Beibu Gulf.

INTRODUCTION

The oceanic light energy- autotrophic plankton is the primary producer of organic substances in the sea. Phytoplankton is the fundamental link in the marine food-net and plays an important role in the substance cycle and energy conversion of marine ecosystem. chlorophyll *a* concentration is an important index indicating the light energy-autotrophic biomass in the sea region. Primary productivity is the important content studying marine ecosystem as well as the important foundation appraising the biological resource in the sea. However, few studies on this were done in the Beibu Gulf, where is the fourth major fishery in China. The paper describes the distribution characteristics of the size-fractionated chlorophyll *a* concentration and primary productivity in the Beibu Gulf during May to June and provides the scientific foundations for appraising the fishery resources and the environmental quality in the sea, and working out the scheme for the administration of fishery resources.

MATERIALS AND METHODS

Sampling

During May 23 to June 4 ,1994, a comprehensive multidisciplinary investigations was carried out on board *China Ocean Surveillauce No.*71 in the Beibu Gulf. Thirty-five stations were launched for analysing chlorophyll *a*, *a*mong them, there is 10 stations for primary productivity. Station 27 and 100 for the diurnal continuous observation were sampled once every four hours (Fig.1). The water samples were collected with Model HQM-1 plexiglass sampler at the layers of surface, 5m, 10m, 20m, 30m, 50m and bottom according to the Marine Biological Survey, the specification for Oceanographic Survey (1991).

Methods

Chlorophyll *a* (Chl *a*) and phaeopigment (Phaeop.) were determined by the fluorescence method (Holm-Hansen et al. ,1965). Water samples of 250 cm^3 at different depths were filtered through 20μm mesh and the Whatman GF/F filter. The particulate substance retained on the mesh and filter were extracted with 90% acetone for 24h and determined with Turner Designs fluorometer Model 10.

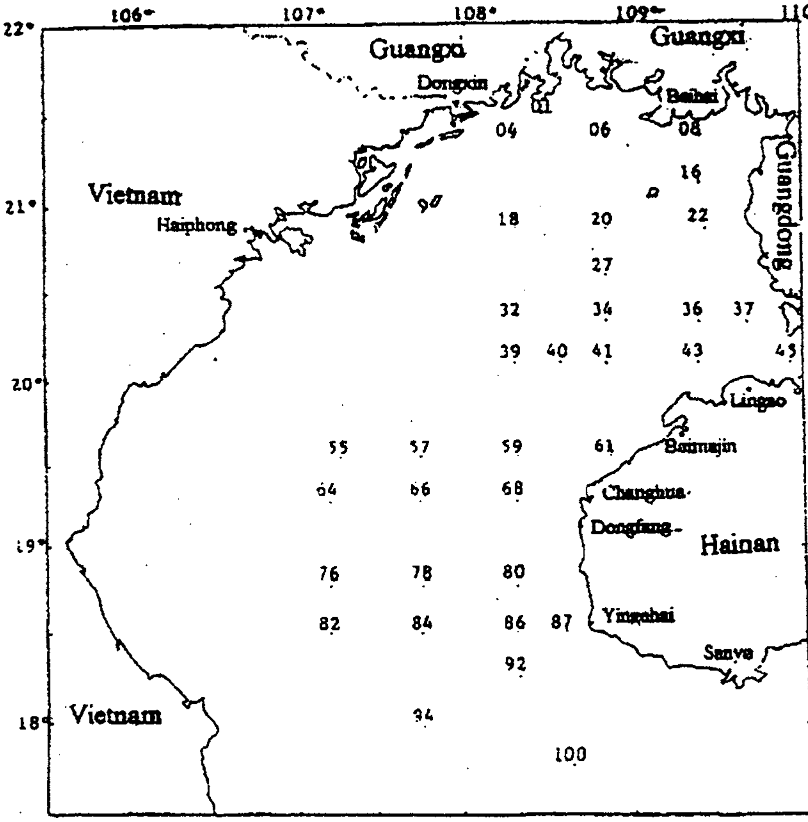

Fig. 1 Sampling locations in the Beibu Gulf during May to June 1994

Primary productivity were determined by using the isotopic (^{14}C) trace method established by Steemann Nielson (1952) and improved by Evans et al. (1987) and Ning et al. (1988), i.e., the water samples collected from the depths at which the light intensity is attenuated from 100% at sea surface to 50%, 32.5%, 10%, 3% and 1%, respectively. Before the water samples were collected, they were pre-filtered through a mesh with a pore size of 280 μm to remove most zooplankton. The waters from each light level were filled into two parallel light bottles and one dark bottle of 250 cm^3, each bottle was added 185 kBq $NaH^{14}CO_3$, laid in an incubator on the deck and incubating for 4h. The incubator possessed the sieve with different neutral light density to control the light intensity and made them complied with the light intensity at original sampling depths. After incubation, the water samples were filtered through 20μm mesh and the Whatman GF/F filter. The potential primary productivity was calculated according to the formula of the Marine Biological Survey, the specification for Oceanographic Survey.

RESULTS

Size-fractionated chlorophyll a

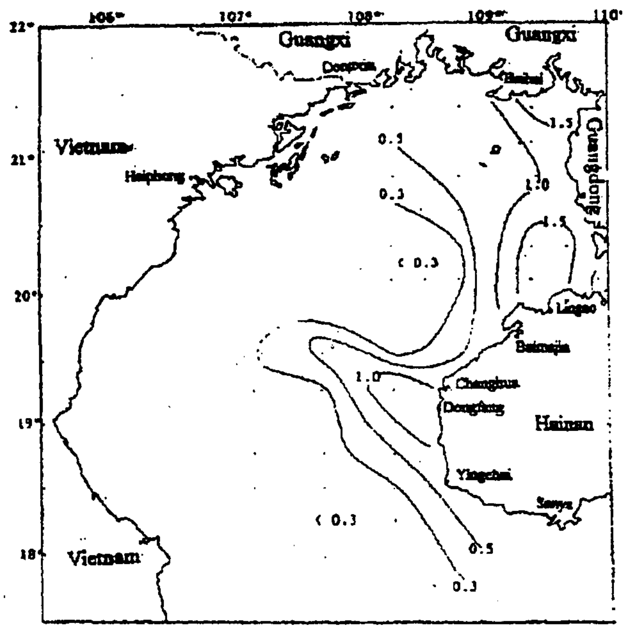

Fig. 2 Horizontal distributions of chlorophyll *a* concentration ($\mu g/dm^3$) in the surveyed area.

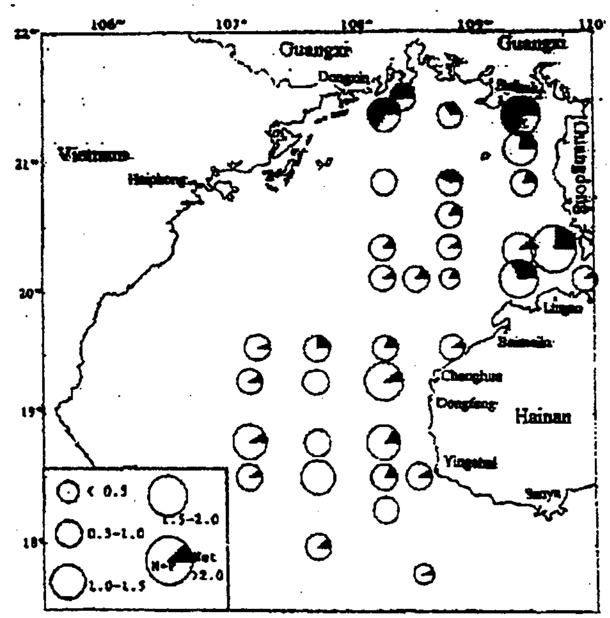

Fig. 3 The distribution of size-fractionated chlorophyll *a* concentration in water column

Horizontal distribution

The high Chl *a* concentration appears in the inshore areas of the west of Leizhou Peninsula, Changhua and Dongfang Harbour, Hainan. It can be seen from Fig.2 that surface Chl *a* concentration decreases gra-dually from the east towards the west, i.e., from inshore area towards the middle area of the Gulf. At the station 36, 37 and 43 in the south-west of Leizhou Peninsula, the surface Chl *a* concentration were 2.03, 1.70 and 1.53 $\mu g/dm^3$ respectively; the sub-high value ($1.28\mu g/dm^3$) area appears at the station 68 in the southern area of the Gulf; the low value areas with the concentration below $0.3\mu g/dm^3$ is located in the mid-west and the south-west of the Gulf; the lowest value ($0.14\mu g/dm^3$) appears at the station 100 outside the mouth of the Gulf.

The high value of the average Chl *a* concentration in water column appears at the stations mentioned above; the average concentration at stations 08, 36, 37, 43 and 68 are 1.73, 1.39, 2.41, 1.87 and $1.71\mu g/dm^3$, respectively; the low values appears at stations 100 and 41, being 0.33 and $0.29\mu g/dm^3$, respectively (Fig. 3).

From the zonal distribution, the surface Chl *a* concentration ($0.98\pm0.57\mu g/dm^3$) in the shallow water at inshore area is three times that in the deep water ($0.32\pm0.17\mu g/dm^3$) at the middle area of the Gulf; the proportion of both increases with the depth increasing, until the depth of 30m, where the proportion decreases; the average Chl *a* concentration is equal to each other at the depth of 50m in both areas. That in the water column in inshore area ($1.23\pm0.53\mu g/dm^3$) is nearly two times that in the middle area of the Gulf (0.68±0.22μg/dm^3)(Table 1).

Table 1. Vertical distribution of size-fractionated chlorophyll *a* (μg/dm^3) in the different depths

Depth	Inshore region			Middle region of the Gulf			Surveyed area		
(m)	Net	N+P	Sum	Net	N+P	Sum	Net	N+P	Sum
0	0.25±0.30	0.73±0.52	0.98±0.57	0.08±0.09	0.24±0.13	0.32±0.19	0.17±0.30	0.48±0.44	0.65±0.53
5	0.26±0.28	0.79±0.83	1.05±0.91	0.07±0.06	0.20±0.11	0.27±0.14	0.17±0.22	0.50±0.65	0.66±0.74
10	0.37±0.46	0.83±0.49	1.20±0.70	0.05±0.03	0.21±0.13	0.25±0.16	0.21±0.35	0.52±0.47	0.72±0.68
20	0.35±0.46	0.97±0.40	1.32±0.67	0.03±0.02	0.24±0.20	0.27±0.20	0.17±0.33	0.54±0.47	0.71±0.69
30	0.32±0.29	1.08±0.40	1.40±0.38	0.09±0.09	0.64±0.54	0.73±0.61	0.16±0.20	0.77±0.53	0.93±0.60
50	0.16±0.15	0.94±0.30	1.10±0.45	0.15±0.07	0.95±0.51	1.10±0.54	0.15±0.08	0.95±0.48	1.10±0.52
Ave.	0.34±0.31	0.89±0.50	1.23±0.53	0.09±0.04	0.59±0.20	0.68±0.22	0.22±0.25	0.74±0.40	0.96±0.54

The results of size-fractionated Chl *a* shows that the nano- with picoplankton (<20μm) predominated mostly in most stations (Fig. 3). The average contribution to total Chl *a* is 77%; the netplankton (>20μm) contribution accounting for 23%. Netplankton predominated in the stations 01, 04 and 08, the contribution to total Chl *a* are 54%, 59% and 70%, respectively. And the cell abundance of netplankton are higher at above stations, being 3.83×10^7, 10.1×10^7 and 2.31×10^7 ind./m^3,respectively.

Vertical distribution

The vertical distribution of Chl *a* concentration in the shallow water at the inshore is rather uniform; the average Chl *a* concentration in surface is lower than that in deep sampling layers; and it increases with depth downwards (Table 1). In the deep water of the middle of the Gulf, the thermocline was situated in the depth of 20~30m. Chl *a* concentration is low and slightly fluctuates over the thermocline, and it is high and markedly fluctuates under the thermocline. It can be seen from Table 1 that the contribution of nano- with picoplankton to total Chl *a* are 69-89% at different layers, average value being 77%.

Diurnal variation

The continuously surveyed results showed that the diurnal fluctuation of surface Chl *a* is indistinct. Chl *a* concentration at station 100 was low (0.12~0.19μg/dm^3, averaging 0.15 ± 0.02μg/dm^3) and the contribution of nano-and picoplankton was predominant (86.7%). Chl *a* concentration at station 27 was higher(0.29~0.71μg/dm^3, averaging 0.47 ± 0.45μg/dm^3) than that at station 100; the contribution of nano- and picoplankton (83.0%) was lower than that at station 100.

The abundance of phytoplankton and dominant species

The results of the net sampling observation showed that the abundance of phytoplankton was 0.97×10^4~10050×10^4 Ind./m^3. The high abundance was distributed in the north in the Beibu Gulf;

the abundance more than 10^7 Ind./m^3 appeared at the stations 01, 04, 08 and 36. The lowest abundance (9725 Ind./m^3) appeared at station 100 in the south in the Gulf. In respect of species composition, there were 176 species belong to 4 phyla, 56 genera through identification by the microscope. Among them, the Bacillariophyta predominated, accounting for 68.2% of total species; Choanoflagellata followed, accounting for 28.4%, the others accounting for 3.4%. The important predominant species was *Thalassionema nitzschioides*, *Rhizosolenia styliformis*, *Rh. alata f. gracillima*, *Rh. calcar-avis*, *Ditylum sol.*, *Trichodesmium erythraeum*, *Oscillatoria* sp., *Ceratium fusus*, *C. trichoceros*, *Hemiaulus membranaceus* and *Chaetoceros pseudocurisetus*.

Size-fractionated primary productivity

The primary productivity, the percentage of the contributions of netplankon and nano- with picoplankton to primary productivity and assimilation number are listed in Table 2. It can be seen from the Table 2 that the high productivity [>500 mgC/(m^2·d)] appears at the stations 22 and 36 in the inshore area and at the station 84 in the middle area in the Gulf; followed, 200~500 mgC/(m^2·d) appears at the stations 27, 45, 92 and station 94, primary productivity below 200 mgC/(m^2·d) appears at the stations 06, 68 and 100, the lowest value appears at the station 06 [99 mgC/(m^2·d)]. The average primary productivity in the surveyed area is 351±172 mgC/(m^2·d). Viewing some results from size-fractionated primary productivity, the contribution of nano- with picoplankton to total primary productivity is 90% or more for most stations, averaging 91%, while that of netplankton accounts for 9% only.

Table. 2 Size-fractionated primary productivity in surveyed stations in the Beibu Gulf

Station	Depth	Euphotic zone	Primary production [mgC/(m^2·d)]			Primary production (%)			Assimilation number [mgC/(mgChl *a*·h)]		
	(m)	(m)	Net	N+P	Sum	Net	N+P	Sum	Net	N+P	Sum
06	17	17	33	66	99	33	67	100	1.7	1.6	1.6
22	18	12	41	495	536	8	92	100	3.3	10.6	9.1
27	44	44	9	380	389	2	98	100	0.7	2.9	2.7
36	20	10.5	39	519	558	7	93	100	1.9	5.3	4.7
45	54	10.5	31	311	342	9	91	100	5.8	5.6	5.6
68	35	10.5	9	143	152	6	94	100	1.7	2.2	2.2
84	67	45	/	/	521	/	/	100	/	/	2.5
92	88	75	/	/	473	/	/	100	/	/	2.2
94	82	82	53	224	277	19	81	100	1.4	1.5	1.5
100	80	78	10	152	162	6	94	100	1.2	1.6	1.5
Ave.	50.5	38.6	28	286	351	9	91	100	2.2	3.9	3.4

The average assimilation number of photosynthesis of phytoplankton in surveyed area is 3.4±2.4 mgC/(mgChl *a*·h); the highest assimilation number is at station 22 [9.1 mgC/(mgChl *a*·h)] and the next are at the stations 45 and 36 [5.6 and 4.7 mgC/(mgChl *a*·h)], respectively; the lowest assimilation number [1.5 mgC/(mgChl *a*·h)] is at the station 100 and 94 (Table 2).

DISCUSSION

The Beibu Gulf is a semi-closed one with smooth bottom and sloping from the north-west to the south-east and there are a lot of rivers on its coast flowing into it, carrying a large number of terrigenous nutrient substances; the average concentration of phosphate, inorganic nitrogen and silicate was 6.40, 12.26 and 276.30 μmol/dm^3 respectively in the surveyed area, providing abundant basic substances for the growth and propagation of the photosynthesis phytoplankton in the Beibu Gulf. In late spring and early summer, owing to sunlight radiation strengthening, the water temperature in the upper layer rises rapidly and that at some stations is higher than 30°C, for example, at the station 06, it reaches to 30.22°C at the layer of surface and 5m. The Chl *a* concentration and primary productivity are rather low (0.57 μg/dm^3 and 99 mgC/(m^2·d) respectively) at the stations; perhaps rather high temperature affects the growth and propagation of phytoplankton.

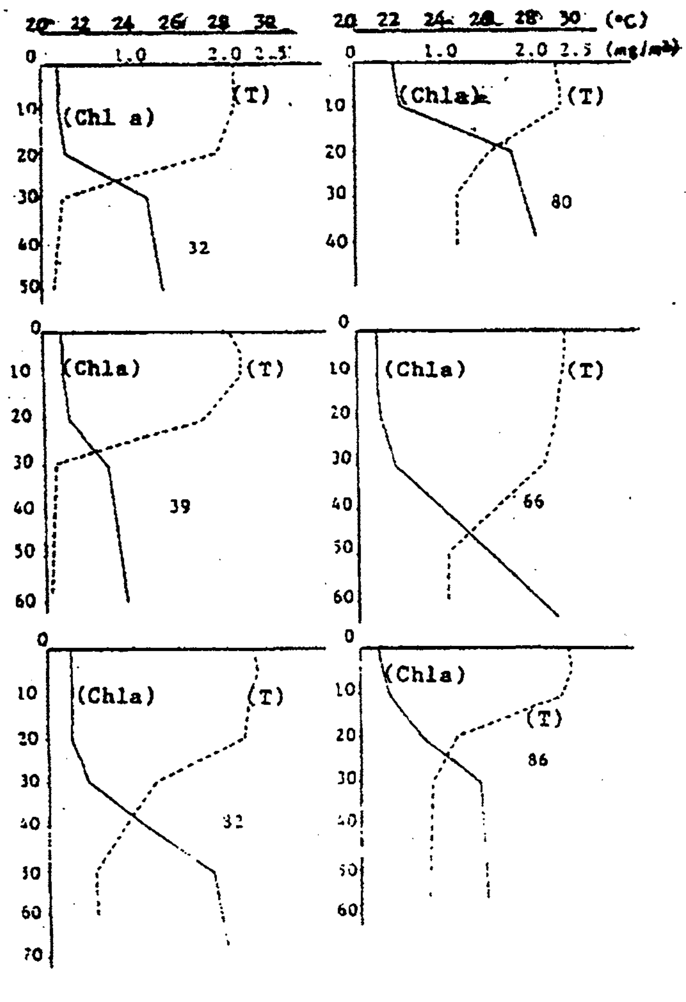

Fig. 4 Vertical distribution of chlorophyll *a* and temperature at the typical stations

Owing to the differences of the geographic environment and the hydrological conditions, the distribution of phytoplankton, Chl *a* and primary productivity possessed distinctively spatial zonation features. The average Chl *a* concentration at 0~10m in the inshore area was 3~5 times that in the middle of the Gulf. Taking the western sector of the Qiongzhou Strait as the boundary, the Gulf is divided into both areas of the southern and the northern; Chl *a* concentration at 0~10m in the northern shallow area is twice or more than that in the southern; the concentration at 20m in both is equal and that is higher at the deep layer (below 30m) in the southern than in the northern (Table 3). The reason possibly is the thermocline strengthening in the southern area, water column being stable, the euphotic layer being thick and reaching the bottom and nutrient concentration being high. Specially, the biomass of nano- with picoplankton was rather high; The contribution to total Chl *a* accounted for 70% at the bottom in the northern area, that in the southern area accounted for 88%. It can be obviously seen that Chl *a* concentration is closely related to the thermocline, the temperature being high and Chl *a* concentration being decreasing above the thermocline and the temperature being lower and Chl *a* concentration increasing below that.(Fig.4)

Table 3. The vertical Distributions of chlorophyll *a*, temperature and salinity in different surveyed areas.

Depth (m)	Northern area				Southern area			
	Temperature (°C)	Sanility	Chl *a* ($\mu g/dm^3$)	Station (n)	Temperature (°C)	Sanility	Chl *a* ($\mu g/dm^3$)	Station (n)
0	28.50±0.66	32.72±0.51	0.82±0.59	18	29.24±0.32	33.42±0.39	0.37±0.27	17
5	28.63±0.67	33.20±0.43	0.88±0.90	18	29.19±0.34	33.70±0.21	0.33±0.16	17
10	28.57±0.73	33.31±0.39	0.87±0.72	18	28.97±0.53	33.77±0.20	0.44±0.51	17
20	27.99±0.62	33.66±0.32	0.56±0.49	10	27.88±1.33	33.91±0.23	0.55±0.54	17
30	24.65±2.64	33.58±0.43	0.90±0.43	9	25.65±1.39	34.11±0.19	0.91±0.83	15
50	21.76±2.87	33.02±0.43	0.82±0.35	5	23.17±0.71	33.96±0.33	1.32±0.49	13
bottom	25.45±3.57	33.12±0.33	1.28±0.61	18	23.83±1.94	33.96±0.32	1.26±0.54	17

High biomass and productivity appeared on the west of Qiongzhou Strait, the south-west of Leizhou Peninsula and the inshore area of Dongfang Harbour, (averaging Chl *a* concentration at the stations 36, 37, 43 and 68 being 1.39, 2.41, 1.87 and 1.71 $\mu g/dm^3$, the potential primary productivity at the stations 36 and 68 being 8.18 and 2.23 $mgC/(m^3 \cdot h)$ respectively). This is possibly related to the influence of upwelling current. The current of Qiongzhou Strait flows westward and meets the protruding topography in wide open position (at the stations 36, 37 and 43, and the depth of 20m or so), making the westward current with low temperature (<28°C) and low salinity (<33.5) at the bottom of the strait to be obstructed and upwelling. Similarly, the current of the cold water masses in the bottom in the mouth area of the Gulf (depth>80m) stretched to the Gulf inwards and is obstructed at the station 68 (35m of depth) and upwelled. In the upwelling current area, owing to abundant nutrients, Chl *a* and primary productivity were in rather high level. However, due to once observation limited, the results are only preliminary. It is necessary to develop the special topic investigation of the upwelling current and understand its formation mechanism, distribution range, the distribution characteristics of standing stock of phytoplankton and primary productivity and their influences on fishery's production and inshore aquiculture.

The Beibu Gulf is the fourth largest fisheries in China and there are abundant nutrient substances and high phytoplankton biomass, and average chlorophyll *a* concentration with 0.94±0.45 $\mu g/dm^3$, being equal to that in Lianzhou Harbour at the top of the Gulf approximately, higher than that in some investigated areas in the South China Sea and lower than that in Daya Bay adjacent to it; the average primary productivity was 351±172 $mgC/(m^2 \cdot d)$, being higher than that in Daya Bay, Balinten Strait and the middle of the South China Sea and lower than that in the Southern Fujian-Taiwan Bank Fishing Ground and that in the sea area of the Nansha Islands, and being conformable to the observation results at the top of the Gulf in spring of 1993 (Table 4).

Table 4 Chlorophyll *a* concentration and primary productivity in the Beibu Gulf compared with those in nearby sea areas.
5

Region	Latitude (N)	Time (Y. M.)	Chl *a* ($\mu g/dm^3$)	PP [a] [$mgC/(m^2 \cdot d)$]	Source
The Middle of SCS [b]	12°~19.5°	1984.4	0.16	325	Chen X. (1989)
Daya Bay	22.5°~22.75°	1986.12.~1987.12.	1.70	4.53 [c]	Chen Q. (1990)
Daya Bay	22.5°~22.75°	1984.11~1985.10	2.03	317	Huang L.(1990)
Balinten Strite	17°~20°	1984.6	0.09	108	Huang L.(1989)
Nansha Island area	4°~11°	1987.5	0.20	396	Huang L.(1991)
Minnan-Taiwan Bank	21.5°~23.5°	1988.4	0.60	520	Li W. (1991)
The East-north of SCS [b]	17°~22°	1982.6	0.2~1.2	100~1000	Fan J. (1985)
Lianzhou Bay	21.1°~21.7°	1993.5	1.00	351	Lu L. (1995)
Beibu Gulf	18°~21.5°	1994.5	0.94±0.45	351±172	this paper

a) PP: Primary Productivity b) SCS: The South of China Sea c) $mgC/(m^3 \cdot h)$

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SUSTAINABLE COASTAL DEVELOPMENT AND DEEP OCEAN WATER

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ABSTRACT

Sustainable development seems to be the phrase of the 1990's. The phrase is a hopeful one in the sense that it implies humankind has the capacity to achieve a state of development that leaves the natural resource endowment intact. In actuality opportunities to achieve 'sustainable development' are rare, and inasmuch as they do exist, population pressure or simply greed, usually preclude their attainment. Although relatively unused to date, deep ocean water (DOW) represents an unparalleled opportunity for sustainable development in the 21st Century. This means major economic and other quality of life benefits can be made available to millions of people located in coastal desert areas in close proximity to the deep ocean. A number of basic technologies to use DOW have been developed, tested and are available for application. To the extent these technologies are applied wisely benefits can be sustainable and without insult to natural environments.

Benefits to be derived from use of cold deep ocean water use resources include: air conditioning and industrial cooling, fresh water production, cool and cold water aquaculture and production of a wide assortment of temperate agricultural crops. Recent discoveries indicate growth of subtropical and tropical crops can also be accelerated through use of DOW. Ocean Thermal Energy (OTEC), the initial interest in cold deep ocean water, is technically feasible but still a stage away from being economical in most locations. This paper briefly summarizes the prominent events leading to the achievement of a transferable DOW technology, reviews these technologies and their stage of development and speculates on their 21st century potential.

EVENTS LEADING TO PRESENT STAGE OF DEVELOPMENT OF DOW TECHNOLOGIES

The single most important factor in the development of current deep ocean water use technologies was the establishment in 1974 of The Natural Energy Laboratory of Hawaii (NELH) at Ke-ahole Point Hawaii by Governor John Burns of the State of Hawaii and John P. Craven Marine Affairs Coordinator of the State. The first major experiment with DOW water was the successful demonstration of ocean based closed cycle OTEC in Mini-OTEC at NELH in the early seventies, a joint venture of Lockheed, Alfa Laval and the State of Hawaii. The net power was approximately 40 kilowatts. U.S. government interest in alternative energy waned by the early 1980's and ambitious plans to follow up Mini-OTEC with larger offshore OTEC installations were dropped.

In 1982 the first 12" deep ocean water pipe to shore was placed in operation at NELH. The first pipeline delivered 4.2 cubic meters per minute. In 1997 there are two deep sea water polyethylene pipelines in operation with a total capacity of 64 cubic meters per minute and three surface sea water pipelines with a distribution capacity of 53 cubic meters per minute. A new seawater system, presently being developed, will have a capacity of 102 cubic meters per minute of cold deep seawater, and 156 cubic meters per minute of warm surface water. (http://bigisland.com/helha/pipeline.html). The initial motivation for developing the 12' pipe was to continue OTEC research. However it was soon learned that electrical energy was, at best, only one of the major products to be derived from deep ocean water. Proof of concept experiments financed by the University of Hawaii Sea Grant College Program and the State Marine Affairs Coordinator's office soon established plant and animal aquaculture as viable uses of DOW. This work set the stage for the development of a number of aquaculture enterprises at NELH with each entrepreneur concentrating his/her efforts on a particular aquaculture innovation. A number of these entrepreneurs have already demonstrated economic viability based on their product alone. NELHA (in 1990 NELH was converted from an independent State Corporation into an Authority) also found DOW the ideal way to cool it's offices and laboratory buildings at substantially lower electricity costs.

In 1990, Dr. John Craven took partial retirement from the University of Hawaii and established the Common Heritage Corporation (CHC). The mission of the CHC is to establish self-sufficient environmentally, economically and culturally sustainable communities in coastal zones and islands for the benefit of the Common Heritage of mankind. As President of CHC Dr. Craven has continued in his role as innovator of new DOW technologies outside of the field of aquaculture, e.g. DOW agriculture and the Hurricane Tower. Today, although a 'transferable' DOW technology has been developed and the potential benefits for mankind are enormous, Hawaii remains the sole user of DOW for three reasons. First the U.S. government's almost complete withdrawal from DOW research and development. The second is the failure of the State of Hawaii to recognize the unique value of what was being achieved and to develop an aggressive program to make Hawaii and NELHA the base for launching these technologies world wide. The third reason is a generic problem with innovation. This was expressed by Machiavelli, "There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in introduction of a new order of things, because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new."

STAGE OF DEVELOPMENT OF DEEP OCEAN WATER TECHNOLOGIES.

Deep Cold Water Systems

To date little attention has been given to the uses of the DOW in a riparian sense and few of the contractors at NELHA take a 'systems' approach to use deep ocean water as a resource. However it is clear that in most localities, large economies can be realized in optimizing the systems use of the unique qualities of DOW i.e., cold, nutrient richness, and purity.

The DOW system defined by the CHC has three major sub systems a) the electrical power and electrical by-product system, b) the cold utilization system and c) the nutrient utilization system. Since there will be a riparian use of the deep ocean water by these three systems it is convenient to discuss them separately. CHC recommends that most small coastal desert communities should focus on the more affordable cold and nutrient utilization subsystems for a sustainable self sufficiency system that could be immediately implemented.

The Electrical Power Subsystem

Attention has been given to Closed and Open Cycle OTEC. Closed cycle OTEC was first demonstrated in Mini-OTEC. Following Mini-OTEC, a project was initiated with Aluminum Company of Canada (AlCan) for the development of Aluminum heat exchangers. Shortly thereafter a project was initiated with Dr. Alastair Johnson of General Electric of Britain to develop a one megawatt closed cycle plant. These developments were technically successful and construction of a demonstration plant was undertaken at NELHA. A series of administrative delays caused AlCan and GE to abandon their participation in the project which was taken over by Pacific Center for High Technology Research (PICHTR) and a newly formed Aluminum Company (AlGoods). The turbine generator of Mini-OTEC was successfully refurbished but the installation of the aluminum heat exchangers have encountered several expensive and time consuming delays and the demonstration is not operable at this stage.

A technically successful open cycle plant of about 100 kilowatts net power has been built at NELHA by PICHTR. Although it is an engineering feat of some magnitude, the cost of more than ten million dollars and the inability of anyone to conceive of technically feasible ways to scale up on land probably eliminates Open Cycle OTEC as a contender in the foreseeable future.

Cold Utilization Subsystem

Air conditioning and industrial Cooling--The most economically valuable use of deep ocean water appears in the form of air conditioning and industrial cooling. Conventional means of cooling are, in fact, forms of reverse OTEC. As a consequence they pay a heavy Carnot efficiency penalty. On the average these systems generate ten times as much heat as they remove in terms of cold. For this reason it is inefficient to generate electricity by Ocean Thermal Energy Conversion and to use that electricity for air conditioning or industrial cooling. As a rule of thumb the amount of water required to generate one megawatt of electrical energy will provide the equilivant of 10 megawatts of air conditioning or industrial cooling (http://www.aloha.com/~craven/coolair.html). A study by Makai Ocean Engineering, Waimanalo, Oahu has indicated that for Guam, 10,000 hotel rooms could be air conditioned with cold seawater and that the capital payback period for installing this system, for air conditioning use alone, would be approximately five to six years.(Van Ryzin and Leraand.)

Fresh water from condensation and desalinization--Everywhere deep ocean water flows through pipes above the ground or near the surface, condensation is generated. It has been estimated that condensate can be generated at a rate which is about 5% of the flow of cold water. Thus a flow of deep water of about 20,000 gallons per minute should be able to generate 1,000 gallons per minute of fresh water through simple condensation. These estimates have not yet been confirmed in an application or experiment designed to concentrate the condensate. Tests with swimming pool heat exchangers suggest that the engineering will be straight forward. The CHC is experimenting with a number of ways of generating and capturing this condensate. These include condensate in the cold bed agriculture demonstration garden, from a cooling facility (chill house) associated with the garden and from simple room air conditioning units that can be developed and used in third world desert island communities comprised of a cold water supply, an automobile radiator and an inexpensive household fan.

CHC and Oceanit Laboratories have a patent pending for a desalinization device called a Hurricane Tower(http://www.aloha.com/~craven/hcane.html) A model, installed at the CHC facility at NELHA in 1996, demonstrated the validity of the fundamental principle. Additional tests will take place in 1997-98 to determine more optimum configurations of the tower and its water supply at which time it will be possible to make predictions on production and price.

Coldwater Agriculture

Condensation techniques coupled with biophysical applications of cold have produced a surprising result in terms of agriculture in coastal desert areas. Quite simply, black plastic irrigation pipe is embedded in agricultural soil at a depth which corresponds to the root depth of the species to be cultivated. For deep rooted plants, e.g. carrots two sets pipes are desirable. Deep ocean water is passed through these pipes and heavy condensation is induced. A thermal gradient between root and fruit is produced which pumps nutrients into the plant at a rate which is probably three times greater than that produced by nature in the spring or fall in temperate climate areas. The more than 100 temperate climate fruits, vegetables and herbs that have been grown in the CHC demonstration garden all show rapid growth, high yield with high sugar and aromatic content.

CHC has also demonstrated that DOW can be used to induce and break dormancy in temperate climate fruits at frequent intervals. More recent experiments indicate accelerated growth of subtropical and tropical crops through use of DOW. For example, pineapples and papaya have been brought to maturity much faster than under conventional methods (http://www.aloha.com/~craven/cldgrdn.html) . These results combine to offer opportunity to use what is often marginal agriculture land in coastal desert areas for a wide variety of crops, temperate and tropical and to optimize production in ways heretofore unavailable.

The economics of ColdAg have not been analyzed to date. The experiments have been small and undertaken mostly to demonstrate the feasibility of producing a wide variety of crops. However the cost for DOW at NELHA runs about 10 cents for 1000 gallons and the cost for the half acre demonstration farm is negligible. Of greater significance is the fact that once chilled, the ground loses very little heat and the water flow required to maintain its temperature is small. At the same time the cool surface causes fresh water condensate to form and irrigate the plants.

Nutrient and Purity Utilization Subsystems

After the deep ocean water has been employed in one or more cold utilization applications it can be utilized again for the nutrients, residual cold, (about 13 degrees C) and purity. The cold seawater contains 200 times more nitrates and 20 times more phosphates than surface seawater. (Intergovermental Agency White Paper) The purity or lack of surface pathogens has proven especially important in the production of marine algae such as spirulina and the microalgae, astaxanthin. Examples of current aquaculture operations at NELHA follow: (http:/bigisland.com/nelha/aqua.html)

- The Cyanotech Corporation is a highly profitable commercial operation for the production of spirulina. The use of cold water to recover carbon dioxide from the butane that is used to dry the algae and make it available for plant food also virtually eliminates the release of carbon dioxide to the atmosphere during the production process.

- Royal Hawaiian Sea Farms have produced and marketed a variety of tasty and nutritious "sea vegetables" using DOW since 1987.

- The Kona Bay Oyster And Shrimp Co. produces blue shrimp and American and Pacific oysters in a symbiotic system. The company also produces the marine algae Chaetoceros, from which unique compounds are to be extracted for pharmaceutical products to combat bacteria infection.

- Taylor United Inc. a shellfish company headquartered in Shelton, Washington maintains a Manila clam and Pacific oyster nursery. Larvae are raised in Washington, sent to NELHA as they settle out of their swimming cycle (250 microns), raised at NELHA to a 5 mm size and shipped back to the Pacific Northwest for growout.

- Uwajima Fisheries produces and markets Hirame a flounder highly prized for sushi for the upscale hotel and restaurant trade in Hawaii.

Salmon, steelhead trout, abalone, oysters, kelp, salmon and black pearl oysters have also been successfully cultured at NELHA some in poly culture systems. Although the above examples demonstrate a wide scope of aquacultural undertakings, it is apparent that these entrepreneurs have only scratched the surface of possibilities for DOW aquaculture.

Economics

Costs of installation of a DOW system is difficult to estimate and may vary by a factor of ten or more depending upon the manner in which the development and procurement are carried out. Until a site is chosen and a study is made to identify contractors, subcontractors and construction techniques only the most tentative estimates can be made. Most uncertain is the cost of the deep ocean pipe and pump installation and this again depends on the site.. Experience at NELHA has indicated that (under proper design) a pipe and pump system can be built and installed for as little as a half million. The basic cost of pipe and pump is about $125,000.00.

Two alternatives exist for the pipes for remote locations a) construction at a remote shipyard and tow to the site or b) transportation of pipe segments by conventional shipping and construction at the site. The former is much cheaper if it is carried out under the supervision of personnel who have had extensive experience with submerged towing. For insurance a two pipe line installation is mandatory. Thus a starter set (pipe and pump and shoreline distribution system) could conceivably be carried out for as little as 3 million dollars but more probably 5 million dollars. The additional cost and the amortization of the pipe and pump depends on the utilization of the water.

If air conditioning and industrial cooling is to be the sole use of the DOW installation, Van Ryzin and Leraand's study shows that the installation costs for the scenario they develop (similar to Keahole) can be paid back in less than two years depending on the demand for air conditioning and industrial cooling with a more likely final pay back period of about 3.75 years(Van Ryzin and Leraand)

If agriculture is the sole function, available evidence suggests that it too would be profitable but on a slightly longer amortization schedule. Thus the combination of the two systems would provide more economic benefits than either one. For cold bed agriculture, development and improvement in terms of soil and pipe installation based on experience to date, will be somewhere between $1,000.00 to $2,000.00 per acre. Once the site is determined and crops and market potential assessed, agricultural economics analysis can provide the necessary information for decision-making information.

If aquaculture is the sole function, our evidence suggests that it could be profitable on its own but an economic analysis would be required depending upon the species chosen and local market conditions and fluctuations in fishing. Again a site-specific economic analysis is needed. Depending on the species the triad of air conditioning-cooling, agriculture and aquaculture can be highly profitable.

If desalinization is the sole function, the technology is not ready for an economic stand alone system (i.e. the hurricane tower). But fresh water is an inevitable by-product of all of the other systems and thus a free resource except for the cost of collection and distribution. Thus for limited quantities the addition of freshwater generation by atmospheric condensation or by atmospheric distillation of solar heated surface water could improve profitability. For many coastal desert areas the fresh water potential may be critical to development. As more systems are installed rapid advancement and development of technologies to maximum the potential of the fresh water resource can be expected.

If electrical power is included there is no way that it can be competitive with oil or gasoline fired motor generator sets for smaller coastal areas at the present. This is particularly true for the small mass produced generators from Japan, Korea or Malaysia. Thus electrical power may be an economic drag on the system at this time and should not be implemented unless it is desired to advertise and demonstrate a full environmentally sustainable enterprise.

To summarize the economics and the risks: an investment of only $5,000,000.00 could prove highly profitable in terms of return on investment but there is a substantial risk of loss of the entire investment due to unforeseen circumstances (e.g. unrecoverable loss of the pipes at sea prior to or during installation). An investment of $10 million would allow for contingencies and/or a larger system or set of systems is almost certain to eliminate risk of loss and be at least acceptably profitable. This figure would allow a strong probability of being highly profitable in terms of return on investment. Similar profitability should exist for larger investments for system development through CHC of up to about $30 million dollars. Beyond this level the risk of loss and reduced profitability begins to return. This is due to the scale of the project and the greater likelihood that large conventional corporate contracting practices and involvement of government agencies in central management will impose unsustainable levels of overhead costs.

A Basic System for Desert Island Communities

A preliminary survey of coastal desert localities by the CHC has produced a list of 22 sites with attributes amenable to early and successful installation and use of DOW technologies. Successful use of these technologies implies the potential for a wide array of benefits to the local community. (http://aloha.com/~craven/okam.html). For such localities, CHC recommends a basic system consisting of a) two 24 inch diameter pipes (and pumps) for DOW recovery and distribution. b) capability for use of ten megawatts of air conditioning and industrial cooling; c) one hundred acres for agriculture and sixteen acres for aquaculture ponds or some combination of these. d) reservation of space and allowance for DOW supply for a one megawatt OTEC electricity plant to be built within the decade.

The size of this system is predicated on capacity for installation by local engineering and construction companies and for operation and maintenance by local people. Since installation costs dominate, the basic small deepwater system may not be less costly than larger systems. Larger systems will require the use of imported barges, construction equipment and imported technologists and specialized personnel for operation and maintenance. Such systems may be beyond the social and structural capabilities of coastal island communities to absorb without a major change in the culture and life style of the island community.

CHC is prepared to suggest a preliminary basic system for interested parties for a number of localities that is both economically viable and environmentally sustainable based in part on the literature, information provided by clients and the experience of the CHC staff and CHC Board. However a recommended system will require specialized modification and tailoring to be culturally compatible and to meet the marketing needs.

THE 21ST CENTURY POTENTIAL OF DOW SYSTEMS

DOW and Agricultural Business

One of the early and perhaps most significant developments in the use of DOW technologies will be the discovery of DOW by agricultural business. The significance of virtually unlimited opportunities to study and experiment with the effects of cold on dormancy, genetics, continuous cropping, etc., will not escape this sector. But until agricultural business discovers DOW we will see little involvement on the part of university agricultural scientists, who are intellectually confined to the existing agricultural science paradigm.

In any case, the early 21^{st} century should see more high technology agricultural business ventures building and looking for space to build facilities at NELHA (and new DOW sites) than by the aquaculture entrepreneurs . Modern aquaculture is in its infancy while agriculture both in terms of business activity, size of the sector and depth of the science support system is enormous by comparison. Agriculture is coming under ever greater pressure to produce more food and to do so under environmentally sustainable conditions. Some larger agricultural businesses and universities will find it to their advantage to develop their own DOW systems, as will advantageously located agricultural industries with large expenditures for cooling and holding fresh farm produce for distribution and marketing..

Fresh Water for Community Growth

For coastal desert communities requiring larger amounts of fresh water development than presently exist, condensate from DOW systems can utilized to meet these needs. Technologies to collect this condensate should develop rapidly as the number of operating systems grow. The Hurricane Tower should also be available within two years at which time the primary questions will be what type and size(s) of installations will best work in a given coastal desert community; larger vs. smaller sizes replicated, electric powered or wind driven, etc. These questions will require innovative engineering solutions but are straightforward.

Another option would simply be deep pipes equipped with a Reverse Osmosis membrane at the deep end. Pressure will force (fresh) deep ocean water through the membrane and to the surface. The process would use very little energy as opposed to the prohibitive expense of producing fresh water from surface supplies by this process. Since fresh water has not been a focus in the installation of the present pipelines at NELHA no attempt has been made to date to wed the membrane to a DOW pipe. Again, since the primary technologies are in place this is a straightforward challenge for creative ocean engineers.

A third DOW option is available for larger supplies of cool fresh water for air conditioning and consumption for a number of coastal desert cities . Many coastal deserts are the lee fringe of coastal mountain ranges e.g. the Kona Coast of Hawaii. These mountains often have abundant rainfall and surplus water that is too expensive to import and chill under normal circumstance. Water could be carried from the windward side of these mountain ranges by tunnels and by gravity down and across the desert and offshore to an underwater dome (of what ever size will optimize the water flow) at the 2000 ft depth, where it would chilled by deep ocean water and carried back to the surface by the water pressure. Such a process could provide a continual supply of fresh, chilled water on tap for a growing desert city.

Ocean Thermal Energy

In 1990 the 'Interlaboratory" study suggested that one megawatt (MW) to 100 MW standalone OTEC plants should be a strong development option for Pacific and Asian islands in the 1990's as a result of a combination of unstable oil prices, growing environmental concern, need for fresh water, and drive for economic self sufficiency. This study estimated at least 350 MW could have been provided by OTEC by 2005 and 2100 MW by 2010 most likely for Hawaii, the U.S. Island Territories, the U.S. Gulf Coast Region and producers of energy-intensive products as the most likely market. In the longer term the study suggested higher energy prices and expanded applications of OTEC could result in large systems for processing seabed ores, producing fertilizer and transportation fuel, developing fisheries and generating baseload electricity. Finally they foresaw markets for military installations in the Caribbean and Pacific and in hotel/resort development.

With the advantage of hindsight it appears that these estimates were extremely optimistic. However they were also based on an intensified (six-fold increase) R&D effort with an accompanied lowering of energy costs. Because support for R&D did not materialize, OTEC is still too expensive for low income coastal desert communities as compared to the other technologies. However this situation may change rapidly as costs of fossil fuels continue to rise and their continued supply grows more uncertain. As closed cycle OTEC plants are demonstrated and built, the costs will decrease and many of these communities will see the merits of having their growth and welfare dependent on their natural resources base rather than on foreign sources. Adding Closed Cycle OTEC to the system menu could enable a community to establish eventual energy independence as well as a wide array of the other system benefits described in this paper.

Immediate feasibility for Closed Cycle OTEC will probably be limited to individual units in the range of from 500 kilowatts (KW) to 1 megawatts (MW) with plant sizes employing multiple units being somewhere in the neighborhood of 5 MW. However the size required to meet electrical energy requirements for energy self sufficiency for island and coastal communities is in this size range. The output interface for these power plants is for baseload electricity for pumps and machinery within the immediate vicinity of the generators, or for addition to some sort of power grid. The limitation in range will be eventually resolvable through mating with the fuel generation system allowing realization of virtual energy independence.

Although three OTEC fuel generation alternatives are under investigation (methanol, ammonia, and hydrogen) early commercial feasibility appears to be limited to ammonia. This is simply because of the ease of modification of gasoline powered equipment to operate on ammonia and because the hydrogen carrier in ammonia is readily available nitrogen. A number of commercial processes are available for electrolysis of water into hydrogen and oxygen and a number of catalytic processes are available for synthesis of ammonia. It is not immediately obvious which process or equipment will be most economical but this is mostly a component review process which requires little if any innovative product development. The output of this subsystem will be of little utility with out modification of the fuel distribution and automotive equipment systems.

The existence of transportable fuels suggests that the community need not install expensive power grids providing that adequate numbers of motor-generators are available which can burn ammonia. Similarly kits must be provided for modifying the carburetion systems of automotive equipment. Initially these modification kits will result in excess amounts of NO_x. The lead time for development of pre-burning separation of the nitrogen and hydrogen is probably in phase with the growth of these systems to the level that the NO_x emissions are significant.

EPILOGUE

Mankind has been slow to recognize the value of DOW, the earth's most abundant and least used resource. And even slow to support the development and even adoption of technology to use it. In a sense this is a shame as countries with coastal deserts adjacent to deep ocean water struggle with population pressure and poverty. In another sense it is good because earlier development would almost surely have been done badly. The growing of recognition that for development to be efficient it must also be sustainable, gives hope that we may do it right.

It has been just a little over 25 years since DOW R&D was initiated at NELHA. The CHC begin its private experiments with DOW agriculture a little over 5 years ago. It now appears that four or five DOW systems will be started and perhaps some completed by the turn of the 21st Century. The success of some of these ventures will result in several hundred DOW systems in the operational, in the construction or in the planning stage by 2005. This would include one or more per developing country with coastal deserts and adjacent deep ocean water, and an increasing number of private commercial ventures. By 2020 these desert coastal zones, formerly capable of supporting only small isolated and often poor communities will be looked upon as great assets for and often the only assets for a country's sustainable development.

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EFFECT OF MICROBIAL BIOFILM ON LARVAL SETTLEMENT OF SCALLOP *ARGOPECTEN IRRADIANS* LAMARCK

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ABSTRACT

The effect of marine bacteria, diatom (*Phaeodactylum tricornutum*) and chemicals (γ-aminobutyric acid and melanin) on larval settlement of scallop, *Argopecten irradians* L. was studied. The experiments showed heavy growth of bacteria on the substratum immersed in sea water for 2 days. In the early period the bacteria produced fibrils and subsequently secreted large amount of adhesive polymers. Ninety-nine strains of attached bacteria were isolated from settlement substratum of larvae *of Argopecten irradians* L. in hatchery tanks. The bacteria were identified and classified into nine genera, viz., *Vibrio*, *Pseudomonas*, *Achromobacter*, *Bacillus*, *Aeromonas*, *Staphylococcus*, *Micrococcus*, *Corynebacterium* and *Flavobacterium*. Though there were gram-negative and gram-positive bacteria on the substratum before the beginning of the experiment, after the settlement of larvae, the bacteria isolated from substratum were all gram-negative rods. It was observed that the settlement of larvae needed certain amount of attached bacteria on the surface of substratum. Experiments with single-species films indicated that individual bacterial strains varied in their capacity in inducing settlement of larvae. Some bacteria failed to induce ssettlement of larvae, or even inhibitted the process. The number of larvae settled on substratum covered with natural bacterial film was more than that on a substratum covered with a mixture of natural bacteria and diatom. Present study indicate that attached bacteria played a major role in inducing larval settlement. g-aminobutyric acid and melanin had detectable effect on the settlement of larvae. γ-aminobutyric acid was also found to stimulate the growth of scallop larvae.

Key words: Microbial biofilm. Larval Settlement, *Argopecten irradians* L.

INTRODUCTION

In the marine environment, bacteria attached to inanimate surfaces plays an important role in the complex biofouling process. When an object is submerged in the sea, bacteria attach to the surfaces initially, followed by diatoms, fungi, protozoa, organic particulate and non-organic grains. All of them formed the microbial biofilm(Colwell, 1982). During the past decade, the mechanism of bacterial attachment, the controlling factors, the biofilm components, and its effect on the attachment of higher organisms have been studied(Fletcher & Marshall, 1982; Rilverman, *et al.*, (1984); Fletcher, 1988; Ling, *et al.*, (1983); Kirchman, *et al.*, (1981); weiner, 1985; Young & Mitchill, 1973). Weiner (1985) isolated a sea water strain (LST), which produced polysaccharide adhesive viscous exopolymer (PAVE) that has powerful ability to enhance the settlement and metamorphosis of oyster larvae. Scallop is one of the major species maricultured in China. Low percentage of scallop larval attachment to the settlement substratum is an important problem in scallop production. Estuary scallop (*Argopecten irradians* Lamarck) larvae use their byssus threads to settle on the substratum and then metamorphose into junior scallops.

The purpose of this study was to find out the different components of bacterial flora on scallop larval settlement substratum and their effect on larval of settlement. The main aim of the study was to look for some species of bacteria that could increase the percentage of scallop larval attachment to the substratum. These species, then, could be used as bacterial bath on settlement substrarum that would improve scallop seed production.

Materials and Methods

Microscope glass slides of 26×75×1.2mm size were prepared by soaking in 1N HCl for one week, washed with sterile water, soaked in 75% alcohol and then burnt on spirit lamp before use. Polyethylene net pieces each weighing 0.5g were washed in sea water and soaked in filter sterilised sea water(0.2μm Cellulose filter). Total bacteria in the rearing sea water was counted by acridine orange direct count (AODC). Viable bacterial number was counted by direct viable count (DVC). Heterophic bacterial number was counted by spread count on Marine Agar (HPC). Total coliforms and fecal coliforms were determined by most probable number (MPN) method.

Attached bacterial number on microscopic glass was counted by modified DVC. The slides were vertically kept in filter sterilised sea water (5μm filter) for a given time and then washed three times in filter sterilised sea water (0.2μm filter). These slides with attached bacteria were immersed in a solutin containing 0.002% Nalidixic acid and 0.025% Yeast Extract, and then incubated for 6-8 hours. The slides were fixed in 2% formalin, stained by 0.01% acridine orange and counted with an epiflourescent microscope.

Attached diatom counting was carried out by keeping the slides in filtered sterilised sea water(41μm polyester monofilament filter) and then counting the diatoms using an OLYMPUS BH-2 Phase-contrast microscope.

The samples were taken from a scallop hatchery in Shazhikuo, Laoshan zone, Qingdao, China. The settlement substrata (nets) were immersed in rearing seawater. These nets were taken out on 2nd and 11th day, rinsed three times with sterile no-particle seawater, and then added 10 ml of sterile seawater and 5 ppm Tween 80. The samples were then ground, diluted and spread on Marine Agar 2216E, cultured at 23℃ for 2 days. The grown colonies were isolated, purified by streak-plate method and then transferred on to agar slants.

The bacteria were classified according to "General bacterial identification methods" (Dasi, 1978) based on morphology, gram stain, flagella stain, luminiscence, pigment and biochemical test like catalase, Oxidase, Oxidation/Fermentation test, giemsa stain etc.

The bacteria were idnetified upto the genus based on "Marine heterotrophic bacterial index table" (Huai-Shu Xu, 1975).

The bacterial and algal films were prepared by immersing the settlement substratum in bacterial bath and/or algal bath.

Scallop larvae settled on substratum were counted by using a stereo-microscope (OLYPUS BH-2).

The natural bacterial film, the mixture of natural bacteria and diatom film were kept in a contianer with 2.5 liters of sterile sea water, and then scallop larve were introduced. The larval density in the container was 2-4 lavae/mL

Single species bacterial film was prepared with 10^8 cells/cm^2 (AODC counting) of bacteria on it and was introduced into a container with 800 ml sterile sea water. The density of larvae In the container was 2-4 larvae/ml.

Scallop larvae and substrata were introduced into sterile sea water with different concentrations of γ-aminobutyric acid(GABA) and melanin. The sea water was changed to 2-3 times Per day in all experiments. The containers were continuously aerated with filter sterilised air. The larvae were fed with phytoplankton culture of *Phaeodactylum, tricornutum* and *Isochrysis galbana.* Scllop larvae were counted after 2 days using a stereo-microscope.

RESULTS

The rearing water was free from fecal coliforms as observed by most probable number (MPN) method. This established that the water was good for culture.

Totally, 99 strains of bacteria were isolated from the substratum before and after the settlement of larvae. The results are shown in table 1. 58.59% of the total strains were garm-negative and bacilliform, The different genera isolated included *Vibrio*, *Pseudomonas*, *Achromobacter*, *Aeromonas*, *Flavobacterium* and some unidentified strains. Majorty of the gram-negative bacteria was represented by *Vibrio* (36.21%) and *Pseudomonas* (24.14%). The remaining gram-positive group included *Bacillus*, *Staphylococcus*, *Micrococcus* and *Corynebacterium* of which 37.93% was composed of *Bacillus*.

Table 1. Morphological and biochemical characteristics of bacteria isolated from settlement substratum

Genera	Morphology	Gram's Stain	Geiemsa Stain	Flagella Stain	Lumines-cence	Pigment	Catalase	Oxidase	Oxidation Fernment-ation Test
Vibrio (n=21)	comma	-	-	+	-	-	13	+	+
Pseudomonas (n=14)	bacilliform	-	-	+	-	4	11	+	-
Achromobacter (n=11)	bacilliform	-	-	-	-	-	+	+	-
Bacillus (n=11)	bacilliform	+	+	peritrich-ous	-	-	-	+	+
Aeromonas (n=8)	bacilliform	-	-	+	-	-	+	+	+
Staphalococcus (n=7)	coccoid	+	-	-	-	4	+	-	+
Micrococcus (n=6)	coccoid	+	-	-	-	5	+	-	-
Corynebacterium (n=5)	bacilliform	+	-	-	-	-	+	+	-
Flavobacterium (n=4)	bacliform	-	-	peritrich-ous	-	+	3	+	+
Unidentified (n=12)	bacilliform	-	-	-	-	4	8	10	11

Many baceria produced fibrils and subsequently secreted large amount of adhesive polymers to get attached to the subatratum. The scallop larvae tended to settle on the substratum to which bacteria had attached already (Table 2).

Table 2. Numbers of viable bacteria on substratum and in sea water of hatchery tank before and after settlement of scallop larvae

Time	rearing water (cells/ml)	Surface of substratum
one days after puting the substratum (before the larvae settlement)	1.7×10^{7}	1.17×10^{9}
11 days after puting the substratum (after the larvae settlement)	1.94×10^{7}	3.42×10^{10}

The bacterial composition changed remarkably after the settlement of larvae on the substratum as shown in table 3.

Table 3. copmonents and varation of bacteria before and after settlement of larvae on substratum

Genera	Number	Number of bacteria before larvae settlement	Per centage of total isolated bacteria	Number of the bacteria after larvae settlement	Per centage of total isolated bacteria
Vibrio	21	18	20.03	3	8.11
Pseudomonas	14	1	1.61	13	35.14
Achromobacter	11	5	8.07	6	16.22
Bacillus	11	11	17.74	0	0
Aeromonas	8	3	4.84	5	13.51
Staphalococcus	7	7	11.20	0	0
Micrococcus	6	6	9.68	0	0
Corynebacterium	5	5	8.07	0	0
Flavobacterium	4	1	1.61	3	8.11
Unidentified	12	5	8.06	7	18.92

The substratum was colonised by many groups of bacteria before the larvae settled on it. Among them *Vibrio* was the dominant genus. *Pseudomonas* and *Flavobacterium* were also represented to a lesser extend. When the larvae started settling on the substratum the species composition also showed a shift in dominance from *Vibrio* to *Pseudomonas*. The *Vibrio* population drastically reduced giving way to a rapid growth in the population of *Pseudomonas*. Thus it was interesting to note the abrupt increase of *Pseudomonas* repalcing *Vibrio*. Before the larvae settled, the gram-positive bacteria constituted about 41.41% of the total bacteria on the substratum. But they could not be observed after the larval settlement.

Population of Achromobater and aeromonas did not vary significantly before and after the settlement of larvae.

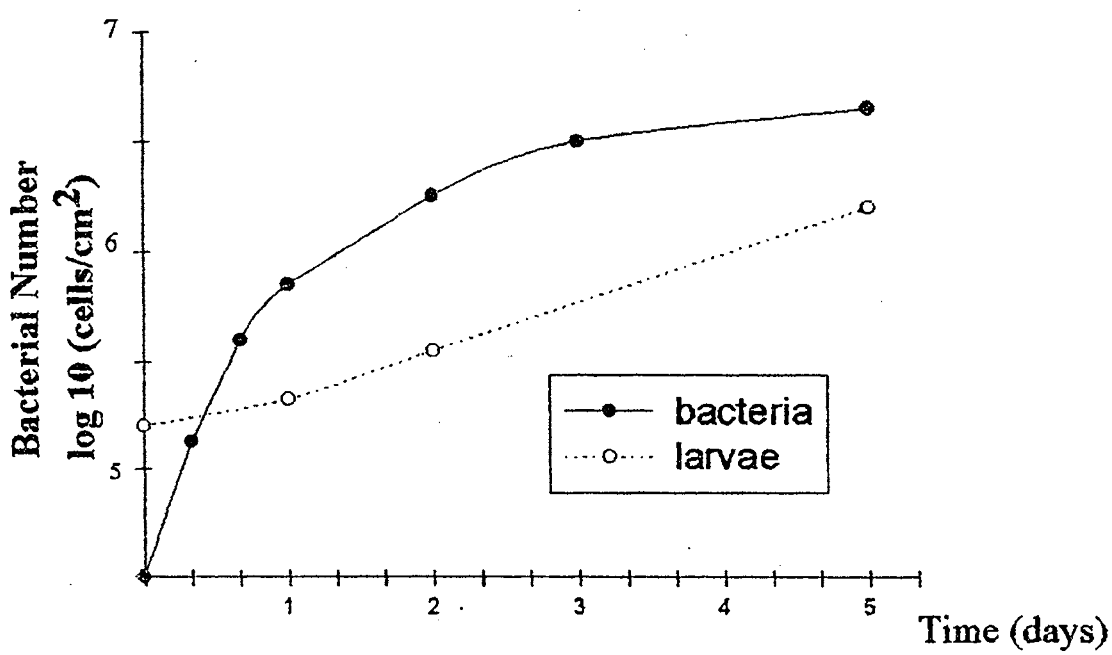
It was observed that there was a relationship between the number of attached bacteria and the larval settlement. More larval settlement was observed on substratum with a favourable bacterial flora in sufficient numbers. The larvae preferred to settle on substratum which was soaked in sea water 48 hours (Figure 1). The number of bacteria on this substratum was 10^6cfu/cm^2 or more. The number of larvae settled on substratum which was soaked in sea water for short time and on control substratum was less.

Some single-species bacterial films on glass slides were found to enhance larval settlement over control films. Larval settlement on single-strain bacterial films wtih strains ss-24 and ss-18 strains showed an increase in larval settlement of 76.92% and 76.47% respectively. Some films did not enhance larval settlement much whereas some others even inhibited the process as shown in table 4.

Table 4. Abundance of larvae settled on different single-species films

bacteria strain	bacteria film	control	increase
ss-24	57.50	32.50	76.92
ss-18	45.00	25.50	76.47
ss16	42.00	31.00	35.48
ss-13	18.00	29.25	-38.46
ss-21	16.50	41.00	-59.76
ss-19	22.50	49.00	-54.08

Figure 1. Relationship between number of attached bacteria and settled larvae with time



The bacterial number on the films increased with time. There was heavy growth of bacterial population within two days after soaking in sea water(Figure 2). 16 hours after soaking, the films were observed under epifluorescent microscope. Bacteria developed some fibrils after two days and subsequently secreted large amounts of adhesive polymers. Number of attached diatoms also increased with time(Figure 3). Cultured diatom *Phaeodactylum tricornutum* was introduced into the bacteria films with bacterial growth. The number of attached diatoms also increased with the number of attached bacteria (Figure 4). The number of settlement larvae on glass slides covered with films of bacteria or miture with *P. tricomutum* and on net pieces was different (Figure 5-6).

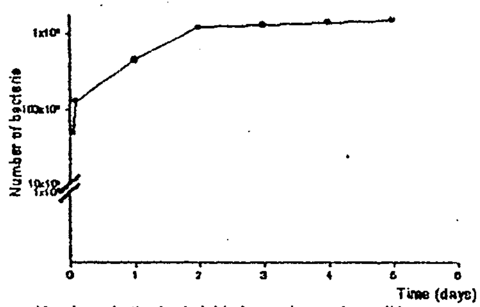


Figure 2. Number of attached viable bacteria on glass slide as a function of time

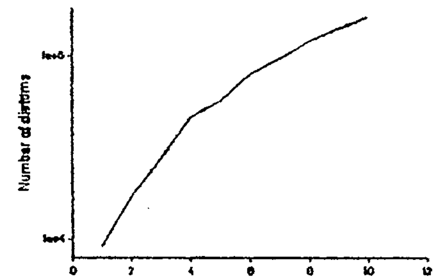


Figure 3. Number of attached diatoms *(Phaeodactylum tricornutum)* on glass slide

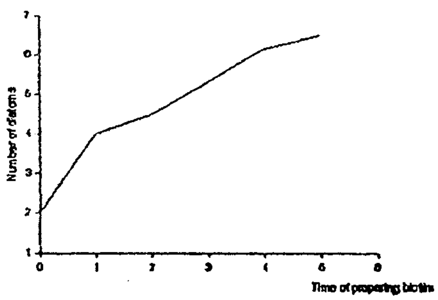


Figure 4. Effect of natural bacterial films and time on attachment of *Phaeodactylum tricornutum*

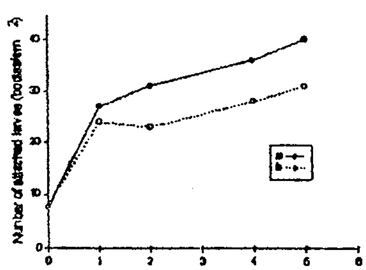


Figure 5. Relationship between number of settled larvae on glass slide covered with films of bacteria (a) or mixture with *P. tricornutum* (b) and days of film formed.

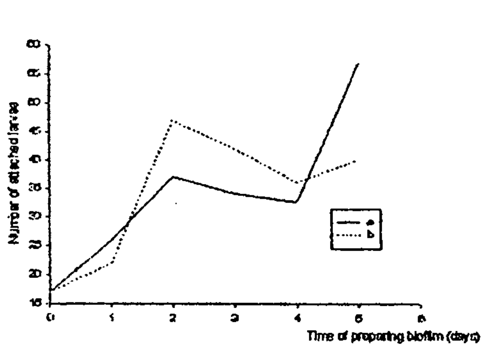


figure 6. Relationship between number of attached larvae on net pieces, covered with films of bacteria or mixture with *P. tricornutum*, and time of film formation

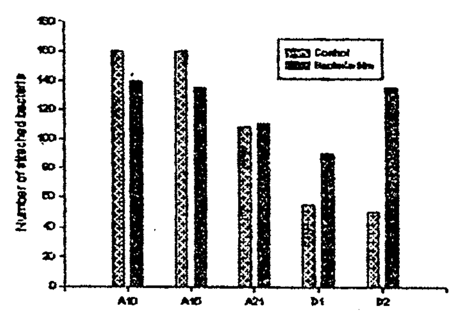


Figure 8. Effect of single species' films of bacteria on attachment of scallop larvae

More number of larvae were attached on films with the natural bacteria compared to films with bacteria and diatoms-mixture and least number of larvae were found on control films as shown in figure 7.

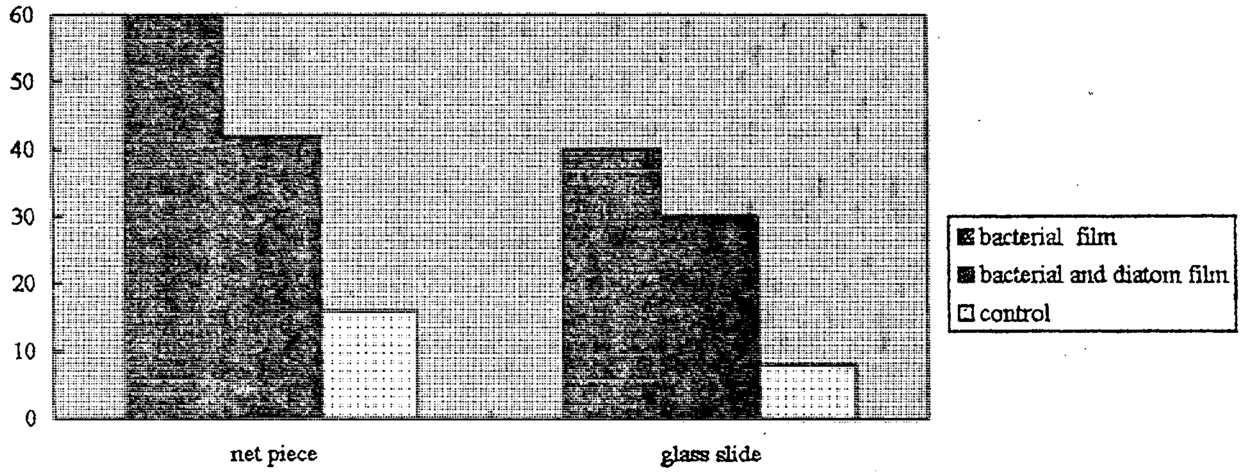


Figure 7. Comparison of number of settled larvae on glass slide and net pieces covered with bacterial or bacterial and diatom films prepared by immersion for 5 days.

61 strains of bacteria were isolated from net piece substratum of which 19 strains were selected to prepare single-species bacterial film. The results showed that the number of larvae was more on 7 strains films and less on the 6 strains films and least on the control(figure 8). There are no difference in the settlement of larvae on 6 strains films. The positive strains D1 and D2 were identified as *Vibrio nigapulchrituda*. The negative strains were A10-*Aeromonas caviae* and A15-*Vibrio natriegenes*. *Pseudomonas nautica* film did not show any effect on settlement of larvae. The larvae were soaked in different concentrations of g-GABA and melanin. The results showed that GABA promoted settlement and growth of larvae($p<0.05$). Melanin also promoted settlement of larvae. (Table 5)

Table 5. Effect of r-aminobutyric acid and melanin on attachemnt of scallop larvae

Chemicals	Acting time	Concertration of chemical (M)	Number of attached larvae (bodies)	Size of larval bodies (μm)
GABA	1 hour	10^{-5}	156	227
GABA	1 hour	10^{-7}	158	231
Melanin	0.5 hour	10^{-5}	144	205
Melanin	0.5 hour	10^{-6}	186	210
Melanin	0.5 hour	10^{-7}	112	-
Control			121	196

Discussion

The development of microbial biofilms on all kinds of non-toxic surfaces in aquatic systems generally shows similar pattern (Lin *et al.*, 1989)(Ji *et al.*, 1991).

Some studies indicated that bacteria could be isolated from objects submerged in sea water for 1 hour(Lin *et al.*, 1983). The number of bacteria showed tremendous increase for the first two days and thereafter maintained a stable growth. We have the similar results. Sometimes attachment has been shown to be a time-dependent process, in which bacteria were easily washed off the surface during the initial attachment phase, but later became firmly attached and resisted washing(ZoBell, 1943; marshall *et al.*, 1971). Film attachment is believed to depend upon the production of an extracellular polymeric adhesive which binds the bacterium to the surface. In our studies, the film was consisted of organic particles, bacteria and micro-algae. The process of bacterial attachment on glass slides was similar to other studies(Ji, *et al.*, 1991). The growth pattern of attached diatoms was also similar to the studies of Lin and Comorkers (1983). The thick bacterial film has detectable effect on diatom attachment. Diatom growth was more on films with high bacterial population.

There are many kinds of attached bacteria observed in marine environment. In our studies, we have found nine different bacterial genera colonizing the substratum of scallop larvae. The major components of bacteria were *Vibrio* and *Psendomonas* which are the normal bacterial flora of the marine environment. The formation of biofilm was found to be very important for the settlement and metamorphosis of larvae. At the same time, the settlement of larvae brought about a change in the community structure of the biofilm. After the settlement of larvae, the complex bacterial flora on the substratum gradually transformed into a relatively simple form. The dominant *Vibrio* group was almost replaced by *Psendomonas* and gram- positive bacteria could not be isolated after larval settlement. In the waters of Qingdao harbor, the natural bacterial flora is generally dominated by *Vibrio,* whereas, in the Xiamen harbor area the dominant group is *Psendomonas*.(Lin *et al.*, 1983) So, studies about the bacterial population on the larval attachment substratum have been complicated by the diversity and difference in population structure of autochthnous flora of different water bodies. The natural bacteial flora, the interaction between bacteria and larvae and the various physico-chemical parameters of the sea affect the settlement of lavae.

Though *Bacillus* is not generally a major component of marine bacterial population, the isolation of 11 strains of this genus, which is very ofen found in terrestrial environments, was unusual. Other related studies have showed the isolation of *Bacillus* from submerged glass slides, stainless steel and pilings(Colwell, 1984). We believe that these *Bacillus* strains might have come from terrestrial environment.

Formation of bacterial film was found to be a pre-requisite for scallop larval settlement. Some bacterial species could enhance larval settlement whereas some others were found to inhibit larval settlement. A few bacteria did not have any effect on it. Based on these observations we believe that specially prepared artificial substrata with specific bacterial strains could be designed which may be useful to enhance the scallop larval settlement leading to improved scallop seed production.

Bio-active chemicals like γ-GABA and melanin were found to influence the settlement of larvae. They could enhance scallop larval settlement. γ-GABA is produced by red algae and Cyanobacteria. Some fungi, bacteria and marine invertebrates also produce melanin. 3, 4-dihydroxy phenylalanine(L-DOPA), a neurotransmitter isolated from bacteria, has been reported to enhance eastern oyster *(Crassostrea virginica)* larval settlement(Weiner *et al.*, 1985). The DOPA auto catalyzes and transforms into a brown-black pigment, which has been identified as melanin.

The evidence gathered to date indicates that DOPA and DOA-based polymers effectively attract invertebrate larvae(Weiner *et al.*, 1985). Coon and Bornar (1985) have demonstrated that the effect of bioactive chemicals is reversible and could be recovered.

There is ample scope for studies on the effect of various bioactive chemicals on scallop larval setttlement. Many other chemicals could be tested for their effect on settlement behaviour of scallop larvae. Suitable bacterial density, proper species compsition and the time of larval settlement are some of the important factors to be further investigated to clearly understand the interactions between microorganisms and scallop larvae on settlement substratum.

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GAMETOGENESIS IN HORSESHOE CRAB *TACHYPLEUS TRIDENTATUS*

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ABSTRACT

Using electron microscopy, gametogenesis of *T. tridentatus* has been investigated . The egg of *T. tridentatus* belongs to unfolliculate type. The oogenesis can be divided into four stages: oogonium, early oocyte, provitellogenic and vitellogenic oocyte. The sperm of *T. tridentatus* has flagellum. The spermatogenesisincludes five stages. It consists of spermatogonium, primary spermatocyte, secondary spermatocyte, spermatid and spermatozoon.

INTRODUCTION

Horseshoe crab (limulus), *Tachypleus tridentatus* is a living fossil. It is an important marine animal resource. It has not only great economic values, but it is also precious material for scientific research. Hemocytes of the horseshoe crab contain a family of arthropodous peptide antibiotics, termed the tachyplesin family, and antibacteral protein, called anti-LPS factor. These substances strongly inhibit the growth of Gram-negative and -positive bacteria, and fungi, such as *Candida albicans*, another hand, they were shown to have antiviral activity against vesiculat stomatitis virus, influenza A virus and human immunodeficiency virus (HIV)-1. So scientists strongly pay attention to horseshoe crab investigation. The studies on gametogenesis of *T. tridentatus* have important meanings on theory.

OOGENESIS

The egg of *T. tridentatus* belongs to unfollicular type. Using cell culture and ferritin labeling technigues, the oogenesis has been investigated. It can be divided into four stages: oogonium, early oocyte, provitellogenic oocyte and vitellogenic oocyte (fig1). It has been found that five cell parts, i. e. mitochondria, SER vesicles, Golgi vesicles, multivesicular bodies and micropinocytotic vesicles, may be involved in the formation of yolk granules (fig2.).

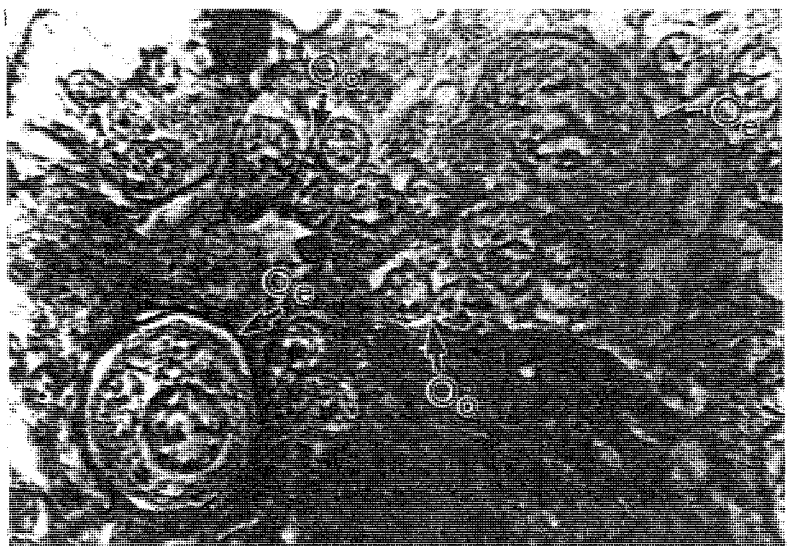

fig. 1. Light micrograph of germinal epithelium. Oo — Oogonium, Oe — early oocyte.

fig. 2. Electron micrograph of oocyte showing the formation of yolk granules. Arrow indicates that the proteins are deposting in the vesicles of smooth endoplasmic reticulum (SER).

SPERMATOGENESIS

The sperm of *T. tridentatus* belongs to mobile flagellum type, whose spermatogenesis is divided into five stages: spermatogonium, primary spermatocyte, secondary spermatocyte, spermatid and spermatozoon. The acrosomal filament emerges during the spermatogenesis. This is an important characteristic of spermatogenesis of *T. tridentatus*. The acrosome consists of the acrosomal vesicle and the subacrosomal space. Extending from the bottom of the acrosomal vesicle, the acrosomal filament penetrates the subacrosomal space and passes through a channel in the centrical part of the nucleus. At the rear of nucleus, the acrosomal filament stretches away from the bottom of the nucleus, then coils up around the nucleus and forms a coil of about 28 turns in the circumnuclear cisternae. The total length of the acrosomal filament is about 210μm (fig3). This peculiarity may be closely related to the fact that the sperm has to penetrate the thick egg investment during fertilization.

The mature sperm consists of head and flagellum. The head looks like a pear and there is a lip-shaped cap looking like a flat disc on top of the head. The head is about 4μm in length. The flagellum is as long as 35μm and exhibits a 9×2 structure (fig.4).

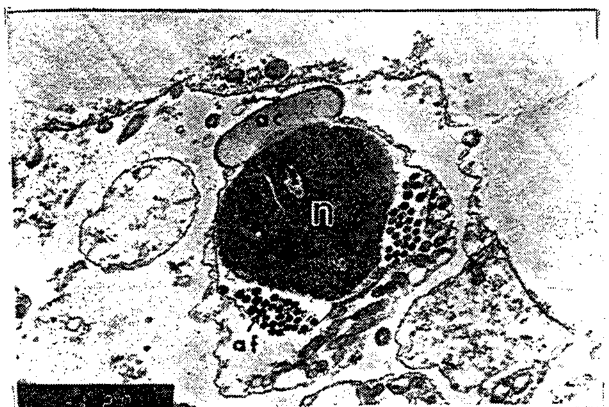

fig3. Electron micrograph of spermatozoon of horseshoe crab, *T. tridentatus*. ac — acrosome, af — acrosomal filament, n — nucleus.

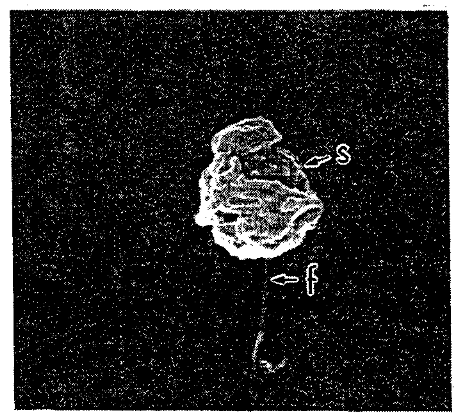

fig.4. Scanning electron micrograph of mature sperm of horseshoe crab *T. tridentatus*. f — flagellum, S — head of spermatozoon.

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