THE COD HOLE: A CASE STUDY IN ADAPTIVE MANAGEMENT

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ABSTRACT

Since the discovery of the Potato Cod (*Epinephelus tukula*) population on the north end of Ribbon Reef Number Ten (Cod Hole) in the Great Barrier Reef in 1972, its popularity as an international dive destination has risen rapidly. With this popularity has come a number of management issues which have changed as the scope and nature of diving has changed in the area over the last 22 years. The management agencies, Department of Environment and Heritage, and Great Barrier Reef Marine Park Authority, have implemented a number of management initiatives over the last 10 years to address these issues. Despite these management actions, none have been broad and flexible enough to quickly adapt to changes in the levels of use, types of operators, and demands for access by commercial users. An analysis of the previous management actions, uses, and issues at the Cod Hole may provide managers with a more adaptive, long term approach to managing the Cod Hole.

INTRODUCTION

The Cod Hole is a small area of coral reef on the north end of Ribbon Reef Number Ten on the Great Barrier Reef(Figure 1). The area is also part of Cormorant Pass, one of many opening through the barrier reefs along the eastern boundary of the Great Barrier Reef Region. The Cod Hole is not a physical feature, that is, a "hole" in the coral. It is an area of continuous coral reef approximately 300 metres long, and 60 metres wide ranging in depth from 1 to 30 metres. A management area of approximately 18,000 square metres or 1.8 ha. The Cod Hole area is typical of barrier reefs in the region. It is characterised by strong currents, steep coral walls, and good visibility. The underwater scenery and topography is similar to other reefs in the region with the exception of the fish aggregations and Potato Cod (*Epinephelus tukula*) population which give the area its name. The Cod population were discovered here in 1972.

The Cod Hole is in the Cairns Section of the Great Barrier Reef Marine Park. The park is jointly managed by GBRMPA and DEH. DEH is responsible for day-to-day management (DDM) of the park including the Cod Hole. The basis of management of any section of the park is the zoning plan. Managers, however, have other mechanisms to supplement the zoning plan, these include regulations, permits and associated conditions, and the declaration of special management areas. Some of these mechanisms have already been used in the management of the Cod Hole.

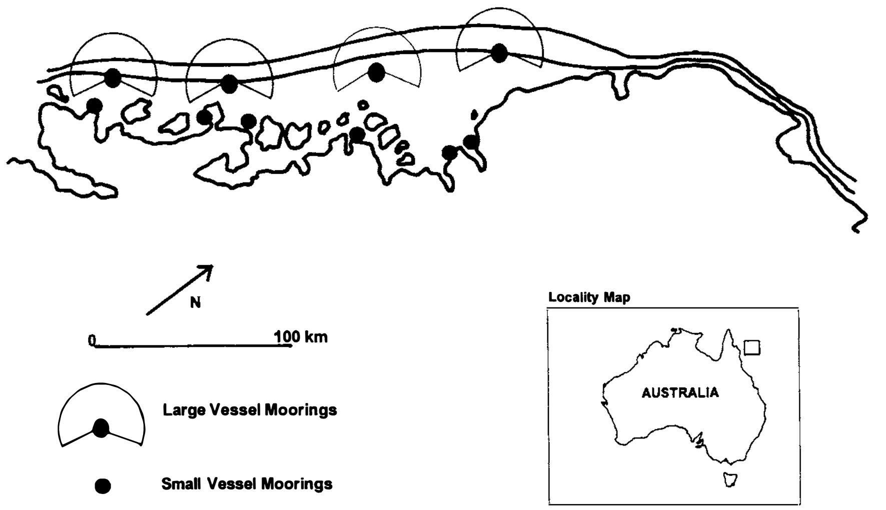

Figure 1. Cod Hole Moorings Plan

THE REACTIVE MANAGEMENT CYCLE

Pre Zoning plan (1970-1983)

The Cod Hole was first discovered in the early 1970's by game fishers and dive adventurers. At this time, there were approximately 10 cod ranging in size from 10 to 50 kilograms. They quickly adapted to human intrusion to the point of hand feeding. Valerie and Ron Taylor, marine documentary film producers, first visited the site in 1979 to investigate possible documentary material at the site. During their visit, 20 cod also in the 10 to 50 kilogram range were sighted. These cod also quickly adapted to their presence and hand feeding. The Taylors' decided not to publicise the area to avoid destruction of the population by over fishing and habitat destruction. A cod population they discovered off Europa, an island in the Indian Ocean, were destroyed when fishers and other visitors learned of the cods' existence in early 1970s. Several dive adventurers began to lobby management agencies for some form of protection for the Cod Hole.

Until 1975, there were no mechanisms in place for the management of the Cod Hole and its resources. State or commonwealth legislation, such as fisheries regulations, could be amended to specifically protect the Potato Cod. When the Great Barrier Reef Marine Park Act was passed in 1975, the Cod Hole area was within the park boundary. Management or protection, however, was limited to provisions specified in the Act which primarily prohibited mining, and entailed the formulation of zoning plans for declared sections of the GBRMP.

Until 1980, few people visited the Cod Hole. The significance of the area was still known only to a few people. The surrounding area was also still considered remote and many vessels were not large enough and equipped to visit the area except in calm weather. In addition, most commercial tourist vessels had sufficient destinations in close proximity to Cairns or Port Douglas to meet tourism demands. Therefore they had no need to discover new dive destinations.

Tourism in the Cairns area at this time was still primarily a winter activity, domestically based and relatively small scale. During 1977-78 just over 300,000 tourists visited the Cairns district, and 10% of these tourists were from overseas (GBRMPA 1981). There were few tourist vessels based in Cairns. In 1981, 50 charter boats operated in the Cairns Section based between Cardwell to Port Douglas (GBRMPA 1981). More than half were gameboats which accessed the area during the marlin season. Other vessels would rarely visit the Cod Hole area.

In late 1981, the Cormorant Pass Section, which included the Cod Hole, was declared (GBRMPA 1982). Regulations were also developed to prohibit spearfishing and line fishing other than trolling in the area. This provided some protection for the Potato Cod, but not for the other resources . Gamefishing operators could still use the area as long as they trolled, and tourist operators could also continue to use the area as before. Resources in the form of DDM staff and equipment to enforce these regulations, however, were not available.

By 1982 the Cod Hole was well known for its cod population amongst the game fishing fleet and a few dive operators who frequented the area during the game fishing season (September to December). The cod were now a target species despite the fact they were not a table or sport fish. Their sheer size excited some fishers. In 1982, the Taylors noted that the population had declined by 50%, and fish had hooks in their mouths, torn jaws and line burns. Correspondingly, some small scale dive tourist operators, Cairns and Port Douglas based, initiated regular trips to the Cod Hole. In 1983 there were 4 regular operators to the site in the October to December period. These operators would access the site 2 to 3 times per year. The Cod Hole was included as a dive destination during a 5 day trip along the Ribbons Reefs.

First Zoning plan (1983-1991)

In 1983, the Cairns-Cormorant Pass Zoning Plan was launched. Primarily through zoning provisions, the Cod Hole was now under some formal management regime. Two zones were used within the Cormorant Pass Section, a Buffer Zone with the objective to:

- protect natural resources
- allow the public to appreciate the undisturbed nature of the area; and
- provide for trolling of pelagic species.

The other zone, Marine National Park 'B' had the objective to:

- protect natural resources; and
- allow the public to enjoy the relatively undisturbed nature of the area.

The Marine National Park 'B' Zone, prohibits all fishing, and the Cod Hole itself is within this zone. The Potato Cod range, however, extends into the Buffer Zone making it vulnerable to trolling. Additional protection was given to the Potato Cod within the GBR in 1983 when they were listed as a protected species under the first GBRMP regulation.

Thus it would appear that the Potato Cod were protected and other resources would be managed. The Cod, however, were still subject to incidental catches and indiscreet fishing feeding by tourist operators in the area. Tourist operators, gamefishing and diving, now needed to obtain a permit to operate within the park. The permits, however, did not place any restrictions on how they operated at the Cod Hole. In late 1984, day-to-day management commenced in the Section.

Since 1985 tourism has expanded in the Cairns area (Table 1), and the Cod Hole has also experienced increasing use from the tourism sector. In 1988, there were 11 permitted dive tourist operators who regularly used the Cod Hole. Their frequency of use ranged from 70 days per year to 12 times per year (Alder 1989). The number of tourism permits issued in the Section between 1984 and 1991 also increased (Table 2).

Air surveillance information also provides some insight into the level of use of the area (Table 3). The maximum number of vessels sighted in the area in one flight was 22 game boats by Coastwatch air surveillance in 1988. Vessel access to the area increased slowly until 1988 and 1989 and has remained constant over the last 4 years.

Table 1. Number (in 000's) of Visitors to the Cairns Region from 1985 to 1992 (FNQPB 1993).

YEAR	85	86	87	88	89	90	91	92
Domestic	772	731	820	915	979	1160	931	1340
International	108	136		320	304	368	393	508

Table 2. Number of Tourism Permits Issued 1984 to 1991 for the Cairns Section of the Great Barrier Reef Marine Park.

Year	pre'85	85	86	87	88	89	90	91
Total Permits Issued	175	192	320	451	404	360	368	457
Tourism Permits Issued	40	25	58	144	135	123	194	274
% Tourism Permits	23	13	18	32	33	34	53	60

Table 3. Number of Vessels Sighted, and Coastwatch Flights in the Cormorant Pass Area from 1983 to 1992 (flights with no sightings not included).

Year	1983	84	85	86	87	88	89	90	91	92	93
Game Boats/Flight	0.5	0.8	0.9	0.6	0.8	4.8	2.0	1.6	0.5	0.5	0.8
Tourist Boats/Flight	0.8	0.0	0.6	0.4	0.4	0.9	1.6	1.1	1.4	1.4	1.2
No. of Flights	36	23	17	18	41	13	5	11	34	25	13

Initially the area was primarily used by the game fishing fleet who also conducted snorkeling in the area. Dive tour operators used the area to a minor extent. Use of the area was also primarily during the game fishing season (September - December) which coincided with dive tour operators frequenting the area due to the consistent calm weather. The use of the area by the game fishing fleet has changed very little over the last 10 years. Dive tourism, however, has increased.

For most tourist vessels using the area it was impossible to anchor without causing significant damage to the benthic communities. There are no sand areas in close proximity to the cod aggregations and anchoring on coral was common. If vessels anchored in sandy area, they were usually too exposed to the rough prevailing weather which made transferring divers between the boat and tender dangerous, otherwise divers had to swim long distances in rough conditions to dive sites. Complaints about coral degradation from tourist operators and visitors were received.

During this same time in the offshore Cairns area, managers began to use permits more effectively. Coral damage from anchoring could be alleviated by requiring operators to install and use moorings. This was considered an viable option for managing reef damage in most areas. For operators using the Cod Hole, however, it was not cost effective to install a mooring. The cost of transporting the material to the distant site alone was over $10,000. Although many operators used the area on a regular basis, the frequency was still not enough to justify the cost of materials and transportation. In addition, there were only 4 possible mooring areas within easy and safe access to dive sites. If management allowed private moorings to be installed this would potentially limit opportunities for other dive operators to the site. There were more than four regular operators already using the site by 1987. Owners of these moorings could be liable for any damaged caused by mooring failures and therefore reluctant to let other operators use them. Compulsory mooring installation was perceived by industry as an unwelcomed imposition of control.

In response to this, management installed 4 large vessel and 6 dive tender public moorings at a cost of over $20,000 in 1989. The large vessel moorings were designed to accommodate vessel up to 35 m OAL and 100 tonne displacement. All vessels accessing the Cod Hole at the time were under these specifications. Moorings were allocated on a first come first served basis. This management ensured that all current operators had access to the site and was supported by the operators. Tourist operation (gamefishing and diving) permit conditions were then altered to prohibit anchoring at the Cod Hole. A special management area (SMA) was also recommended for the area to prohibit anchoring by all vessels.

It appeared that damage to the coral was now under control and natural rehabilitation would proceed, and the Potato Cod were totally protected from fishing. Management had done its job. The problem of diver damage on coral reefs, anchoring by private vessels, anchoring in northerly winds, and fish feeding, anchoring between moorings when all 4 mooring sites were occupied, however, were still unresolved.

Later that year, a crown-of-thorns infestation together with Cyclone Ivor destroyed much of the coral cover at the Cod Hole. The cyclone effectively sandblasted the coral communities from their substrate. The Cod and other fish, however, remained.

In 1990, larger and faster vessels were introduced in the Section to meet the demands of marine tourism. Visitation levels to the Cod Hole increased, and vessels exceeding the public mooring specifications were accessing the area. Moorings were dragged from their original sites, and mooring lines damaged making them unsafe. The moorings were not upgraded to accommodate these larger vessels since issue of liability was not resolved by upper management. Consequently, no anchoring permit conditions could not be enforced for large vessels accessing the site. Excluding large vessels from the site was not feasible due to the marine tourism industry's economic dependence on the site. The Cod Hole was a 'bread and butter' destination for many operations who were operating in a recessed market.

The Second Zoning Plan (1991 - current)

In 1991, a revised Cairns Section Zoning Plan was introduced. The National Park zone at the Cod Hole was extended to include the range of the Cod and a "No Structures" subzone was applied to the entire area. These changes had limited impact to the current use of the area. They reduced the possibility of incidental catches of the cod from trolling, and ensured that permanent structures such as pontoons would not be allowed.

Marine tourism continued to grow in the Cairns Section. After 1991, 3 year permits were issued for tourism operations, which makes it difficult to determine the exact number of tourist operators per year post 1991. Nevertheless, there has been no decrease in the number of permits issued since 1991. Most of these permitted operators also have some form of access to the Cod Hole.

Initially, dive trips to the Cod Hole were on demand or part of a once per year expedition to distant dive sites. Divers considered it a remote wilderness experience, and an attractive article for many dive magazines. Divers throughout the world soon were aware of the 'Cod Hole'. This, in turn created a demand for regularly scheduled trips to the site. Many divers from around the world come to Cairns to "dive the Cod Hole".

With larger vessels capable of transporting guests in relative comfort, dive operators are accessing the area all year round and on a regular or seasonal basis. Often a visit to the Cod Hole is part of a 3 day dive tour of the Ribbon Reefs.

The types of vessels using the Cod Hole has also changed. In 1989, most vessels accessing the area were well under 20 m OAL and less than 100 tonne displacement. The average passenger capacity was 8. Now, many vessels using the site exceed 20 m and 100 tonne, and average passenger capacity is 25 or 30 guests. The number of visitors accessing the site has increased more rapidly than the number of vessels accessing the site.

By 1992 up to 14 vessels were accessing the site from 12 (monthly) to 200 (daily) days per year. The estimated annual diver visitation exceeded 15,000 divers. A visit usually includes two dives, which is 30,000 dives per year in an area 300 m long. At coral reef dive sites in the Caribbean, diver carrying capacity is considered to be between 4000 and 6000 dives/site. A site is approximately 600 m strip (Dixon et al. 1993). Use levels higher than this result in observable environmental damage by other divers visiting the area. An annual level of 35,000 dives per site may exceed the carrying capacity of Red Sea coral reefs (Hawkins and Roberts, in press). Here, these levels resulted in significant environmental damage to benthic communities. Their sites were 500 m long sites.

Current use of the Cod Hole may have reached or exceeded its carrying capacity. The site is 300 m long, and therefore has an annual capacity of 3000 (based on the Caribbean model) or 21,000 (based on the Red Sea model). Indeed, the current level of use at the Cod Hole may be maintainable in the absence of natural perturbations, however, if disturbances such as cyclones or COT occur, anecdotal evidence suggests that this level of use may in fact prevent natural regeneration of benthic communities at the Cod Hole.

Increasing visitation with its corresponding increase in diving and fish feeding may have impacted on fish communities. Management recorded the following incidents and changes at the Cod Hole.

- moray eels competing with Cod for food handouts;
- tourists lacerated by eels on the arms and hands;
- increased abundance of small predatory fish;
- slow recovery of benthic communities compared to adjacent areas affected by Cyclone Ivor;
- vessels regularly anchoring in coral areas;
- damage by divers kicking, grabbing, standing and touching benthic communities;

- bread, vegetables, fruit and pasta fed to fish, fish refusing to eat, and fish regurgitating pasta; and
- cod aggressively attacking divers apparently in expectation of food.

Competition for mooring sites was evident between vessels and seaplanes, dive tenders were accessing sites in the vicinity of divers, and vessels arriving when the moorings were occupied would anchor between the moorings. This impacted on the benthic communities and created an unsafe situation.

DDM once again needed to rethink their approach to management of the site.

In 1992 management staff initiated a regular on-going liaison program with regular operators of the Cod Hole to address many of the above management issues associated with the area. This resulted in the formation of the Cod Hole and Ribbon Reef Operators Association Inc.(CHARROA) Working with management, the association developed objectives, rules of membership and a code of practice. Through this association many management issues were addressed. This was the first case of the tourism industry in the Cairns Section (could we say the GBR) exercising a degree of self-regulation.

The association was formed to ensure long-term sustainability of their industry through effective management of the Cod Hole. The association has a limit of vessels per day accessing the site. Vessels in the association are restricted to 30m OAL, and passenger capacity of 28. Their code of practice assists the industry in self-regulation, monitoring, and compliance. The code includes mooring use, anchoring practices, diver behaviour and safety, fish feeding, interpretation, scheduling of visits and duration of visitation at specific sites, and cooperation with managing agencies. The industry and management benefited from this arrangement. The industry is managing for long term sustainability, enhanced visitor experience, ecological sensitive reputation, and improved diver safety. Management benefits included reduced effort and resources in managing this component of the industry, human impacts were reduced, factors impeding coral regeneration were minimised, healthier fish, industry having a better understanding of management objectives, and a possible management model for other areas or activities on the GBR.

There were costs to day-to-day management for this arrangement. The association was allocated two large vessel mooring sites at the Cod Hole for their exclusive use. Management relinquished ownership of these two mooring sites. This further reduced site management options. Not every operator to the Cod Hole fell within the Association's membership, or wanted to be a member of the association. Therefore, for these operators, their opportunity to access dive sites at the Cod Hole was reduced by 50%. Future tourist operators who want regular, guaranteed access to the Cod Hole will see their access limited. As the CHARROA membership expands, access to the two moorings is shared between more members, with each one's share of access diminishing. This implies that future operators may access the site and ignore anchoring restrictions, or demand one of the two remaining public moorings. This will result in increasing demands on management in the future.

FUTURE ISSUES

If marine tourism trends continue, vessel technology improves, and management mechanisms remain unchanged several issues may need to be addressed in the future. Managers anticipate the following issues will arise:

Expansion of current permitted operations - current operators will no doubt want to maximise profits by expanding their business by increasing the frequency of visitation, and increasing the size and passenger capacity of their vessels. This results in more divers at the site at any one time.

New operators wanting to access the site - new operators will seek destinations which produce profits and the Cod Hole meets this criteria. Regular access to prime destinations offshore of Cairns are limited and the Cod Hole provides an alternative.

New styles of operations and activities - Australia recognises tourism as an industry and actively promotes regional tourism development. If the Cooktown area becomes a focus for tourism as the Port Douglas and Daintree Areas have developed, then access by fast high passenger capacity catamarans to the site is feasible. Consequently the style of tourism may change from one focused on diving to one of mass tourism. The style change will also introduce new activities such as glass bottom boats and semi-submersible operations. The introduction of catamarans has the potential to at least double current weekly access and consequential impacts from associated activities.

Manipulation of resources - the site is a prime destination and alternative sites offering the same experiences are unknown. Therefore in the event of natural perturbations such as COT outbreaks, the industry will want remedial action taken. In the past, operators have relocated aggressive eels without consultation with management. Problems with the moray eels will no doubt continue as long as fish feeding continues.

Maintaining or rehabilitating the site to a more natural state - the Cod Hole is zoned Marine National Park with the objective of providing areas in a natural state while allowing the public to appreciate and enjoy the relatively undisturbed nature. It can be argued that fish feeding alters the natural system of the area. If there are more operators and divers to the area this equates to greater feeding activity and further withdrawal from the Cod Hole's natural state. The issue this raises is: should feeding increase, remain at current levels or be eliminated so that the area can return to a natural state? Should the area in fact be zoned differently to reflect the altered state of the area to facilitate tourism or should maintenance of the area in its natural state be the priority?

MANAGEMENT OPTIONS

There are several options available to address these issues, regulations, zoning, education, research, monitoring, co-management, industry based initiatives, increased on-site presence. Some of these require a greater management effort and increased resources in the long term than others. The options also vary in user acceptance, ease of implementation, costs, compliance monitoring, stewardship and short and long term benefits.

In managing the Cod Hole DDM and the GBRMPA seeks to

- maintain the environment and resources, and where possible improve coral cover
- minimise effort and resources
- minimise government regulation
- maximise user/industry based self-regulation
- maximise user acceptance and compliance with management prescriptions
- maximise stewardship of resources
- maximise long term benefits to the environment and users

Already recent management initiatives at the Cod Hole have begun to approach some of these objectives, one major factor controlling this, is the diversity of uses. Where use is homogeneous, it is easier to organise users and to focus them towards a common goal. If the site is the main destination for most users, a sense of stewardship is often present since they have a vested interest in self-management.

Once a consensus is reached on how self regulation is achieved acceptance and compliance generally follows.

As the diversity of uses increase, the task of balancing the demands of the various users becomes more complex, and reaching a consensus on self regulation as a whole is more difficult to reach. Usually a combination of self regulation and statutory mechanisms are used.

At the Cod Hole there are at least 4 distinct types of tourism; game fishing, regular operators, irregular operators, and private visitors. All have different demands of the site. Future use of the area also indicates new uses and greater intensity of use. How can management reach it's desired position for the Cod Hole on the management scale?

Managing the Cod Hole in the future will require a combination of self-regulation and minimum of statutory mechanisms. The establishment of an SMA over the Cod Hole which prohibits anchoring would simplify the statutory regulations for the area and eliminate the need for permit conditions specific to the Cod Hole.

The other benefits of the proposed SMA include:

- better environmental management since anchoring will be prohibited for all vessels;
- limits to use will be imposed through the availability of only 4 moorings which ultimately improves the setting and the environment;
- the site cannot be dominated by a single or group of operators since access to the SMA is limited to 4 hours in 24; and
- includes commercial and private users in the management of the site.

Overall, however, effective management and ultimately maintenance of the natural resources (as per zoning purpose) relies on user based management. As discussed before, this has started, but efforts towards self-regulation must continue in several areas:

- Educate users on resource management for improved self regulation;
- Engender a sense of ownership or steward ship amongst users so that they take responsibility for management of the site (hey need to perceive their management benefiting themselves);
- Management needs to work with industry to set long term objectives for the site so that the environmental goals are met and economic gains are achieved; and
- devolve more decision making power to industry, CHARROAH is a good initiative, so is gamefishing association Code of Practice, but further advances needs to be the goal.

SUMMARY

The Cod Hole is a classic example of reactionary management, a history of increasing statutory regulations have proved to be of limited effectiveness in resource protection at the site. Recent initiative towards self-regulation by users of the area shows promise for the long term benefits to the site. If management responds positively towards these initiatives, and devolves some of the decision making responsibilities to these users, the cycle of reactive management will at least be interrupted, or at best, cease and effective long term management will start.

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STOCK ENHANCEMENT IN MARINE SYSTEMS

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ABSTRACT

Stock enhancement programs have been identified as a means of improving the declining yield in wild fisheries. However, the cost-effectiveness of such programs have yet to be proved. The genetic changes in hatchery-produced populations relative to wild stocks, and the impact of introduced stocks on the genetic diversity of the wild populations they are designed to enhance, are poorly understood. Genetics provides a theoretical framework and the practical breeding technologies to manage cultured populations, and the molecular tools to assess dispersal, and impact on wild populations. However, the effectiveness of the different genetic management regimes that would be required for conservation of specific stocks, enhanced production, or the ranching of 'wild' populations remains untested. Actual examples of the use of genetic markers to test the effectiveness of releases and their impact on wild stocks are rare. This lack of information makes it more difficult to refine approaches. A growing philosophy by fisheries agencies not to invest in such research on the basis that the systems may be too complex to understand, is illogical when faced with the requirement to manage complex systems, and will slow the development of new technologies to do so.

INTRODUCTION

The decline in production from many wild fisheries has led to considerable interest in stock enhancement. Mechanisms envisaged for restocking range from the release of hatchery-reared young to the creation of protected marine reserves that are designed to act as sources of recruits to areas that are fished. However, the technical feasibility and the economic benefit of such approaches are yet to be established.

Successful models for stocking fisheries using hatchery-reared young can be found in freshwater recreational fisheries. The cost-benefit of such programs is best understood for well-defined populations in isolated lakes, particularly where there was no natural population originally. Where there are natural populations, the production of the stocked fish relative to those from the wild stock has proved difficult to assess. There is also considerable concern now over the impact of stocked fish on the genetic integrity and biodiversity of wild stocks. Despite the social and economic importance of these issues, and the long history of stocking freshwater fisheries, research that tackles these questions effectively has been limited.

These basic issues are likely to prove far more difficult to investigate in the marine sphere where there are few clear geographical boundaries to the populations of many fished species, and the spatial scales involved can be far greater. There have been few marine restocking programs attempted, the best known of which are the large scale scallop and prawn stocking programs in Japan and prawn reseeding programs in China. There has also been some effort on fish and abalone reseeding in Japan. The cost-effectiveness of none of these programs has been adequately determined, nor has their impact on wild stocks, or the marine environment, been assessed. There have been some large programs restocking North American pacific salmon, but monitoring programs were introduced very late in the programs so that the effectiveness and impact of these have not been clearly identified. Only recently have carefully designed studies been started on the marine fish species cod (*Gadhus morhua*), red drum (*Sciaenops ocellatus*), striped mullet (*Mugil cephalus*), and white seabass (*Atractoscion nobilis*), and attempts made to devise clearly defined and responsible strategies for marine fish restocking (Blankenship and Leber, 1995).

Genetics offers the theoretical framework with which to model the effects of dispersal between, and the changes within, artificial and wild populations. It can provide the practical tools to manage cultured populations, and recently developed molecular technologies have the potential to measure the effectiveness of restocking programs and their impact on wild populations.

The technical feasibility of stock enhancement programs will depend on a range of ecological, oceanographic and genetic issues, and their social acceptability will depend on their overall, and some specific, cost-benefits. This paper provides a perspective on the capacity of genetics to tackle key issues of concern with respect to estimating dispersal and return of stock, to measuring impact on wild genetic diversity and to managing the genetic structure of introduced stocks.

HATCHERY-BASED STOCK ENHANCEMENT

The rate of return

The primary question with respect to the cost-benefit of a stock enhancement program is whether sufficient of the stocked fish are harvested to justify the cost of the stocking program. While it is possible to physically tag the individuals released, the cost of tagging is high and is restricted to circumstances where the animals being released are large enough to survive tagging with little or no effect on mortality. The additional cost of nursery facilities required to house juveniles until they are large enough to tag, and the extended period for which animals require to be maintained, are often prohibitive.

Genetic tags provide a means of tracking the stocked animals without the need to handle them individually before they are released and allow juveniles to be released at any stage or size. Genetically tagged animals do not suffer tag-related effects on growth or mortality, and the progeny produced by the released animals can also be detected. Such genetic tags can be either morphological attributes or biochemical attributes detectable as protein or DNA variants. The former have the advantage that they can be scored easily and without the need to take tissue samples. The latter have the advantage that they are more likely to be selectively neutral markers, are more likely to remain as discrete character units or combinations of such units, and offer a far greater range of variation more easily accessible than discrete morphological characters.

The best example of a morphological marker that could prove useful in marking released stock is the fine-spotted brown trout (Skaala *et al.*, 1991). The mode of inheritance of the pattern has been demonstrated to be Mendelian and under the control of a single locus with two co-dominant alleles (Skaala and Jorstad, 1988). Tests on survival and growth of the fine-spotted variant showed no difference in mortality patterns or growth rate compared to fish displaying the normal pattern. However, the marker has not been used as yet to track the effects of introductions.

Several tests in freshwater populations (usually of salmon or trout) have been made using hatcheries to rear large numbers of an allozyme variant that is rare in the wild population (see Jorstad *et al.*, 1991). These, and the occurrence of genotypes that are common in aquaculture stock but rare in natural populations, have demonstrated the survival of hatchery-reared fish and significant changes in gene frequencies in sites where considerable stocking has been undertaken.

Leaving aside the tests on salmon, which form a special case given their homing to freshwater breeding grounds in lakes and rivers, where they are normally sampled, there has been little work on marine species. Jorstad *et al.* (1991) have described the formation of artificial stocks of cod that have a high frequency of a GPI variant that is rare in natural populations and have demonstrated individuals with this marker have the same survival and growth performance as those with other alleles at that locus. Several thousands of marked fish have been released in a cod population known to be restricted to one fjord but as yet results of the returns from the stocking are not published.

It is clear then, that genetic markers have the potential to provide useful information on the success of a stock-enhancement programs but that there have been no studies yet completed for marine species.

Genetic changes in hatchery populations

In the previous section, the use of hatcheries to rear the young of specific matings designed to obtain large numbers of otherwise rare genotypes was described. However, when hatcheries are used with the aim of gaining high production levels without any deliberate attempt to change the genetic structure of the population, standard hatchery procedures have been found to be flawed. The advantage of hatcheries is that large numbers of young can be produced from few parents. However, the use of a limited number of broodstock is likely to result in reduced genetic diversity, the occurrence of gene frequencies that are highly skewed with respect to the wild populations from which the parents were derived and, where the process is extreme enough, inbreeding and loss of fitness. All these effects have been well documented in hatcheries, or in populations derived from cultured populations (Allendorf and Ryman, 1987), including salmon (Verspoor 1988), other marine fishes (Taniguchi *et al.* 1983; Bartley and Kent, 1990), marine molluscs such as pearl oysters (Durand *et al.* 1993), giant clams (Benzie, 1993a), hard clams (Dillon and Manzi, 1987), and edible oysters (Gosling, 1982; Hedgecock and Sly, 1990), and crustaceans (Sbordoni *et al.*, 1986).

The potential for manipulation of the genetic structure of artificially reared populations through selective breeding has long been recognised (Newkirk, 1980; 1993; Allendorf and Ryman, 1987). The need for careful genetic management of cultured stocks has long been recognised by geneticists but has been ignored in most hatchery practice. The use of multiple hatchery spawns to approximate the genetic variability observed in the wild has been demonstrated for one marine fish, white seabass (*Atractoscion nobilis*), where 98% of the genetic variability observed in the wild could be maintained using a population of 100 broodstock (Bartley and Kent, 1990). Red drum enhancement programs used 140-170 broodstock with a view to addressing the problem of maintaining genetic diversity (McEachron *et al.*, 1995).

Even where the problem of inbreeding has been recognised, simple approaches such as holding large numbers of adults (several hundred) that are allowed to mate at random, and mixing eggs and sperm from many individuals to create the production batch, can still result in reduced and skewed genetic variation. Despite several hundred adult prawns being present in the lagoon population, Sbordoni *et al.* (1986) found the actual number of adults contributing to the next generation was only about four. Reduced effective population sizes of breeding populations have been described in mixed egg and sperm batches of salmonids as a result of uneven success in fertilisation rates by individuals (see Withler, 1988).

Whether hatcheries are used to rear large numbers of particular genotypes, or whether they are to be used to produce stocks that, at least over time, differ little from the natural populations from which they are derived, careful genetic management of the programs will be required to achieve the desired outcomes. The genetic effects of given levels of inbreeding and the effective population sizes required to achieve certain goals can be determined from genetic theory. The practical methodologies to achieve this for many species have yet to be tested, and the unexpected results of common sense approaches attempted to reduce inbreeding, demonstrate the requirement to monitor the effectiveness of hatchery management procedures and not to rely on faith. No large scale resource enhancement program for marine species has attempted such management with effective genetic monitoring and with the possible exception of recent pacific salmon work in progress.

Impact on wild stock

The impact of stock enhancement programs on the genetics of wild stocks is largely a matter of conjecture. Increased numbers of fish, prawns or scallops being caught after restocking implies good survival of the introduced genotypes. Stocked fish contributed some 50% of samples of striped mullet in one of the few carefully controlled experiments undertaken in marine fish enhancement, demonstrating the potential for genetic and environmental impact of restocking are high (Leber *et al.*, 1995). The genetic effects of escaped or introduced salmon on wild stocks have been summarised by Hinder *et al.* (1991) where results have been variable, but marked effects on wild stock have been observed in areas of intense culture/release. Knowledge of the shifts in gene frequencies and the limited genetic base in cultured stocks using standard hatchery procedures has given rise to concern that wild stocks substantially enhanced from such sources will show reduced genetic variation. There are also concerns that, because of the reduced selection pressures on the hatchery animals and the greater likelihood that larvae reared artificially will survive to adulthood, and because of increased inbreeding, the wild stock will become less fit. Indirect evidence to support this view comes from recent observations in Canada where reduced returns of pacific salmon are being recorded from many rivers which have had high levels of hatchery enhancements over the last decade or two (Hinder *et al.*, 1991). However, the genetic condition of the stocks was never monitored and the reason for the decline has not been firmly established. There is still considerable debate over the role over-fishing may have played in the decline.

There is also a divergence of opinion on the possible outcomes of introduced stock. Where these are escapees from an aquaculture environment it is argued that such individuals may be better adapted to the culture situation but because they are less fit or 'less hardy' they are unlikely to survive long in the wild. Even if they breed their genes would be selected out of the wild population. An alternative view is that cultured fish, because they are selected for growth may become bigger and would out compete their wild cousins. Interbreeding between cultured and wild stocks could produce vigorous hybrids that might well prove fitter than either parent and lead to genetic change in the wild population. Even where cultured fish were less fit, continued introductions of large numbers might change the genetic constitution of the wild population which, if reseeding stopped, might result in the extinction of the resultant 'unfit' wild stock. All this is conjecture, and the models have largely been developed with respect to salmon. Experiments are only now being undertaken to test the fitness of cultured and wild salmon fry, the performance of hybrids and the tracking of fish tagged by rare alleles in Ireland and Spain (Ferguson *et al.*, 1995). Even where reseeding has been extensive the lack of definitive genetic markers between stocks from different areas has made it difficult to estimate the size of the impact (Youngson *et al.*, 1991).

Some observations, such as the lack of dispersal of pearl oysters with different allozyme variants from the farm into which they were introduced, to sites several tens of kilometres away after ten years, suggest little spread into wild stocks (Johnson and Joll, 1993). However, there has been no completed studies that attempted to specifically track genetically marked individuals to determine their dispersal and the extent of their population growth, in any marine taxa. Once again, the technologies can be developed, and there is some work underway on salmon and cod. There is much more conjecture and few established facts.

MARINE RESERVES

Stock-enhancement by establishing marine reserves is likely to be the only effective means of replenishing a multi-species fishery and single species fisheries where there are no resources to establish hatchery infrastructure. The idea is that the reserve will provide a base population whose excess recruits spill out to colonise fished areas. Recruits from this source would not only be available locally on the margins of the reserve, but could also be transported considerable distances downstream by ocean currents and help to restock distant sites. Careful choice of a network of sites would allow an effective source of recruits to be maintained for a much larger area.

Such an approach using natural populations might be thought to be reasonably straightforward to plan and to have few adverse genetic effects. The principal difficulty is determining which populations are connected by dispersal and to what degree. A second difficulty is identifying which populations act as sources and which act as sinks for recruits. Neither of these problems is trivial and genetic techniques provide a useful means to establish the connectedness of populations, and in some circumstances, the direction of dispersal.

The geographical pattern of gene frequencies at a number of loci (allozymes or DNA variants) provide information on the extent of gene exchange, or dispersal, among the populations sampled. Analysis of subsets of populations can identify the patterns or routes of dispersal. There is a huge literature on the structure of wild populations. Those on marine species have tended to show high levels of dispersal among species with significant planktonic larval phases but have shown that some species do not disperse as widely as had been thought (Benzie *et al.*, 1992; Benzie, 1993a; Benzie and Ballment, 1994). Importantly, the major paths of genetic connectedness of some species have not coincided with major present day ocean currents (Benzie, 1993a).

It is not therefore immediately obvious from hydrological patterns which sites are likely to act as sources and sinks or which are likely to be representative of the genetic diversity of a region. Genetic data do not readily allow the direction of gene exchange to be identified, although progressive founder effects in prawn populations have been used to suggest a migration from east to west of giant tiger prawns (Benzie *et al.*, 1992). Usually other biological and hydrological information would be required to interpret the direction of the connections identified by spatial patterns of gene frequency data.

Often the development of marine reserves is considered when populations are already reduced (Juinio *et al.*, 1989; Munro, 1993). The reduction of genetic diversity associated with such bottlenecks in population size needs to be considered. All the potential difficulties of hatchery-reared stocks require to be managed effectively if the reserve stock is enhanced artificially (Munro, 1993; Benzie, 1993b) as may be required if populations of wild stock are non-existent or very rare.

Once again molecular marking technologies offer the potential to assist the identification of routes of dispersal among natural marine populations but have been rarely used in practice, and are rarely considered in planning reserves designed to act as sources for other sites.

STRATEGIES

There is an obvious conflict in developing a genetically identifiable group for release, so that the effectiveness of return from a restocking exercise can be assessed, with the goal of managing hatcheries to provide recruits that will have minimal genetic impact on the wild population. This does not present an insurmountable problem in that early phases of a restocking program might concentrate on producing genetically identifiable stocks to determine the extent of dispersal, and the proportion of the catch contributed, by the artificially reared stock. Having established the viability of the operation, hatchery production could then concentrate on rearing offspring from large numbers of adults to maintain genetic diversity and match the constitution of the wild stock as closely as possible.

The natural variability in recruitment of marine species means that several marked stocks would be required to obtain reasonable estimates of return, but also suggests that minor variations in the overall gene frequencies these would induce in the wild stock would be diluted in time. The relatively little stock separation in many marine species means dispersal from other populations would assist in the rapid removal of perturbations induced by specially marked hatchery stock. The problem of artificially induced changes in the genetic constitution of wild stocks is particularly important where the aim of restocking is to conserve a particular strain or to maintain natural populations.

However, the circumstances in which stock-enhancement is now likely to be used for increased production will involve stocks that are localised, or return to the same area to breed. In this situation those who have invested resources in releasing young to the population are most likely to see some return on their investment. Fish with large ranges and widespread movements over ocean scales such as tuna (see Richardson, 1983) would not be attractive candidates for restocking. Where the proportion of the stock provided by hatcheries is high, it becomes a moot point as to whether the operation is essentially farming or ranching cultured stock as opposed to enhancing a wild fishery. As the situation more closely approximates farming the option to selectively breed the stock for improved production traits would become more attractive.

The difficulties in managing wild populations has led some agencies to the view that fisheries are so complex that there is no point undertaking research to do so. Sequential mining of wild stocks is seen as inevitable. One corollary of a lack of research information is that it becomes more difficult to assess the contribution of particular decisions to the success or failure of a reseeding project and hence the responsibility of those making the decisions. There are technologies available in genetics to assess and manage key aspects of restocking programs. To ignore those tools that might provide further understanding of complex systems, and allow the development of technologies for restocking, is illogical in the face of a need to deal effectively with complex systems.

To date, genetics has not been effectively used in stock-enhancement programs for any marine species but has considerable potential to address the issues of impact, production enhancement and effects on biodiversity. Until this potential is tapped, the issues concerning stock-enhancement of marine species will remain the subject of conjecture rather than fact, and of opinion rather than tested technology.

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PROSPECTS FOR A MARINE ENVIRONMENTAL DATABASE FOR THE ASIA-PACIFIC REGION

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ABSTRACT

In this paper, we examine the prospects for a regional marine environmental database for the Asia-Pacific region. We look first at the size and shape of the ecologically sustainable development (ESD) problems that drive the need for such a database. Then we look at how well some current datasets 'fit' these problems. From this, we are able to sketch the outlines of a regional database. We then ask about the computability of such a database before concluding with a discussion about the ways in which regional information centers might help bring the database into fruition.

INTRODUCTION

A major outcome of the recent UNCED process was an appreciation of the pivotal role of environmental and resource information in ecologically sustainable development (ESD). Indeed many countries, particularly in the Asia-Pacific region, have begun to build the infrastructure necessary to acquire, manage, access, integrate, enhance, visualise and assess environmental and resource data. These efforts are often collaborative, with developing countries receiving significant assistance from developed countries to bring their information systems up to modern standards necessary to underpin ESD initiatives.

Most of these initiatives are necessarily national or even provincial in scope, but there is a growing appreciation of the need for regional databases. This is especially so in the marine environment where ESD issues show no regard for national borders.

We propose to examine the prospects for a regional marine environmental database for the Asia-Pacific region by first looking at the size and shape of the ESD problems that drive the need for such a database. Then we will look at how well some current datasets 'fit' these problems. From this, we will sketch the outlines of a regional database. We will then ask about the computability of such a database before concluding with a discussion about the ways in which regional information centers might help bring the database into fruition.

THE SIZE AND SHAPE OF ESD PROBLEMS

When one first examines the sorts of problems that are lumped together under the rubric ESD, one is astounded by their range and diversity. But on reflection, they have a shared character. Think, for example, of problems such as biogeographic reorganizations for planning marine protected areas, integrated coastal zone management, oil spill contingency planning, multiple use plans for marine environments, mangrove reforestation of degraded aquaculture ponds, or remediation plans for eutrophied estuaries.

Each of these problems, while distinctive, shares with all the following features:

- they are complex problems, so that the data required to describe them must be sought from many disciplines, and the data themselves are often multivariate;

- they occur over large areas;

- the underlying biophysical and socioeconomic processes are often very fine scaled.

Thus, ESD issues are alike because, in sharing similar concerns, they share similar structures as problems. ESD issues share sizes and shapes.

Let us now consider this idea in a little more detail.

Ecologically sustainable development concerns the harmonization of the biophysical systems of the natural world with the socioeconomic systems of man. It cannot be sensibly considered in anything but a whole systems way. But the system, so considered, is vast and complex, as is the information needed to describe it.

The underlying processes driving both the biophysical and socioeconomic systems operate over large areas - think of the geographic extent and effects of ocean currents, trading patterns, or wars. These same processes also operate at very fine scales - think of the tyranny of small decisions in the degradation of the coasts, the local effects of fishing or point sources of pollution.

Furthermore, while individual processes may be reasonably simple and well understood, they themselves interact in complex ways which may be only poorly understood - think of the comparative simplicity of tides or waves or currents, now think of the complexity of the interaction between them, and finally think of the full gamut of interactions in biological or socioeconomic systems.

The information needed to describe such systems needs to be at once extensive in area and intensive in resolution to cope with the needs of capturing phenomena which are both extensive and intensive. We will refer to this as the **size** of the ESD problem. It also needs to be abundant and diverse enough to cope with the range and complexity of processes that make up the real world. We will refer to this as the **shape** of the problem.

These demands drive our information needs for ESD.

Views of ESD problems

In order to understand how these demands shape our information needs, we will attempt to describe the shape and size of the ESD problem envelope by casting our ESD problems, with a few heroic assumptions, into two distinct phase spaces:

- a problem **size** space with axes measuring the extensiveness and intensiveness of the underlying phenomena;

- a problem **shape** space with axes measuring the abundance and diversity of the underlying phenomena.

Table 1. shows an eclectic range of current or planned ESD programs in the region, chosen more to highlight their diversity than anything else. This table shows clearly that the areal extent of individual ESD programs is now vast. It is unlikely to do anything but increase in the future.

Table 1. Some regional ESD programs

PROGRAM	ISSUE	AREAL EXTENT
Marine Resource Evaluation Project, Indonesia	Sustainable development of Indonesia's coastal resources	Indonesia's archipelagic EEZ
Great Barrier Reef Marine Park, Australia	Management of GBR for multiple sustainable use	Great Barrier Reef province
Zone of Cooperation, Indonesia and Australia	Management of Timor Gap region	Arafura Sea and Timor Sea
COMEMIS, South China Sea	Management of South China Sea	South China Sea
Coastal Zone Environmental and Resource Management Program, ASEAN	Management of ASEAN coastal zone	EEZ of ASEAN
COBSEA	Coastal marine management	SE Asian seas
NOWPAP	Coastal marine management	NW Pacific
Commission for conservation of southern bluefin tuna, Japan, Australia and New Zealand	Management of global stock of southern bluefin tuna	Southern Ocean and NE Indian Ocean
Natural disasters information system	Management of natural disasters	Southwest Pacific

Table 2 shows an arguably minimal set of defining ESD processes and their characteristic time and space scales. By defining processes, we mean those processes which can reasonably be expected to be found in most ESD problems, and by characteristic scales, we mean the scales at which significant changes occur.

Table 2. Scales of some defining ESD processes

Process	Example	Characteristic scales
Demography	Dwellings	days, 10s of metres
Demography	Life tables	years, kilometres
Ecology	Competition	days, centimetres
Ecology	Predation	hours, metres
Geography	Coastal zone geomorphology	hours to years, metres
Geology	Sediments	years, metres
Macroeconomics	Markets	minutes, hundreds of kms
Meteorology	Microclimate	hours, metres
Microeconomics	Workplace	hours, metres
Oceanography	Currents	days, kilometres
Oceanography	Tides	hours, metres
Oceanography	Water column	hours, 10s of metres

We approach the *shape* problem in Table 3 where we show our defining ESD processes in terms of the complexity of the data necessary to describe them. We characterise the abundance of the data by the number of entities typically tracked in these processes, and the diversity of the data by the number of attributes typically measured for each entity. In a strict sense, the number of attributes measures the dimensionality of the problem.

Table 3. Complexity of some defining ESD processes

Process	Number of entities	Number of attributes
Demography	hundreds	tens
Ecology	thousands	hundreds
Geography	hundreds	hundreds
Geology	hundreds	hundreds
Economics	hundreds	tens
Meteorology	millions	tens
Oceanography	millions	hundreds

Taken together, the data in Tables 1, 2 and 3 result in the problem envelope shown in Figures 1 and 2. Figure 1 shows a view of the problem envelope in terms of the size of the ESD problem, while Figure 2 shows a view of the shape. From Figure 1, we conclude that the envelope is being stretched by the demands of ESD into the upper left hand corner, where problems are extensive in area and intensive in scale. We conclude from Figure 2 that the envelope is being stretched by the demands of ESD into the upper right hand corner, as the number of entities and attributes needed to describe ESD problems increases.

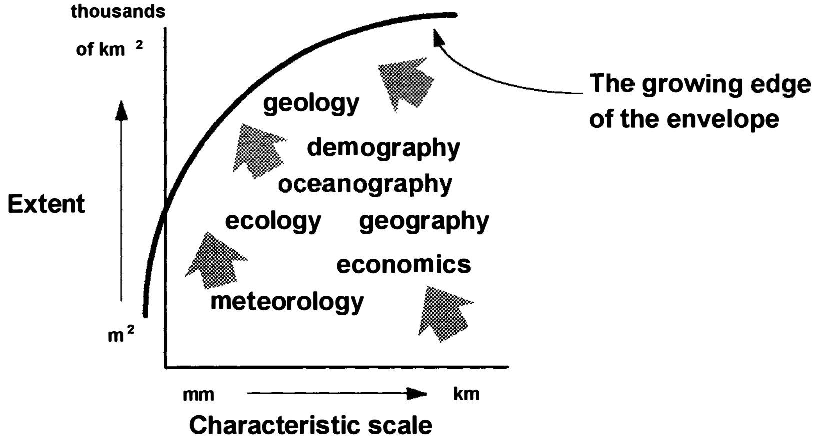

Figure 1. The size of ESD problems

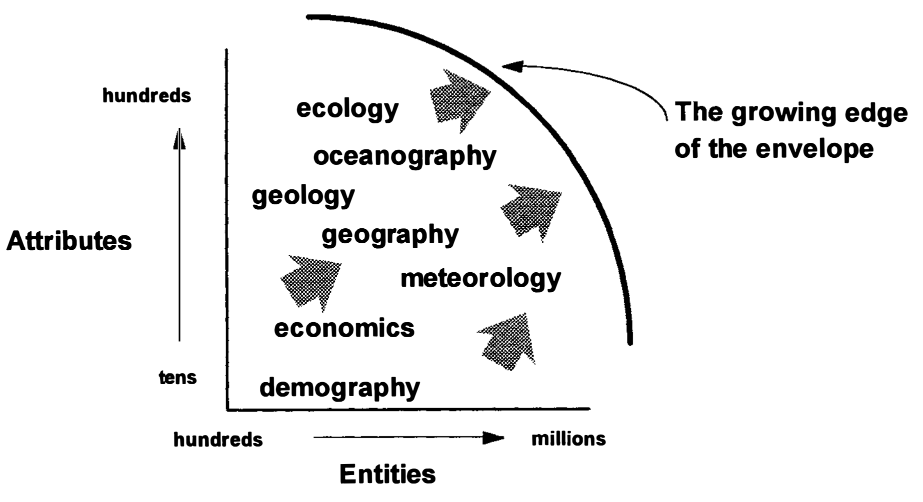

Figure 2. The shape of ESD problems

WHERE ARE THE PRESSURES COMING FROM?

The pressures which are stretching the envelope look set to continue into the indefinite future because they stem from the idea of ESD itself:

- the pressure to examine ESD problems over greater areal extents, particularly in marine issues, stems from the fundamental idea that ESD problems are connected problems which need a large context;
- the pressure to examine ESD problems at fine scales stems from the need to move from inferring process from observed pattern to measuring process directly;
- the pressure on entities and attributes stems from the need to approach ESD problems as whole systems problems with its consequential higher dimensionality.

ARE THERE DATA TO SUPPORT THESE PROBLEMS?

The data available to support the analysis of ESD problems come mostly from surveys for other, usually simpler, purposes. Table 4 summarises a range of (mostly) Australian survey programs generating data for their own purposes, but which themselves would certainly form a core for any ESD analysis in their region. From this table we can locate their constituent datasets in the size and shape spaces in Figures 3 and 4 respectively.

Table 4 Size and shape of some recent marine survey programs

	Size		Shape	
Program	**Areal extent**	**Characteristic scale**	**Entities**	**Attributes**
Benthos	GBR	metres	245000	5
Bioregions	Australia	kms	274	1
Biogeography	ASEAN	100s of kms	400	150
Coral reefs	GBR	100s of kms	66000	11
Geophysics	Australia	metres	4000	50
Hydrography	Australia	100s of metres	150 million	4
Oceanography	Indo-Pacific	kms	608000	25
Taxonomy	Indo-Pacific	100s of kms	900	1
Water quality	GBR	10s of kms	2000	13

In Figures 5 and 6, we show the problem and data envelopes in the size and shape domains.

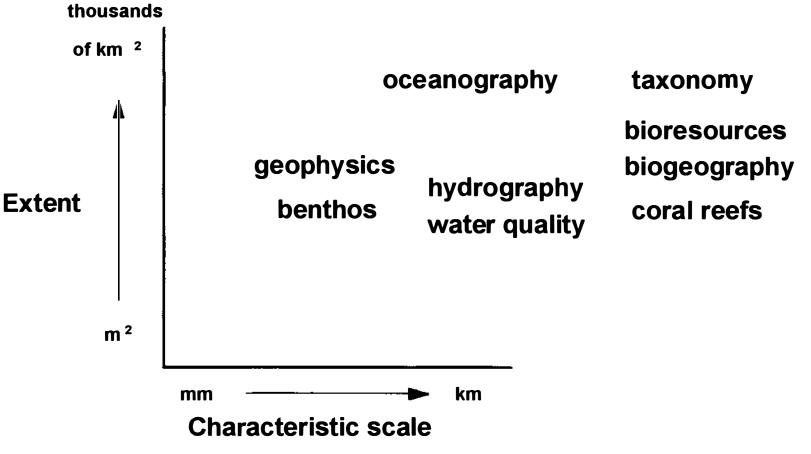

Figure 3. The size of ESD datasets

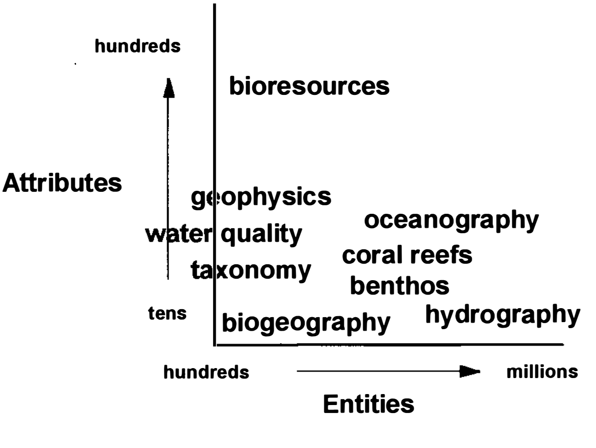

Figure 4. The shape of ESD datasets

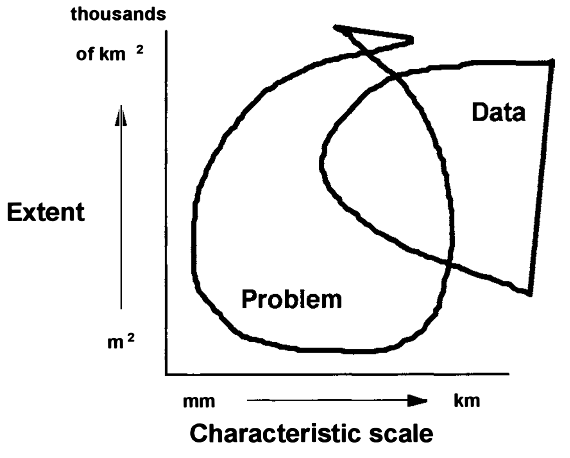

Figure 5. The fit of data to problem - Size

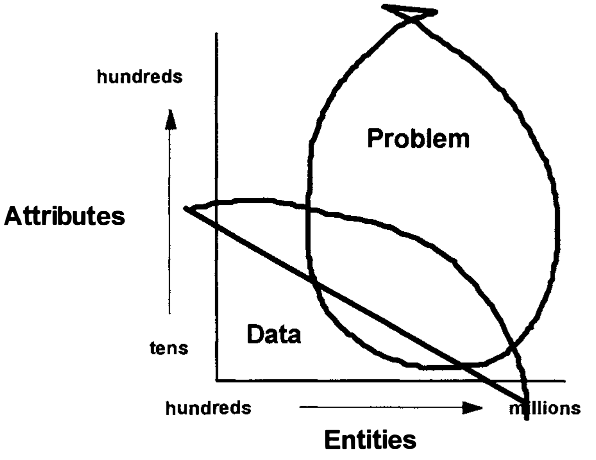

Figure 6. The fit of data to problem - Shape

These last two figures clearly show that the data envelope does not overlap the problem envelope very well. In general, the datasets we are currently collecting, by and large, are too small and not complex enough to meet the needs of ESD problems. In particular, they are not being collected at anything near the characteristic scales required to begin to capture, instead of infer, dynamics; and the data descriptions are not multivariate, rich or high-dimensioned enough to serve the needs of anything more than a rough caricature of a whole systems approach.

In the broadest sense, the present data envelope is, at best, several orders of magnitude too small in terms of size, and at least a couple of orders of magnitude too simple in terms of complexity to satisfy the needs of regional ESD problems.

This qualitative analysis begs the question: just how much bigger and how much more complex does the data need to be?

The first part - how much bigger - can be answered in terms of ordinary bits and bytes. The largely single discipline datasets in Table 4 range in size through megabytes (Mbytes or 10^6 bytes) to gigabytes (Gbytes or 10^9 bytes), which implies that we need to think, at least, in terms of terabytes (Tbytes or 10^{12} bytes) as the physical size for datasets which are effective enough to support regional ESD problems.

The second part - how much more complex - is more difficult since it involves a consideration of the way ESD data need to be handled by computers. We defer it to the next section.

ARE BIG, COMPLEX ESD DATASETS COMPUTABLE?

Just as ESD datasets need to be the right size and shape to match the size and shape of ESD problems, so too does the computing environment need to be the 'right' size and shape. It is the computing environment, after all, which does the actual 'matching', by bringing the data to bear on the problem. And ESD problems are typically whole systems problems. Typically with such problems, we wish firstly to analyse the structure of the system, using tools such as geographic information systems (GIS); and then secondly, to analyse the dynamics of the system, often using simulation and modelling tools; and thirdly to evaluate possible future trajectories of the system, using scenario analysis tools such as those found in decision support systems (DSS).

Because ESD problems are whole systems problems, a big problem cannot usefully be broken down into a lot of little problems done one at a time. Thus a big ESD problem is qualitatively different from, say, an 'equally' big transaction processing problem that a bank or stock exchange might encounter. Those big problems are only the sum of lots of little problems. In short, the most significant point to note about ESD datasets is that they have to be handled 'all at once'.

Thus what 'size' means in terms of the computing environment is clear: it has to do with its power and speed. But what do we mean by 'shape' in this context? This is more subtle, but essentially has to do with the architecture of the computing environment which allows the ESD problem to be gracefully handled.

The size of the computing environment

The three features of a computing environment that determine the computability of a problem are the computational speed, mass storage size and communication speed.

Speed on high performance computers is usually measured in *flops* or floating point operations per second. (For comparison, the peak speed of a fast 486 PC is about 5 megaflops (Mflops or 10^6 flops), while a Sun 690 Unix server operates at about 60 megaflops). Big ESD datasets will typically require gigaflops (Gflops or 10^9 flops) of performance to complete in reasonable time. For example, as part of an ongoing study of Australia's southeast forests at NRIC, we required the 2 gigaflop performance from our CM 2 supercomputer to get our results in a reasonable time (Table 5).

Table 5. Timing the analysis of a large dataset

ESD issue	Classification of forest areas in Southeast Australia
Dataset	14 edge-matched 6-band Landsat scenes, each 300 megabyte, each about 3000 x 3000 pixels
Algorithm	Multivariate non-hierarchical classification
Compute time	**40 minutes** on a Thinking Machines parallel supercomputer CM 2 *cf* > **100 hours** on a Sun 4/690 Unix server

However, few high performance computers will be able to hold terabyte or even gigabyte datasets in core during computation and so will rely on large online mass storage devices and fast communication between computer and store for effective computation.

To feed processors capable of gigaflops of speed with terabytes of data from a mass store requires gigabits per second of communications band width.

Therefore we can confidently say that together, gigaflops, terabytes and gigabits define the size of the high performance computing environment required to address regional ESD issues, and each of them require leading edge technology.

At the present time some computing environments are able to offer one or two of the three elements, few are able to offer all three. For example, some 'supercomputer' facilities may have the gigaflops of raw computing speed, but be unable to handle a terabyte mass storage requirement, while other 'supercomputer' facilities may offer the speed but be unable to communicate with databases located offsite at acceptable speeds. The typical ethernet speeds of 10 megabit/s in many networked environments are incapable of handling the data traffic generated by big ESD problems.

The shape of the computing environment

The two features of ESD problems which are most difficult to reconcile within a computing environment are their complexity and their whole systems nature. The latter requires that the problems be analysed, in some sense, 'all at once', while the former requires that the problems be very highly dimensioned. These features can be most elegantly reconciled by matching the shape of the computing environment to the shape of the problems by using a massively parallel supercomputer.

In such a computer, the material fact that all the components of the ESD system are operating 'all at once' is matched by the parallel computer's ability to operate on all the data 'all at once'. The inherent parallelism of ESD problems is explicitly modelled in the computer's architecture. Thus instead of becoming a difficult problem, as it does on conventional computers, the inherent parallelism of ESD problems is turned to advantage on parallel computers. The result is cleaner, simpler analyses and a better understanding of the ESD problem.

Parallel architectures also answer our concern above about how much more complex the data need to be. Because these architectures are fully scaleable, they are able to always fully match the complexity of the problem as its dimensionality grows. The data can be as complex as needs be, without major concerns about their computability.

TOWARDS A REGIONAL DATABASE

We have used the term 'computing environment' instead of 'computing system' in our discussion above to make a crucial point, whose logic goes like this. Regional ESD problems are big, complex problems. They will require big, complex analyses of big, complex datasets within big, complex computing environments. Neither the component datasets nor the component computers will necessarily all be collocated in the one computing system. Rather, they will be spread around the region. The linking of these datasets into a regional database, and the linking of the computer systems into an ESD computing environment will require an evolution in the role of the regional information centers. We will conclude our essay by describing this evolution.

Initially centres such as the Global Resource Information Database (GRID) and the National Resource Information Centre (NRIC):

- maintained copies of some key disciplinary datasets;
- developed prototype information systems for clients;
- maintained directory systems with pointers not only to datasets but also to other national and international systems;
- and facilitated the flow of information by acting as data brokers as well as gatekeepers of data standards.

The emergence of a regional database, in anything like the form discussed here, together with the evolution of technology, will redefine their roles. Their success in spreading the enabling technologies for the analysis of ESD problems will mean that their role in prototyping will probably come to an end. Their other roles will similarly change.

We think three new roles will emerge: The first will be a data role. With their experience in the problems of ESD datasets and in metadata directories, the information centers will be well placed to carve a new data broking niche, one that emphasises not only helping clients find the data they need, but which also helps assure the client of its quality and utility for his particular purpose, and which undertakes the necessary preliminary analytical work to tailor the data for that purpose.

The second will be an analytical role. The information centers will be called upon by consortia of clients and partners to undertake the major, canonical analyses that can only be done with their high performance computing platforms.

The third is a quite novel data management role. The regional database will not exist as a single object in a single place. Instead it will be, invariably, a set of disciplinary databases located in a set of disparate locations, linked together by a metadata system. It is a virtual database. The information centers will provide the metadata systems needed to manage it. But they will also help clients get the data they want by accessing, integrating and enhancing different bits of this database. Thus the information centre will be to this virtual database what a database management system is to the simple disciplinary database: a filter or process which not only gives it its utility, but also allows the emergence of new data.

ACKNOWLEDGMENTS

We thank Lindsay Hood of Thinking Machines Corporation for helpful discussions on the parallel computing paradigm. For advice on size and shape of disciplinary datasets, we are grateful to: Valonna Baker (Australian Institute of Marine Science), John Busby (Environmental Resources Information Network), Anthony Cheshire (University of Adelaide), John Leech (Australian Hydrographer), Kim Navin (Australian Institute of Marine Science), Eugene Petrie (Bureau of Resource Sciences), Sandy Radke (Bureau of Resource Sciences), Ben Searle (Australian Oceanographic Data Centre), Simon Woodley (Great Barrier Reef Marine Park Authority), and Peter Young (CSIRO Fisheries).

MANAGEMENT OF SEWAGE DISCHARGES IN THE GREAT BARRIER REEF MARINE PARK

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ABSTRACT

Increased coastal runoff of sediment and nutrients to the Great Barrier Reef region, following European settlement of coastal catchments, is recognized as one of the most significant long-term threats to the Great Barrier Reef. Best estimates suggest four times as much sediment, nitrogen and phosphorus now enter the GBR lagoon as before European settlement. The largest source is agriculturally derived material, but sewage discharges are also significant and particularly important at local scales due to their concentrated point source entry. Eutrophication from sewage discharges leading to ecosystem changes is evident at Green Island and in Trinity Inlet in the Cairns area and in the past at Hayman Island. In 1991 the Great Barrier Reef Marine Park Authority (GBRMPA) introduced a requirement for tertiary, nutrient-reduction treatment of direct sewage discharges into the Marine Park. A five year compliance period was allowed for existing operations while new operations were required to comply as constructed. Most resorts in the Marine Park have now introduced either tertiary treatment or no-discharge systems. The no-discharge systems rely on reuse of effluent for irrigation of golf courses and gardens. Ocean discharge from coastal cities is slowly being reduced, the effluent primarily being used to irrigate golf courses. A number of local authorities have adopted 'nil discharge' policies and GBRMPA is promoting this as its preferred option for mainland sewage disposal.

ISSUES

The Great Barrier Reef Marine Park (GBRMP) extends along the north and central Queensland coast (Figure 1). The seaward boundary is near the edge of the continental shelf. The landward boundary is the low water mark on most of the coast but a few kilometres offshore in some areas particularly near the major cities and ports. As a result of these boundaries, while most of the sewage outfalls from island resorts discharge directly into the Park, the city ocean outfalls discharge into waters between the inner boundaries of the Park and the coast. These discharges may still be affecting waters and ecosystems within the Park but are not within the direct jurisdiction of the Great Barrier Reef Marine Park Authority (GBRMPA) for management. The Great Barrier Reef Marine Park Act (1975) states 'A person shall not discharge waste in the Marine Park unless the discharge is authorised by a permission granted to the person under the regulations being a permission of a kind declared by the regulations to be a permission to which this section applies.' (Clause 1). The Act also gives GBRMPA a reserve power to regulate activities occurring outside the boundaries of the Park but which could impact on the Park. However this reserve power has been rarely used and cooperative management arrangements with Queensland State agencies to manage such activities has been the rule.

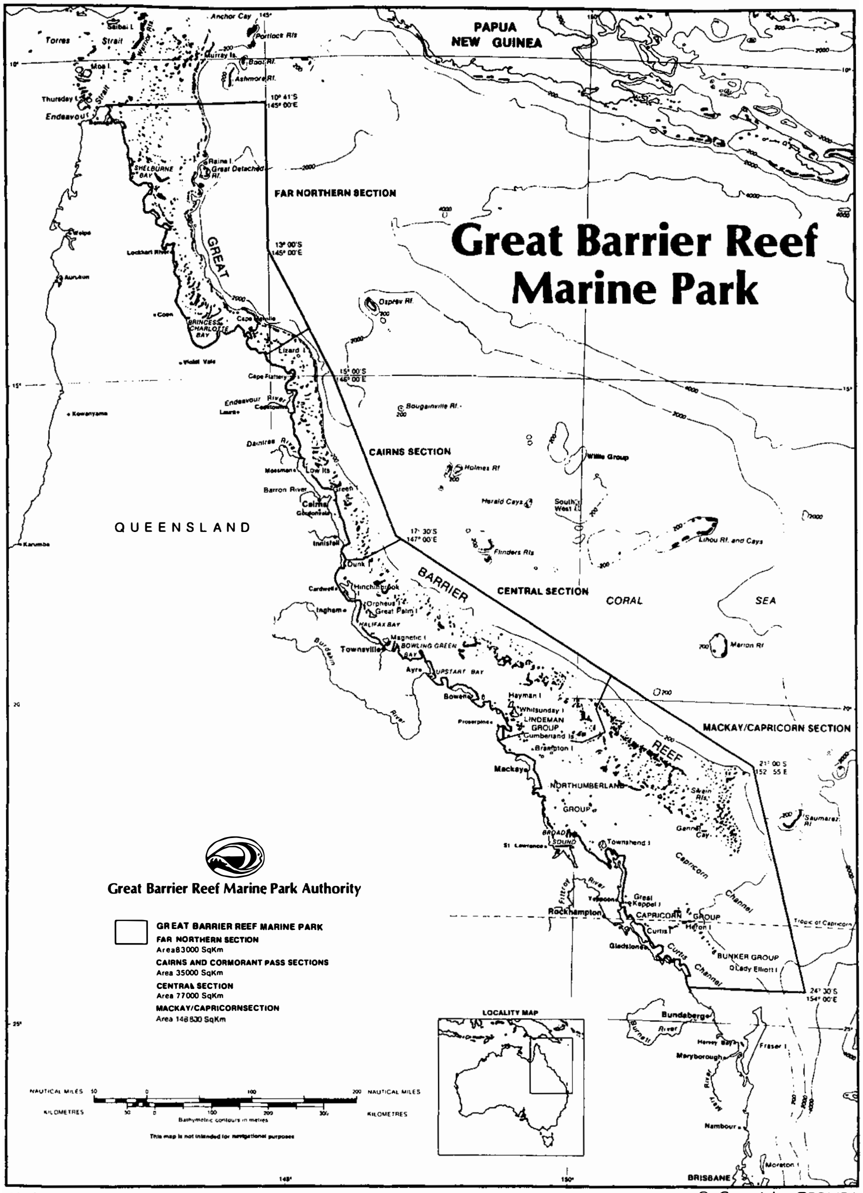

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Figure 1. The Great Barrier Marine Park.

SEWAGE EFFLUENT COMPOSITION

Sewage effluents contain a range of potentially polluting substances including organic matter capable of causing oxygen depletion in receiving waters; suspended solids capable of causing turbidity in receiving waters; microorganisms (bacteria, viruses, fungi, protozoa, parasitic worms), some of which may be pathogenic; plant nutrient substances, particularly nitrogen and phosphorus compounds, but also micronutrients such as iron and zinc; toxic trace metals such as lead, cadmium and chromium; toxic synthetic organic substances such as pesticides and solvents; petroleum oil; detergents; biologically active drug residues such as vitamins and steroids; and litter. While many of these pollutants may cause problems at very local scales, research has suggested that the pollutants of major threat to the Great Barrier Reef are the nutrients nitrogen and phosphorus. Most of the rest of the substances listed are adequately reduced by secondary sewage treatment, the norm on the Queensland coast, or prevention of industrial waste entering the sewage system, which is also now common.

Sewage may be treated to a number of stages of final effluent quality, commonly known as primary, secondary and tertiary treatment. Primary treatment removes a proportion of the solids in the sewage, secondary treatment reduces the organic loading as well as further solids while tertiary treatment, in addition, reduces the nutrient content. Table 1 shows typical effluent quality from the various treatment stages.

Table 1. Effluent Composition.

Component	**Raw Sewage**	**Primary Treatment**	**Secondary Treatment**	**Tertiary Treatment**
Biological Oxygen Demand (mg/l)	300	200	15	2
Suspended Solids (mg/l)	300	120	20	2
Total Nitrogen (mg/l)	50	45	20	4
Total Phosphorus (mg/l)	10	9	7	0.6
Surfactants (mg/l)	2	2	1	<1

Sewage discharges are not the only source of nutrient input to Great Barrier Reef (GBR) waters. Research into the sources of nutrients to the central Great Barrier Reef lagoon by Furnas *et al.* (1994) has shown that sewage inputs to a section of the lagoon near Cairns are only a small fraction of the total. Even as a proportion of the terrestrial sources of nutrients sewage makes up a small fraction as shown by Moss *et al.* (1992) for the GBR coast. For the whole GBR sewage inputs are approximately one tenth as large as diffuse runoff of nutrients resulting from agricultural activity. For areas near the larger cities however sewage may make up a significant proportion of inputs. Table 2 shows loads to the GBR adjacent to Cairns, comparing discharge from the Barron River, Cairns sewage discharge, Green Island sewage discharge (before the startup of the tertiary treatment plant) and discharges from tourist vessels offshore from Cairns.

Table 2. Nutrient Load Comparison.

Source	Nitrogen Load (tonnes/year)	Phosphorus Load (tonnes/year)
Barron River		
• Diffuse load	760	80
• Sewage load	117	31
Cairns total sewage load (3 plants)	234	62
Green Island before 1993	4	1.2
Tourist vessels off Cairns	4	1.2

Impacts from the nutrient content of sewage discharges is thus likely to be local in effect. Effects will be exacerbated where effective dilution of sewage effluent after discharge does not occur. This is most likely to occur in poorly flushed inlets with long residence times. This has been the case in Trinity Inlet (Cairns), as described later, and for some resort discharges in the past which discharged into shallow water on top of the reef flat. Cleveland Bay (Townsville) is also a potential problem area with large sewage discharges, only moderate flushing and considerable areas of coral reef. Sewage discharges may also have different effects than agricultural nutrient runoff as they are continuous in nature and thus constitute a chronic stress. Agricultural runoff mainly occurs in periods of intense rainfall and river flow (Furnas and Mitchell, 1991), usually only for a few days per year and often only once each several years. It thus acts more as an acute stress although the nutrients once released into the GBR lagoon may continue to be recycled and maintain elevated levels for some time.

EFFECTS OF SEWAGE DISCHARGES

Tropical oceanic waters have low nutrient concentrations and coral reefs and tropical seagrass beds appear to be adapted to these nutrient-poor conditions. Increased nutrient loadings in coral reefs waters leads to a range of effects including decreased calcification; changes to the growth form and crystal structure of the coral skeleton; increased macroalgal growth with the potential to overgrow the coral; and increased phytoplankton biomass leading to increased water turbidity (adversely affecting light levels for coral growth) and increased growth of filter-feeding organisms which both compete for space with coral and by bioerosion, destroy the reef structure (Kinsey, 1988).

The best documented example of the effects of sewage effluents on a coral reef is from Kaneohe Bay, Hawaii (Smith *et al.*, 1981). Sewage discharges into the Bay from the end of the Second World War to 1978 saw the waters become increasingly rich in phytoplankton (Clutter, 1971; Laws and Redalje, 1979) and reefs closest to the outfall become overgrown by filter-feeding organisms (sponges, tube-worms, barnacles) (Banner, 1974). Reefs in the centre of the Bay further from the outfalls were overgrown by the green alga *Dictyosphaeria* sp. (Smith *et al.*, 1981). After diversion of the outfalls into the ocean in 1978, the reefs have slowly recovered (Maragos and Holthus, 1985).

On the Great Barrier Reef, a secondary treatment sewage discharge from the Hayman Island Resort in the Whitsundays caused localized effects on the adjacent coral reef (Steven and van Woesik, 1990) including reduced species diversity, lower coral cover, suppressed coral recruitment and greater turnover of species. The outfall is now rarely used as effluent is used for resort gardens irrigation.

Green Island, near Cairns, is the GBR's most visited reef. Prolonged discharge of primary treated effluent has led to abnormal and luxuriant growth of seagrass in an area near the cay where hydrodynamic retention of the diluted effluent occurs (Van Woesik, 1989). Since December, 1992 the primary effluent has been replaced by a smaller volume of tertiary effluent and studies are continuing to monitor the effects on the seagrass beds.

In the coastal city of Cairns, one large (45,000 EP) and one small (15,000 EP) secondary treatment plants discharge into the back of the Trinity Inlet estuary system. The outfalls are in a poorly flushed section of the Inlet and monitoring has now revealed the symptoms of a classic eutrophic system. Chlorophyll measurements show phytoplankton concentrations to be continuously high, nutrient concentrations are very high, while dissolved oxygen concentrations are low near the bottom of the Inlet and the benthic communities are reduced in diversity (Sinclair Knight Merz, 1994). Table 3 compares nutrient and chlorophyll concentrations in a similar nearby relatively pristine estuary (Coral Creek, Hitchinbrook Island - unpublished data from Alan Mitchell, Australian Institute of Marine Science) with Trinity Inlet.

SEWAGE TREATMENT

Sewage, treated in a treatment plant to increasing levels of effluent quality, is normally referred to as having received either primary, secondary or tertiary treatment. The steps are cumulative and secondary treatment has a primary step built-in while tertiary treatment has both primary and secondary stages incorporated. All the sewage plants in the GBR region can be classified into these categories, based on effluent quality, even though a large range of different types of plant operate. Typical effluent quality for each type is listed in Table 1.

Primary treatment involves removal of a portion of the solids from the sewage by screening, skimming and sedimentation. Hook Island Resort retains the only discharging primary treatment plant in the region although a few other resorts and many communities use septic systems with transpiration trenches. Secondary treatment, in addition to primary solids removal, involves removal of organic material by bacterial mediated oxidation and further removal of solids. This is achieved through various aeration techniques with the sewage in contact with bacteria or filtration. Examples include oxidation ditches, trickling filters, extended aeration tanks, rotating disc bioeroders and Memtec membrane systems. An additional sterilization step to remove all microorganisms, achieved using chlorination, oxonation or ultra-violet treatment of the final effluent, is generally all that is required to make secondary effluent suitable for irrigation on gardens, golf courses, agricultural crops or sporting fields. Tertiary treatment involves additional bacterial processes which convert nitrogenous material to gaseous nitrogen which escapes to the atmosphere. Phosphorus is removed by flocculation into the sludge using either chemical additions of iron, aluminium or calcium compounds or through a bacterial flocculation process. Tertiary plants operate on Green Island (Gersekowski, 1992) and Lindeman Island.

Table 3. Trinity Inlet/Coral Creek Comparison.

Location	Parameter	Mean	Range
TRINITY INLET (Data from Sept., 1993 - March, 1994)	Ch- a (μg/l)	7.8	3.0-39
	Ammonium (μM)	3.7	0.7-21
	Phosphate (μM)	0.7	0.1-1.9
CORAL CREEK /MISSIONARY BAY (Data from 1977/78)	Ch-a (μg/l)	0.8	0.19-5.6
	Ammonium (μM)	1	0.0-3.7
	Phosphate (μM)	0.4	0.1-1.2
(Data from Oct. and Nov., of 1990)	Ch-a (μg/l)	1	0.68-2.1
	Ammonium (μM)	0.6	0.25-1.2
	Phosphate (μM)	0.06	0.01-0.11

MANAGEMENT OF DIRECT DISCHARGES

Only limited studies of the adverse effects of nutrient enhancement from sewage discharges have been carried out in the GBR region. Experience from overseas and other parts of Australia (Brodie, 1994) has demonstrated the long-term damage to coral reefs and seagrass beds caused by such discharges. While monitoring the effects of outfalls is possible, statistical rigour and scientific certainty of the results are a continuing problem in monitoring programs which also tend to be extremely expensive to implement.

In view of these monitoring difficulties but convinced that better management of sewage discharges in the Park was necessary, GBRMPA introduced a policy in 1991 requiring all direct sewage discharges into the Park to be of tertiary standard (Brodie, 1991). The alternative to a tertiary discharge was basically no-discharge (ie reuse of secondary effluent for land irrigation of suitable areas). Existing dischargers were given five years to comply with the new standard while new operations were required to comply as the facility was built. As noted above, only island resorts were involved as they were the only existing direct dischargers into the Park but the policy would also apply to municipal authorities and mainland resorts if they built outfalls which were inside the boundaries of the Park. Resorts using irrigation were allowed limited direct overflow discharge during periods of heavy rainfall when irrigation was not practical.

Most resorts implemented irrigation systems as they often had water shortages or expensive water supplies and the irrigation approach allowed them to save on potable water. A number of resorts already had such systems operating (eg Brampton Island Resort). A few tertiary or part-tertiary plants were built or upgraded from existing secondary plants (Table 4). Compliance with the policy in the period since 1991 has been good, with 14 out of the 19 island systems now satisfactory (Table 4) with eighteen months of the implementation period still to run. Table 4 shows the status of sewage plants on the island resorts and communities at present.

Table 4. Status of Island Sewage Systems.

Operation	System at Jan, 1991	System at Jun, 1994
Lizard Island Resort	Septic	Secondary/Land Irrigation
Green Island	Primary Treatment	Tertiary Treatment
Dunk Island	Secondary Treatment	Irrigation system being installed
Bedarra Bay Resort	Secondary Treatment, marine outfall	Secondary Treatment land irrigation
Hitchinbrook Island Resort	Secondary Treatment, land irrigation	Secondary Treatment land irrigation
Orpheus Island Resort	Septic	Septic
Nelly Bay Community	Secondary Treatment, land irrigation	No change
Hayman Island Resort	Secondary Treatment, land irrigation	No change
Hook Island Resort	Septic with discharge	Unsatisfactory Septic
Daydream Island Resort	Secondary Treatment, marine outfall	Partial tertiary treat, land irrigation
South Molle Resort	Secondary treatment, marine outfall	Partial tertiary treat, marine outfall
Radisson Long Island Resort	Partial tertiary treatment, land irrigation.	No change
Hamilton Island Resort	Secondary treatment, marine outfall	Secondary treatment 40% land irrigation
Lindeman Island Resort	Secondary treatment, marine outfall	Tertiary treatment land irrigation
Brampton Island Resort	Secondary treatment, land irrigation	No change
Great Keppel Island Resort	Secondary treatment, marine outfall	No change
Wappaburra Resort	Septic	Secondary treatment land irrigation
Heron Island Resort	Secondary treatment, subsoil injection	No change
Lady Elliot Island Resort	Secondary treatment, land disposal	No change

MANAGEMENT OF COASTAL CITY SEWAGE DISCHARGES

All the large Queensland coastal cities adjacent to the GBR: Cairns, Townsville, Mackay, Rockhampton, Gladstone and Bundaberg, as well as the smaller centres such as Innisfail and Ingham have secondary treatment sewage systems. These have outfalls into coastal streams or the ocean with some using a part of the effluent for land irrigation. Discharge from the plants is regulated under the Queensland Clean Waters Act by the Department of Environment and Heritage (Moss and Bennett, 1991). Standards for discharge are for secondary effluent as regulated under the Act with the principal requirements being Biological Oxygen Demand <20 mg/l and Suspended Solids <30 mg/l. Problems have resulted from a number of these discharges, particularly in dry season conditions, where discharge into a stream may constitute the total stream flow. With no dilution under these conditions algal blooms and anoxia result. The problems of Trinity Inlet and potential problems in Cleveland Bay have already been described.

While not having an enforceable policy on sewage discharges in these areas outside of its direct jurisdiction GBRMPA has an unwritten policy to encourage municipal authorities to minimize discharge of sewage effluent to the ocean or to streams which drain into the ocean. The Authority thus encourages the maximum reuse of effluents for irrigation on golf courses, cropping and pasture lands and public parks and gardens. As the Queensland Government now also encourages such reuse of effluents the joint approach is increasingly successful. Many local government agencies now have policies to maximise reuse of effluents and some have already ceased ocean discharge. Examples include Mulgrave Shire (near Cairns) where effluent from the large Smithfield plant is used to irrigate the Paradise Palms Golf Course; Townsville City where over 50% of effluent is used for irrigation on golf courses and beef pasture land and plans are in place to increase this proportion; Thuringowa City (near Townsville) where a large proportion of effluent is already used for irrigation on golf courses and a policy has been adopted to move to reusing all effluent; and Yeppoon (Livingstone Shire near Rockhampton) where a marine outfall has been removed and all effluent is used for golf course irrigation.

CONCLUSIONS

Effective methods are now available to remove nutrients from sewage discharges either in the sewage treatment plant, by wetland processing or by use of the effluent for irrigation. The increasing use of these methods in the GBR region, encouraged by management action and policy guidelines, should ensure that coastal eutrophication caused by sewage nutrient discharge is no longer a problem.

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INTEGRATING SCIENCE AND POLICY: THE OREGON TERRITORIAL SEA PLAN AS A CASE STUDY

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ABSTRACT

A key issue in the management and conservation of marine resources is the integration of ecological knowledge and policy. Too often policy does not incorporate new advances in ecological thinking. Past policies that have ignored biological reality, have often resulted in conflict, or been unsuccessful (eg. Endangered Species issues). The Oregon Territorial Sea Plan is a unique approach to managing Oregon's coastal resources. The development of the plan involved a partnership among research scientists, agency personnel and local groups. The central focus of the plan was firmly biological, and management actions were designed to fit within the framework of ecological information. Previous natural resource policy has focused regulation at the level of an individual species, site, and by individual agencies. By contrast, the Territorial Sea Plan is designed as an adaptive, ecosystem-based management strategy. This paper describes the integration of key biological and policy processes in the development of natural resource policy. This partnership and adaptive framework is suggested as a model for future approaches to resource management.

INTRODUCTION

An important issue in conserving and managing natural resources is the integration of biological knowledge into resource policy and law. Too often policies fail to reflect ecological complexity, and to incorporate new advances in biology. The aim of most environmental policies and laws is to protect diversity. However, policy and legislation usually target single populations, species, or small areas. In addition a single agency will often implement a policy in isolation from other agencies. This is despite our understanding that species and communities are woven together in an intricate interconnected web, over large areas (ie. complete ecosystems). Policies or activities that affect a single species can cascade throughout the ecosystem and result in changes in the abundance and distribution of other connected species. For example, loss of sea otters resulted in the decline of kelps and their associated species, and the development of an alternative community dominated by urchins and coraline algae (Duggins, 1980).

Maintaining diversity in natural communities requires an understanding of the processes that affect diversity, and the integration of those processes into management strategies. This type of approach needs the collaboration of research scientists (who understand ecological systems and the limitations of current knowledge), and policy makers (who recognize the frameworks necessary for implementing policy). Since local communities and interests are affected by natural resource policy, it is important to also include these groups in the development of natural resource policy. It is vital that representatives from all groups be included at the beginning of policy development. This will help to ensure that the focus remains on the natural resource, and on the processes that affect the persistence of that resource. It will also increase the probability that policy reflects biological reality, and that local interests both understand the reasoning behind policy and have a role in developing management strategies (See Brosnan *et al.*, 1994 for further details).

The Rocky Shore protection policy of the Oregon Territorial Sea Plan developed as a collaboration between science, management, and local concern. Key features of the plan were a focus on biological processes, and an integration of agency efforts to set policy. The result was a plan which uses an ecosystem process-based approach to management of natural resources, and which includes an adaptive component to take advantage of new information. This paper describes the key steps in the development and implementation of this strategy

BACKGROUND

Visitor impacts on marine coastal areas are increasing worldwide (see references in Brosnan *et al.*, 1994). In Oregon, increased migration to coastal areas, and development along the shoreline has resulted in more people using Oregon's rocky shore resources for recreational, educational, and harvesting purposes. The marine life on Pacific Northwest shores is highly diverse (Kozloff 1983). However, recent experimental studies showed that visitor impacts from trampling have serious negative effects on marine diversity (Brosnan 1993; Brosnan and Crumrine 1992a, 1992b, 1994; Grubba and Brosnan, *in press*). For example, trampling locally eliminated dominant plant and sessile animal species. Negative effects on an individual species can be reflected in changes throughout the community. For instance, mussels are easily removed by trampling: mussels provide a habitat for a diverse assemblage of over 300 associated species. Consequently the removal of mussels by trampling results is a significant loss in diversity. Furthermore, continued visitor use prevents recovery in these areas. At heavily used sites along the coast, diversity is low and many key species are rare or absent from the community (Brosnan and Crumrine 1992a, b). Normally these species are present in high abundance.

As a result of these studies, which indicated the nature and extent of the problem, and out of growing concern for conservation of marine resources, the State of Oregon decided to focus the first stage of the Oregon Territorial Sea Plan on protecting rocky shore communities. The Oregon Territorial Sea Plan continues the efforts of the State to protect coastal resources through the Oregon Ocean Policy Advisory Council. The plan is designed to protect natural resources from the high water mark to three nautical miles offshore. The plan is in a late stage of development (Oregon Ocean Policy Advisory Council (OOPAC) 1994). When adopted by Oregon State and US governments, all State and Federal agency activities will need to be consistent with the goals and policies of the plan.

Jurisdiction and responsibility for coastal resources

Many State and Federal laws govern the natural resources and activities on Oregon's coastline (Table 1). One result of these laws is that different State and Federal agencies have responsibility and jurisdiction for different resources (Table 1). For instance, the Oregon State Fish and Wildlife Laws created the legal framework for setting up the Oregon Department of Fish and Wildlife (ODFW). This department has authority to enact laws to protect marine wildlife, including setting harvesting limits, and defining reserve zones. In addition, the National Marine Fisheries Service administers the Marine Mammal Protection Act. Some agencies share responsibility for parts of the coast: The Oregon Parks and Recreation Department and the Division of State Lands co-manage the shore between Mean Low Water and Mean High Water. The overall result is a complex network of agencies with different mandates that govern particular areas and species. All these laws must be integrated into the Territorial Sea Plan.

Table 1. Summary of main State and Federal Laws governing coastal resources, and main agencies with jurisdiction over coastal resources and activities.

State Laws	Ocean Resources Law; Ocean Shores; Submerged Lands; Fish and Wildlife Laws; Kelp Leasing; State Threatened and Endangered Species; Water Quality
Federal Laws	Clean Water Act; Coastal Zone Management Act; Endangered Species Act; Fish and Wildlife Act; Magnusson Fisheries Act; Marine Mammal Protection; MARPOL; Marine Sanctuaries; Migratory Bird Conservation; Migratory Bird Treaty; National Environmental Policy Act; National Wildlife Refuge; Ocean Dumping Act; Rivers and Harbors; Submerged Lands; Wilderness Act; and others.
Main State and Federal Agencies with responsibility for coastal areas	**State:** Oregon Department of Fish and Wildlife; Department of Agriculture; Department of Land Conservation and Development; Division of State Lands; Parks and Recreation Department; Bureau of Land Management; Health Board.
	Federal: US Department of Fish and Wildlife; Department of Environmental Quality; Environmental Protection Agency; US Forest Service; National Marine Fisheries Service. US Coast Guard; Army Corps of Engineers.

DEVELOPING THE OREGON TERRITORIAL SEA PLAN

A first step in developing a plan to protect Oregon's Rocky Shores was to convene representatives from State and Federal Agencies (with jurisdiction over Coastal resources), academic marine scientists, and local groups (See OOPAC 1994 for complete list). A key issue that proved important in the plan's development was the involvement of research scientists at the beginning stages. The role of these scientists was in maintaining a scientific focus, and integrating knowledge on ecological processes into a management plan. Ecological research has been ongoing on the Oregon shore and in the Pacific Northwest region since the 1940s, and there is considerable information on key ecological processes, and on the biology of individual species. This scientific knowledge subsequently formed the basis of a management plan.

Initial development of the plan focused on defining a set of goals, objectives and policies (Table 2). The goal, to protect biodiversity and allow for appropriate use, represents a recognition of the need to integrate human activities into conservation efforts. The techniques, as outlined in the objectives and policies (Table 2) emphasize the focus on maintaining natural resources (ie., a biological focus), and acknowledge that interpretation and public education are key factors in maintaining natural resources.

AN ECOSYSTEM FOCUS

In the past, natural resource management was orientated towards individual species, particular sites, and was carried out independently by individual agencies. Little attention was given to the wider biological communities, or the processes that maintain them. For instance, the overall effect on marine diversity of increasing the harvesting limits on a single species was rarely considered. If the goal of policy is to maintain diversity, then successful implementation of this policy requires an understanding of the processes that regulate diversity. These processes include, for example, predation (Paine 1966, 1980), disturbance and succession (Connell and Slatyer 1977; Connell 1978; Sousa 1979; Paine and Levin 1981; Farrell 1989, 1991). The Rocky Shore component of the Oregon Territorial Sea Plan was unique in recognizing that ecological process bind populations and communities together, and that factors that affect one shore can also cause changes in other areas of the coast. This ecosystem-based approach was adopted as the framework for the plan. There was also recognition that the boundaries of this ecosystem extended beyond the Oregon boundary. The coast of the Pacific Northwest effectively forms a large marine ecosystem. Therefore, one of the objectives of the plan is to carry-out co-operative programs with other States and agencies at appropriately large scales.

Table 2. Summary of main goals, objectives and policies of Oregon Territorial Sea Plan for Rocky Shores.

Overall Goal	Protect the ecological values, and coastal biodiversity within and among Oregon's rocky shores, while allowing for appropriate use.
Objectives	Develop a management plan that allows for enjoyment and protects from overuse. Enhance appreciation and stewardship through interpretation and education. Maintain, enhance, or restore habitats and biological communities. Foster co-operation among all groups to ensure protection of the resource.
Policies	Encourage appropriate visitor behaviors Use agreements, permits, and regulation to control harvesting and collecting. Education and interpretation are the preferre techniques to promote stewardship. Work in partnership with Coastal Indian Tribes, and recognize existing agreements. Recognize that management technique will differ between coastal and offshore regions.

MEETING THE GOALS OF ECOSYSTEM MANAGEMENT

An ecosystem management approach incorporates the ecological processes and scales needed to maintain natural communities. Four key elements need to be incorporated into this strategy (OOPAC, 1994):

- Maintain representatives of all native ecosystem types and successional stages.
- Maintain viable populations of all native species in natural abundance and distribution patterns.
- Maintain ecological and evolutionary processes.
- Incorporate short- and long-term changes.

Maintain representatives of all native ecosystem types and successional stages

This step requires that all native marine habitats and communities be identified, and that the processes that maintain these ecosystem types be maintained. An inventory of the coast helped to identify these ecosystem types and stages (see below).

Maintain viable populations of all native species in natural abundance and distribution patterns

Maintaining viable populations is essential. A sound ecosystem strategy can ensure that viable populations of all species are maintained. However, certain species are particularly vulnerable to extinction because of their biological characteristics, or because of past human practices (eg. harvesting eliminated, or reduced below viability some marine mammal populations). Therefore special attention needs to be focused on rare or threatened species, species with small populations or patchy distribution, species with sporadic recruitment (eg. urchins), or poor dispersal mechanisms (Behrens-Yamada, 1989).

Maintain ecological and evolutionary processes

A unique factor in ecosystem management is its focus on biological processes. Ecosystem management must allow processes to occur at natural levels and variability. These processes include natural disturbance and recovery (succession); dispersal and recruitment; biological interactions (including predation and competition); effects of keystone species; physiological responses and evolutionary change. All of these factors help to regulate diversity patterns. The relative importance of each factor varies spatially and temporally (eg. keystone species effects can vary among Oregon shores, (Menge *et al.,* 1994)). Thus the goal is not to maintain static communities, but rather to incorporate the natural variability in community structure.

Human impact can interact with natural processes, and thus indirectly alter diversity patterns. For example, disturbance and succession are natural occurrences on Oregon's rocky shores, and play major roles in maintaining diversity. In winter, heavy wave action dislodges small patches (usually $<0.25m^2$) of mussels, creating areas of bare rock (Sousa 1979; Paine and Levin 1981). Mussels are dominant competitors for space on the shore, but are poor colonizers of bare space. Thus patches of bare rock are subsequently occupied by a successional sequence of different plant and animal communities before a late successional mussel-bed re-establishes. This process can take over 7 years. Early successional species are usually ephemeral, and depend on disturbance and the creation of new patches for their long-term persistence. Human trampling increases the rate of disturbance in mussel beds, by increasing the size of patches (often $>1m^2$). Furthermore, continued visitor trampling prevents succession, and maintains bare space (Brosnan and Crumrine 1994). The result is a significant loss in biological diversity. Human activities affect diversity by altering disturbance patterns. In the framework of ecosystem management, the goal of the Territorial Sea Plan is to maintain natural rates and patterns of disturbance (but not to maintain the same mussel bed in perpetuity).

Incorporate short- and long-term changes

Populations and communities are subject to change at all scales. For instance, El Nino Southern Oscillation (ESNO) events can temporally alter distribution and abundance patterns. These changes are natural, and resulting fluctuations in recruitment and abundance need to be accounted for in a management strategy. Thus sufficiently large areas must be maintained, so that populations and communities are resilient to temporary reductions in size, or structure. A major challenge for the Territorial Sea Plan will be to anticipate and incorporate long term changes (eg. climate changes). The adaptive component of the plan (see below) can help to ensure that these changes are included.

USING ECOSYSTEM MANAGEMENT ON SHORE COMMUNITIES

Successful implementation of an ecosystem approach requires the integration of four different components (Table 3). For instance, it is necessary to inventory habitats and biota to determine nature and extent of the resource. However, this information must be integrated with knowledge on the factors that maintain this resource, and current activities or threats to the resource. In addition, relevant spatial and temporal scales must be considered.

Table 3. Components of Ecosystem Management in Marine Areas

• Inventory habitats and populations. • Build up an understanding of the natural processes. • Monitor activities and concerns. • Integrate large-scale (and biologically relevant) co-operative programs.

PROGRESS

In 1993, the Oregon Department of Fish and Wildlife in co-operation with US Fish and Wildlife Service, and the Oregon Parks and Recreation Division conducted an aerial coastwide survey of habitats and biota. Teams of field biologists subsequently inventoried these sites. Data were collected on species composition, presence of threatened and endangered species, geological characteristics, upland facilities, current and future uses and concerns. This study resulted in a physical and biological profile of the entire Oregon coast. Each shore was then evaluated based on three criteria:

- site type (eg. any current reserve designation);
- environmental considerations (including size and diversity of intertidal habitat, mammal populations, conflicts in resource use) and
- current site use (eg. visitation levels, types of use (educational, recreational or scientific), sources of impact or concerns (eg. tramping, boating, harvesting)

Scientists reviewed these studies in light of ecological knowledge of rocky shore communities. This was based on research on the Oregon coast (eg. Castenholz, 1961; Frank, 1965, 1982; Cubit, 1984; D'Antonio, 1985; Turner, 1985; Farrell 1988, 1991; Brosnan and Crumrine, 1992a, 1992b, 1994; Brosnan, 1993; Menge *et al.*, 1993, 1994) and other Pacific Northwest sites (references above). The result of all these efforts was the development of four shore management categories: Habitat Refuge; Marine Garden; Research Reserve; and Marine Shore (Table 4). It is recommended that all shores be classified into one of these categories. Criteria for designation are based primarily on biological considerations. Management techniques are incorporated into the designation (eg. interpretation as a means of maintaining diversity).

At this stage of the plan, efforts are concentrated on designating sites into one of the four categories. Future efforts will focus on developing more detailed site management strategies for particular shores. These efforts are intended to be co-operative ventures which involve local communities, agencies, and scientific expertise. Plans will be subject to periodic review to evaluate success and incorporate new information.

Table 4. Summary of Shore Management Categories.

Category	Criteria for Designation	Management Actions
Habitat Refuge	• Unique or high biodiversity • Threatened and Endangered species present • Key Ecological Processes (eg. source populations)	• Limit Access. • No harvesting or collecting permitted
Marine Garden	• High diversity of intertidal and subtidal communities. • Focal Point for education and interpretation	• Develop interpretive programs (centers) • No collecting or harvesting permitted • Monitor for overuse and close areas if necessary
Research Reserve	• Key Ecological Processes • Ongoing Research Sites • Control Sites for study of impacts	• Restricted access • Scientific permits required for collecting
Marine Shore	• Low Diversity • Small Area • May be subject to frequent natural disturbances (eg. sand scour)	• Focus for recreational use • Collecting and harvesting by permit • Little or no on-site interpretation.

CONCLUSIONS

The Oregon Territorial Sea Plan for protecting rocky shores is unique in that it represents a partnership between science, management and community interests (Figure 1). Scientific knowledge formed the framework of the plan, and management actions were designed within this ecological framework. At the same time, the concerns and interests of the public and local conservation groups were incorporated in management goals. This type of partnership offers a viable approach to conserving large ecosystems without the need to polarize concerns and interests.

Partnerships in the Development of Natural Resource Management and Policy

Science----------------	*Resource Management and Policy*------------------	*Community*
Research	Resource Managers	Business Groups
Scientists	Agency Personnel	Conservation Groups
	Legislature	Community Leaders
	Natural Resource Lawyers	Traditional Users

Figure 1. A collaborative approach to natural resource policy and management.

ACKNOWLEDGMENTS

The author thanks Steven Courtney (SEI) for advice and comments, Daniel J. Rohlf (Northwestern School of Law) for information on legal statutes, Bob Bailey for co-ordinating the Rocky Shore Group, Jan Auyong, Dave Fox, Bob Malouf, members of the Rocky Shore Group, and the support of Oregon Sea Grant, and Sustainable Ecosystems Institute.

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THE DEVELOPING ROLE OF THE FISHERIES MANAGER; IMPLICATIONS FOR TRAINING

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ABSTRACT

Capture fisheries require management to ensure, biological, economic and environmental sustainability. This paper outlines the phases that the management of Australian fisheries have undergone, as fishing pressure has increased and stocks have declined. These phases consist of an early reliance on the control of inputs including vessels and gear, the application of output (catch) controls in the form of Individual Transferable Quotas (ITQ's), and the current trend towards co-management through Management Advisory Committees. Each phase of development has placed differing demands on fisheries managers. The skills and training required by today's fisheries managers are described, emphasising the needs of the fishers who increasingly have to make key decisions about the use of those fisheries resources within which they are participating.

INTRODUCTION

It has long been known that some form of management is essential for the sustainable exploitation of fisheries. Under open access, a fishery will become over-exploited due to the dissipation of economic rent by unregulated competition (Gordon, 1954). This will lead to reductions in catch rates and profitability as fishers increase their fishing effort in an attempt to secure their share of a dwindling resource. Traditional management measures to control effort may take many forms, from legislating for a particular mesh size for nets, to controlling virtually all inputs, including number of fishermen, size and number of vessels, and fishing gear.

Whilst in some developing nations the management of fisheries has occurred at village and community level without major Government intervention (McGoodwin, 1990), most coastal fisheries in OECD countries have involved federal (and state) government intervention, as is the case in Australia.

Fisheries management measures employed by Governments have met with varying degrees of success, for the most part doing little to arrest the decline in fisheries resources (McGoodwin, 1990). In 1992, a Government report within Australia (Anon., 1992) noted that despite approximately one eighth of the gross value of production of Commonwealth commercial fisheries ($20 million) being spent annually on their management, most were ....'overfished, and grossly overcapitalised'. Further, ... 'management has achieved neither of its two major objectives, sustainable use of the resource and economic efficiency within the commercial fishing industry'.

It would appear that the learning curve for fisheries managers is not steep, and within fisheries administration, a number of repetitive mistakes have been made. This calls into question the capacity of fisheries agencies to learn from experience (Hilborn, 1992). Fisheries management tragedies around the world may suggest the experience, abilities and knowledge base of those charged with making fishery management decisions is limited (Hilborn 1992). However there may be fundamental socio-political constraints on managers that prevent the proper decisions being made.

As fisheries management measures shift away from the largely unsuccessful attempts to regulate inputs towards controlling catches and the allocation of property rights, it could be argued that the traditional role of the federal and state fisheries manager will become somewhat easier. However there are still considerable challenges to face, not the least being the growing and often conflicting uses of the coastal zone, including recreational fishing, diving, shipping, marina development and aquaculture. The impact of land management practices on fish habitats must also be considered.

The definition of 'fisheries managers' *per se* has changed, and under emerging participatory schemes, they are increasingly becoming the fishers themselves. This raises complex issues of husbanding the resource, and the ability of traditional hunters (fishers) to display the required restraint to ensure the sustainable use of living marine resources. However the involvement of fishers in cooperative management will increase the understanding and stewardship of users.

This paper discusses the developing role of fisheries managers, the associated demands in terms of skills base, and concludes with a brief series of training strategies, designed to assist with the task of successfully managing Australian fisheries.

THE DEVELOPING ROLE OF THE FISHERIES MANAGER

From the time the impact of humans on the living resources of the oceans first became apparent, the management of fisheries has been largely reactive. As early as 1376 Charles III was petitioned concerning the use of a particular beam trawl in UK coastal waters; the petitioners claimed that it was damaging both fish stocks and the seabed (Butcher 1980)[1]. Modern regulations focus increasingly on regulating catches, which have been introduced in reaction to the apparent failure of input controls in some fisheries.

Early days; limited entry and associated regulations

Initially the goal of the fisheries manager was to maximise yields and ensure the health of the stock; a largely biological objective. Among the first management measures introduced in Australia was "limited entry licensing", which restricted new entrants into a fishery. Such measures have been a common feature of Australian fisheries since the 1960's. The emergence of limited entry regimes, combined with pre-existing biological measures, created a growing need for fisheries administrators and managers. Limited entry failed to adequately halt rising fishing effort, and the regulatory framework expanded with the introduction of additional regulations including vessel and gear restrictions, and seasonal closures.

Input regulations grew and became increasingly complex with the introduction of unitization schemes[2] designed to contain the expanding effort caused primarily by the introduction of new vessels and technology. Such fisheries included the South East Trawl and Northern Prawn fisheries. By the mid 1980's most Australian fisheries had gone from having no major management restrictions to complex input control regimes, all within a period of 20 years (Anon., 1989).

The staff of fisheries administrations changed to cope with these early developments. The initial response of most government systems was to consider fisheries management as another function of the fisheries research department. Familiarity with the habitat, biology and dynamics of fish populations were considered the main prerequisites for the early fishery manager or administrator. Through the 1960s and 1970s this remained the case with growing protests from economists that a more economic approach was required (Moloney and Pearce, 1979). It soon became apparent that the economic significance of

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1 The new trawl was accused of...' catching immature fish and of destroying the breeding grounds and spawn of various species' A claim not dissimilar to that made in Port Philip Bay in 1992, some three hundred years on.

2 A 'Unit' is a method of (somewhat arbitrarily) measuring the fishing power of a given vessel. It usually includes such factors as length, breadth, depth, hold capacity, and main engine horsepower.

allocating licences to a number of individuals and companies, was insufficiently understood, since they rapidly became capital assets transferring for large sums of money.

The goal of fisheries management was later updated to include economic factors, and maximising the economic yield became the new objective. By 1980 some fisheries departments had adopted various measures to increase economic returns by initiating buy back schemes in a number of fisheries. The main purpose of these schemes was to reduce the numbers of licenses and thus halt the overcapitalisation[3] becoming apparent under the input regimes.

The complexity of the new input regimes in the early 1980s led to a number of court challenges contesting the allocation of licences. The resulting legal proceedings required fisheries managers and administrators to have a broader understanding of the legal implications of fishery management. This widening of management associated tasks required staff to have an increasingly multi-disciplinary background. In the absence of these ideally trained people, many fisheries departments reviewed the management functions they were undertaking and created policy groups within fisheries departments. This was a structural response by fisheries departments to develop a wider skills base in management and coincided with management being separated from research in many fisheries departments, for example in Western and South Australia.

A new approach; the advent of output controls

Inspite of a number of regulations augmenting limited entry and the establishment of improved fisheries management groups, the problems in many fisheries appeared to be critical (Anon., 1989). It appeared to many that the input control regulatory framework was not addressing the problems in many fisheries, as predicted by a number of fisheries economists.

By the mid 1980s the first output control[4] fishery was in place in Australia (Southern Bluefin Tuna). Limited entry regimes with transferability had established greater property right characteristics in licences and the adoption of Individual Transferable Quotas (ITQs) encouraged this process. Since the early 1990s fisheries departments in Australia have been wrestling with the failure of input controls in several major fisheries and have examined the move to ITQs and fuller property rights as a means of management. The most recent example of the implementation of a comprehensive output control policy is that announced for New South Wales fisheries (Anon., 1994). This switch to output (catch) controls has required staff to adjust to a new mode of management and has led to a different style of fisheries enforcement and prosecution to prevent under-reporting of catches and other breaches of regulations.

Integrated fisheries management; development of wider responsibilities under Management Advisory Committees

Through the 1980's there were several other significant issues in fisheries management. The "user pays" principle stated that in Commonwealth managed fisheries the management costs would be borne by the fishing industry. Thus the industry wished to have a greater say in the management of fisheries and the administrative structure was reorganised at the federal level to form the Australian Fisheries Management Authority. States were also beginning to evolve a more participatory approach to fisheries management, focussing on 'stakeholders' in the fishery, and encouraging input from all sectors including recreational fishers.

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[3] Overcapitalisation refers to the tendency for fishers to increase their efficiency to a point where the same (or greater) total catch could be taken by fewer vessels.

[4] King (In press), defines output controls as those that place 'Limitations on the weight of the catch (quota), or the allowable size, sex or reproductive condition of the individuals in the catch'.

Another major change in the early 1990's was the emergence of wider issues such as Ecologically Sustainable Development (ESD), Coastal Zone Management (CZM), and non commercial user groups such as recreational and traditional fishers. Most of these groups wished to alter the resource allocation process. This required managers to move from a bilateral view of fisheries management systems involving fishers and government, to one dealing with wider community issues. Thus the command and control mode of the regulatory framework had to alter towards more communicative fisheries management, incorporating greater consultation in the decision making process. Fisheries management is less advanced than other natural resource management areas in this respect.

It is not clear to what extent the larger agendas of ESD and CZM may influence the future structure of fishery management. Their effect may be legislative, with moratoria being proclaimed in some fisheries due to over-exploitation reaching critical level. The 1994 decision by the International Whaling Commission to effectively ban all Antarctic whaling provides an example of growing community interest in fisheries management issues. Incidental catches of turtles, dolphins and dugongs also place intense pressure on fisheries managers, who are often forced to make decisions based on a desire to avoid criticism from environmental groups.

More recent national trends in the management of the commercial fishing industry are towards Management Advisory Committees (MACs) as a mechanism to manage fisheries on a wider basis. MACs are effectively management forums where professional managers assume a watchdog and advisory role as other stakeholders including both professional and recreational fishers seek to devise more effective management measures. As their name suggests, MACs provide advice to the Minister (or federal statutory authority in the case of Australian Commonwealth fisheries), who also receive independent advice from departmental managers. This suggests fisheries management training will be needed by a wider range of people in the future. The Fisheries Act 1991 requires each Commonwealth fishery to have a management plan, to promote continuity in spite of changes in MAC membership.

The powers of each MAC group differs between the Commonwealth and the states, but one of the central issues is a reduction in the role of the professional fisheries manager as a policy guide. The question arising from this is whether or not managers have the right to veto MAC policy proposals that they consider detrimental to the fishery. The capacity exists for considerable conflict within the MAC group, illustrating the need for training in mediation and conflict resolution skills. Further, new industry participants in the management process will require training in the fundamentals of resource management, if they are to enter an informed debate on issues regarding quota levels and other regulations.

In December 1993, a Senate Standing Committee (Anon., 1993) recommended that MACs be developed further into Management Committees which would '... assume the function of manager for the fishery; developing management plans, deciding local policy issues, and settling internal disputes'. If accepted, this would further reduce the role of Government in the management of fisheries, and place greater onus on the Committee members to provide effective and informed management decisions. This is also a trend in the management of other natural resources.

If fisheries management moves closer to allocating fuller property rights to fishers there is potential for more conflict in this process. Scott (1990) points out that fuller property rights for fishers will only eventuate if the administrators who design the system are prepared to let the free market work with a minimal amount of government interference. This step would put more management rights in the hands of the fishers. The only government input required would be in enforcement and in holding the right to intervene if the fishery exceeds quota and environmental baselines to the detriment of the long term viability of the fishery. It is argued that as shareholders in the resource, the fishers will see management as being to their long term benefit and quota holders would fund corporate management, research and stock enhancement through reseeding ventures (Scott 1989). This suggests that in the future some fishery management may be undertaken by private stock corporations where the manager uses 'long-run stock management' and tries to capture the economic benefits of 'joint harvesting activities'. The short term behaviour of some participants may be a significant problem.

DEFINING THE MODERN FISHERIES MANAGER

There is little doubt that today's fisheries manager is different to those of 20 years ago. Whilst it is still the Minister's prerogative to finally agree (or otherwise) to fisheries management regulations in state fisheries, this decision is likely to be based on advice from senior policy advisers. In the case of Commonwealth fisheries, much of the control of the Minister has been devolved to the Australian Fisheries Management Authority, partially as an attempt to depoliticise fisheries management. Increasingly Australian fisheries have seen a switch away from the biologist as manager towards the professional fisheries manager, frequently with an economics and policy making background. These government professionals are often members of management teams, and continue to be the primary force behind policy development in modern fisheries management.

A number of non-professional fisheries management groups are emerging under the new participatory schemes where fishers are increasingly participating in the management process. Eventually, groups of emancipated fishers may be represented by paid professionals, who take instructions from their clients, and wield considerable power, albeit indirectly.

Finally there exists a growing force in fisheries management from three other groups; recreational fishers, conservation and community interest groups, and traditional fishers. All three are set to assume an increasingly significant role in fisheries management, as the use of living marine resources is seen in a wider context.

THE ROLE AND OBJECTIVES OF THE MODERN FISHERIES MANAGER

In most cases, the government retains the "ownership" of the resource. However, the political life cycle is shorter than the period required to measure the long run effects of some management measures, and this may be a factor in determining objectives and making decisions. Hopefully, the professional manager as distinct from the politician, will be able to provide independent advice and management, with the objective of achieving pre-set objectives. These objectives most frequently include securing the biological integrity of the stock, and some declared 'optimum' yield of economic returns from the fishery. Another role will be as arbiter in the conflicting interests, of commercial, recreational and traditional users of the resource, although all of these users will frequently have their own representatives on management groups.

Fishers as managers of the resource can be expected to have objectives that maximise their own welfare, with varying regard for the resource and other users. Theory states that under the full and optimum allocation of property rights, fishers will become competent stewards of the resource in their own right, and as such will assume a more fundamental management role (Faloon, 1993). However, it is likely to take some time for such resource stewardship to develop, particularly if fishers only have a short-run involvement with the fishery.

The recreational fisher also has an increasing management role, and via an effective lobby is beginning to influence major decisions, particularly in estuarine and coastal fisheries. Their objective is to ensure the availability of the resource to recreational fishers and by implication, to ensure the biological integrity of the stock. It is worthy of note that the optimum economic valuation placed on a fishery by a recreational fisher may be significantly greater from than of a professional counterpart (Cunningham *et al.*, 1985).

TRAINING STRATEGIES FOR THE MODERN FISHERIES MANAGER

Professional fisheries managers

New entrants to the area of fisheries management should ideally have a multi-disciplinary fisheries education. Programs are offered by Southern Cross University, University of New England as part of natural resource management courses. The bachelors degree in Fisheries, at the Australian Maritime College provides a multi-disciplinary approach, and graduates now occupy a range of management posts in both state and federal fisheries. Frequently, fisheries managers in relatively senior positions have unrelated tertiary qualifications, and the necessary theoretical skills are picked up 'on the job'. To enable managers to fully enter the debate on alternative management strategies, a sound working knowledge of fisheries biology, economics, technology and sociology are essential to augment the usual legislative and administrative skills. Communication, conflict resolution and extension skills are also required to interact with resource users. Adaptive fisheries management techniques in particular will require additional skills in the evaluation of appropriate '.... responses to new information, or the deliberate manipulation of fishing pressure or other aspects in order to learn something of their effects' (King, In press).

Existing managers need to keep abreast of developments across a wide range of disciplines, and be fully aware of industry aims and requirements. Intensive in-service short courses, delivered by a range of fisheries management practitioners and educators with considerable recent experience, provide a useful and effective means of updating fisheries managers. Participants on such courses should be drawn from a range of state and federal fisheries, to maximise cross fertilisation of ideas and establish networks. Learning from past experience through case studies from both within Australia and overseas is essential.

Increasingly, there is a developing cadre of professional fisheries managers within Australia, and many of these are returning to tertiary studies to augment substantial working experience. A range of courses which enable practicing fisheries managers to obtain formal qualifications are now on offer, including courses from the Australian Maritime College and the University of Wollongong. Finally, there is the need for professional fisheries managers to maintain a perspective of reality, best achieved through regular interaction with fishers usually via port meetings.

Fishers

Providing fishers with an appropriate level of training to enable them to fulfil their increasingly pivotal role in fisheries management is of vital importance, particularly if the emerging concepts of co-management and the proposed management committees are to yield benefits. Such training must be tailored to ensure it is innovative, appropriate and interactive. Lack of academic qualifications in many instances, makes fishers suspicious of formal learning situations and the removal of these barriers must occur for effective learning to take place.

Use of case studies, lecturers with proven records of good fisheries management practice, and use of carefully selected workshop groups, are some of the strategies which should be employed. Respect for the considerable skills and working knowledge of fishers must be given during the training process, and capitalised on through planned participation. Involving fishers from a range of different fisheries on training courses should enable participants to realise that many of the problems facing fisheries managers (including access and allocation) are common. Working through a series of alternative management strategies, with the assistance of lecturers acting as advisers, has been a useful method of communication for fisheries managers, and may well have a useful application for the training of fishers. However, the definition of "good management" is often subjective, and a problem in appraising the effectiveness of such strategies.

Recreationalists/conservationists/community representatives

Responsibility for a resource as a community asset, will be shared with other user groups which are currently unlikely to have formal training of the types suggested for professional fisheries managers or fishers. These groups see fisheries in a wider context and are likely to have an interest in the marine ecosystem as a whole. Informal short courses that focus on inter-relationships between fisheries, the environment, and other uses of the coastal zone would be appropriate.

Field officers from state fisheries departments may be seen as having an 'on site' role in the fisheries management process. They require training in a number of aspects of fisheries management in order to appreciate the wider implications of their regulatory and monitoring activities, especially at the interface with fishers. Field officers working in Australia's expanding number of marine parks will also require an understanding of commercial fisheries.

The role of conservationists and other community interest groups is at present not well defined. Given the rise in community interest in the exploitation of living marine resources, both as target and by-catch species, it is likely that conservation groups will exert growing influence over the management process.

Indigenous fishers

Experience has shown that to be effective, any training of indigenous fishers must be carried out at community level, and take full account of traditional customs. Many management concepts including economic yield and quotas will be alien to traditional users and owners of the resource and where necessary, will require careful presentation. Little work has been carried out in Australia in this area, and if the current claims to traditional ownership of marine resources are successful, this training will become increasingly significant.

Finally, the Mabo decision has placed traditional fishers in a position where it is believed that they will become the ultimate managers of certain fisheries. Complexity and uncertainty cloud the issue at present, and it is not clear exactly how the Mabo decision will translate into returning coastal sea areas and the associated living resources back to their traditional users.

CONCLUSIONS

The recent stages of development in fisheries management require managers to be more flexible than in the early years when a single disciplinary training was adequate. As the failures resulting from an over-reliance on input controls in some fisheries became apparent, the subsequent move to ITQs required a change in management skills. The allocation of property rights in the form of quotas, and the subsequent readjustment of vessels and other inputs has revealed the need for managers to be able to appraise situations and anticipate outcomes in biological, economic and social terms. This suggests that multi-skilling is needed, augmented by the creation of specialist fisheries management teams that obtain synergism from a group approach. Increasingly sophisticated adaptive management strategies will require an ability by managers to devise policies that are readily able to adopt change.

In addition to developments within fisheries departments, the creation of MAC's has widened the group charged with managing fisheries, creating an opportunity for greater input by stakeholders into management decisions. These broader, communicative styles of resource management require substantially different skills. Conflict resolution and strategic planning, are key attributes for a fisheries manager.

Probably the largest and most rapid exposure to fisheries management skills is going to be needed by representatives from the fishing industry. As the industry takes more control over its future, it is apparent that they must gain resource management expertise by either enhanced training under current management arrangements, or by employing management skills should fuller property rights be forthcoming.

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COASTAL MARINE DEVELOPMENT IN KYONGGI BAY, KOREA

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ABSTRACT

With rapid increase of national economic growth many coastal development projects have been planned in Kyonggi Bay in order to accommodate the demands. The bay is quite close to the capital of Korea, and has many small bays and large tidal flats. Major projects are analyzed in detail through field measurements and numerical simulations for the prediction of environmental changes and ecological impacts due to coastal constructions. Types of coastal constructions are mostly dike construction, dredging of fine sediment for land fill etc. Such construction activities cause significant changes in the physical conditions of marine environments and generate much suspended sediments, which result in major adverse ecological impacts. Even though there is a regulatory permit of Environmental Impact Assessment for all development plans, the coastal zone of the bay becomes excessively exploited. A sharp conflict between the needs for immediate use of coastal resources and long-term supply of those resources, and thus an effective action is need. To solve this problem an Integrated Coastal Zone Management is recommended.

INTRODUCTION

Coastal zone attracts particular attention in Korea for the development of industrial complex, harbour and residential area, because it has large population within a small mountainous country. The demand for the development has grown rapidly with an increase of economic activities especially in Kyonggi Bay located on the eastern part of the Yellow Sea, where tidal range is large and thus tidal flat is well developed (Figure 1). The developing areas are close to Seoul, the capital of Korea.

Recently, many projects such as the New Seoul Metropolitan Airport at Youngjong Island (Figure 2) and Shiwha land reclamation have been planned and some of them are already under construction. Such large-scale coastal works of sea dike construction (Figure 3) and dredging related with the projects will certainly change marine environments and ecosystems. This is an inherent problem to minimize the conflict between development and conservation. As the coastal zone is directly related to offshore biological productivities, modification of the region will cause the decrease of productivities.

In this paper, various coastal development projects in Kyonggi Bay are discussed, and the subsequent environmental changes, possible effects and damages on marine ecosystem are analyzed through the studies based on the environmental assessments and impacts on fisheries due to those projects listed in Table 1.

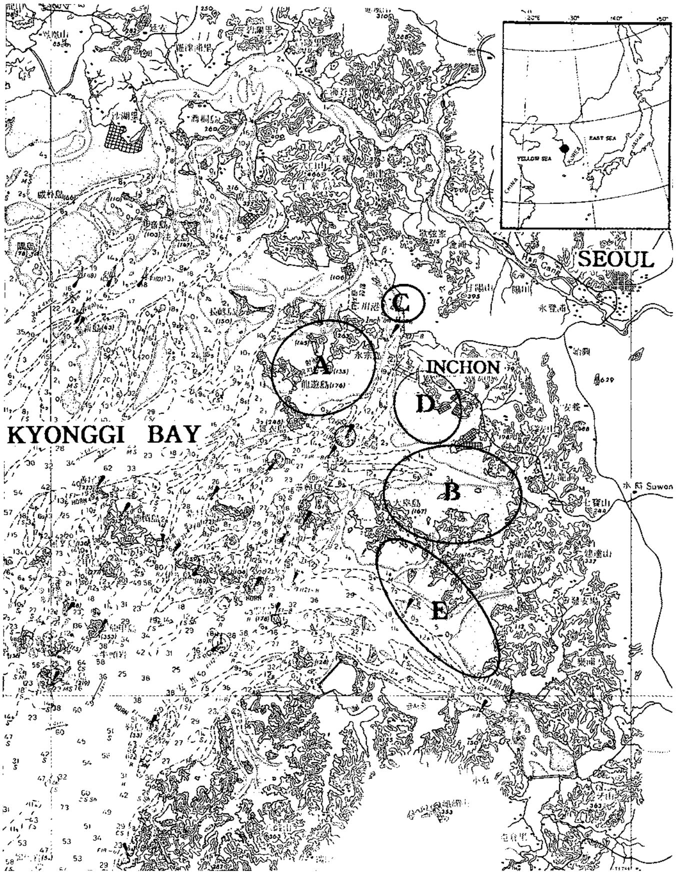

Figure 1. Map showing water depth, tidal flats, and major coastal development sites in Kyonggi Bay.

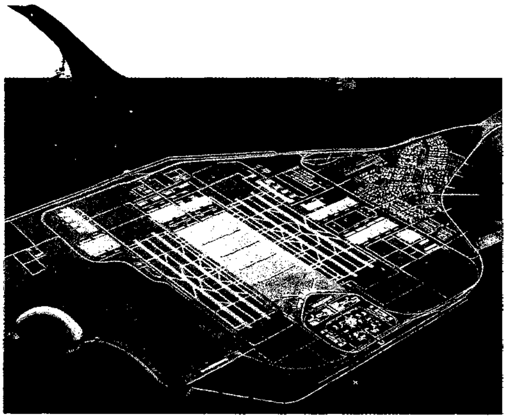

Figure 2. Bird eye's view of New Seoul Metropolitan Airport.

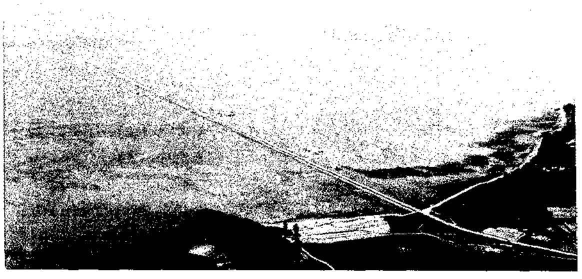

Figure 3. Dike constructed on a tidal flat in site A.

COASTAL DEVELOPMENT PROJECTS

Description of the study area

As shown in Figure 1, Kyonggi Bay is located in the west coast of the Korean peninsula. There are many small islands and bays including extensive areas of semi-diurnally flooded and dewatered tidal flats. Tides at Inchon harbour, the second largest one in Korea near the developing site A in Figure 1, have a range of 7.7m in spring tide and the maximum current speed is about 2 m/s in major channels. Most of the sediments deposited on the tidal flats were transported from the Han River during flood in summer, and consist of sandy silt and silty sand in the depth of 10m to 30m. By small islands and large tidal flats is the Bay area well sheltered from the waves generated in the Yellow Sea by strong north westerly winds in winter. There are many aquafarms spread over shallow water area especially in small bays.

Types of coastal projects and construction activities

Korean government has intension to decentralize population and manufacturing industries from Seoul in order to derive more balanced regional development (eg. the western coast regional development plan (Lee, 1993)). In the past decade, agricultural and industrial projects have generated most coastal constructions in the west coast. Recently, transportation (harbour and airport) and resort projects have become important economic force in Kyonggi Bay, because the bay is located near densely populated Seoul and also has good site conditions for construction works. By necessity, land reclamation and dike construction projects are located at small bays and tidal flats in the bay.

The major coastal projects are briefly described in Table 1 and the sites are shown in Figure 1. In site C, a long dike was constructed for land reclamation and now a new advanced city of teleport is in the stage of basic design. Major coastal works have been taken place on shallow tidal flats and at the mouth of the bay in the forms of rubble mound dike, dredging and landfill etc. Those are common coastal construction practices that are directly or potentially damaging to marine aquaculture and ecosystems.

Table 1. Coastal development projects in Kyonggi Bay.

Site	Name of Project	Construction Period	Area	Content	Reference
A	New Seoul Metropolitan Airport (Figures 2,3)	1992-2020	41.2 km^2	airport terminals intl. business centre airport community intl. free tradezone	MOT, 1991
B	Shiwha land reclamation	1990-2011	277.6 km^2	dikes agricultural field residential area	ADC, 1987
C	Seoul-Inchon canal	basic design	19.2 km	canal navigation lock	KWRC, 1993
D	Songdo New Marine City	1994-2006	39.6 km^2	residential area	Inchon City, 1993
E	Whaong land reclamation	1993-	119.4 km^2	dikes agricultural field	KORDI, 1993

PREDICTION OF ENVIRONMENTAL CHANGES

Model description

A two-dimensional, depth-averaged, finite-difference model in the horizontal plane was used for the prediction of changes of tides, sediment transport, and pollutant diffusion due to the coastal construction works. The flow module was extended from the 2D model of Flather and Heaps (1975). Some details of the governing equations and numerical method can be found in KORDI (1987). Modelled area covered beyond the boundaries where tidal conditions will not be changed after the large construction works and river flows. A part of the fine grid area shown in Figure 4 was used to simulate the changes of physical environments for the projects in the sites A, B, and C in Figure 1. Measured values of tides, currents, suspended and bottom sediments in the field were used for the boundary conditions and verification of the models.

Simulation of tides and sediment transports

The coarse grid model was used to simulate the tides and currents of the large area shown in Figure 1 in order to provide boundary conditions for the fine grid model. The time series of computed water surface elevations were then used as boundary value data at each grid point on the open boundaries of the fine grid model. Computed values of water surface elevation and current speed in a time series were compared with measured data at a point in the modelled area, and they are in an excellent agreement (KWRC, 1993).

Time histories of the surface elevations at points, p5 and p6 (Figure 4), are shown in Figure 5 for the simulation of coastal construction effects. As the difference in the tides and currents at p5 between the two conditions of before and after the Airport construction is very small, only two single curves of water surface elevation and current speed are shown in Figure 5(a). The dike and landfill with dredged material are located on tidal flats and hence do not obstruct flow in the deeper channels. At high tide, when the tidal flats are inundated, flow across these shallow areas is impeded.

The magnitude of tides at point p6 does not change when the bay in the site B is closed, but the phase becomes faster than the present by 25 minutes and significant changes of the current speed and direction occur. This is mainly because the volume of tidal flow through the bay mouth is considerably large.

For the site E, another fine grid model was used to predict the changes of flows, suspended sediment concentration, bottom topography, and COD concentration after the construction of the dikes and land reclamation of five sub-areas as shown in Figure 6. An example of computed vector plot of tidal currents for the area around site F is shown in Figure 6, and the currents appear to flow mainly in deeper channels.

ENVIRONMENTAL CONSEQUENCES OF COASTAL CONSTRUCTION

Physical short-term effects of dredging and land filling

Mechanical dredging and land filling during construction physically disturb or remove the bottom substrate, deposit on the substrate, suspend sediment in the water column, reduce light penetration, increase turbidity, change circulation, reduce dissolved oxygen, and increase nutrient levels in the water column (see Bak, 1978 and Maragos, 1991). The most widely spread and visible effects of dredging and land filling for dike construction are the generation of suspended sediments and turbidity, and changes of circulation as mentioned before. Dredged materials high in organics can theoretically generate BOD and depress oxygen level. In general, the dredging of fine sediments in the site A generates greater levels of turbidity and suspended sediments. The magnitude of the physical effects varies considerably depending on the types of dredging and land filling methods.

Direct ecological effects of coastal construction

An unavoidable impact of the dredging operation is the direct elimination of benthic habitat in the dredged area and reduction of associated demersal species (Bak 1978). Suspended sediments generated during the construction and also significant changes of water circulation can have serious effects on seaweed farming which is wide spread in the study areas (sites A and E). An example of the effects of current speed changes on marine aquafarms is shown in Figure 7 (site E), where water flows in two major-deeper channels divided by tidal flats. Dike construction at the mouth of the estuarine bays (sites B and E) blocks water circulation, migratory pathway in the bay and also nutrient supply. This can have substantial effects to valuable aquatic habitats or degrade water quality by sewage discharge from industrial complex (site B). Strong changes of flow generate erosion or deposition of sediments, which may in turn cause damages to shellfish ground in the study area.

The potential synergic effects of combination of water pollution (such as sewage discharge and oil spill during construction) and sedimentation stress on marine ecosystem.

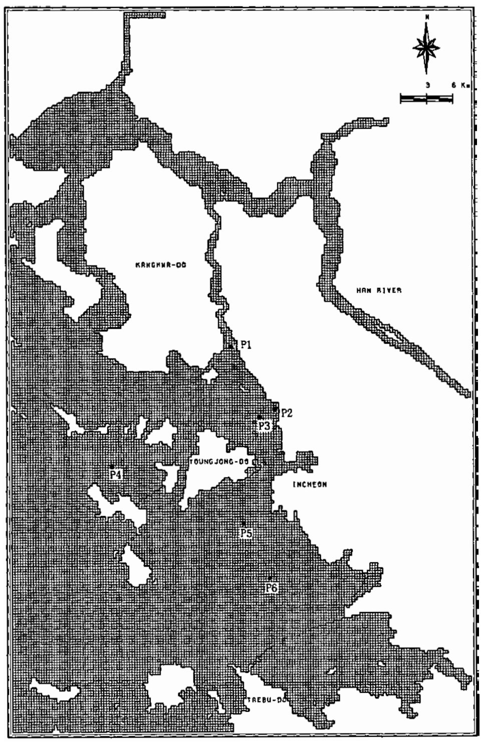

Figure 4. Fine-grids for numerical simulation of environmental conditions and points to compare the changes of tides and currents between before and after the construction.

The direct and indirect effects of the coastal constructions in the Kyonggi Bay will substantially reduce fish catches and aquafarm products.

In order to mitigate the suspended sediment impacts silt screens are effective measures of reducing the affected area during dredging and dike construction. An example of numerical simulations of suspended sediment concentration is shown in Figure 8 when silt protectors are used during dredging to provide fill materials into the Airport construction area (site A).

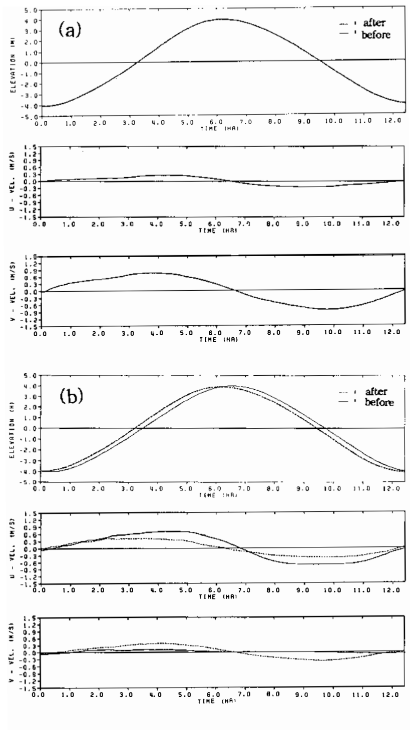

Figure 5. (a) Comparison of tide and current at p5 between before and after the Airport construction at site A with closure of Shiwa bay; (b) at p6 between before and after the construction of Shiwa tidal barrier.

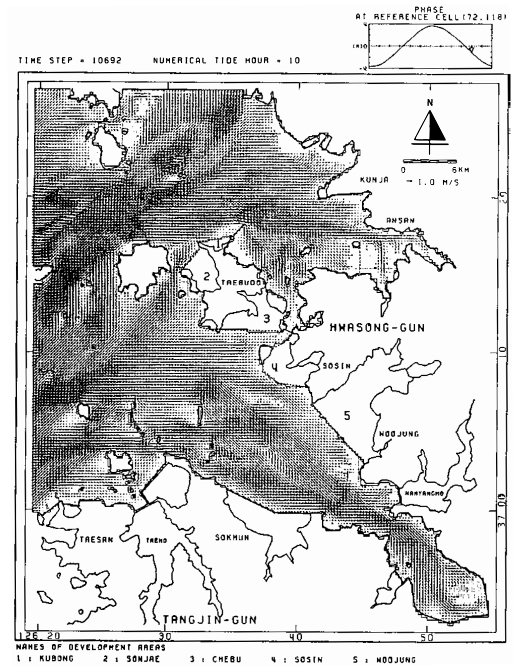

Figure 6. Computed maximum ebb-current distribution at a spring tide after Whaong land reclamation (site E).

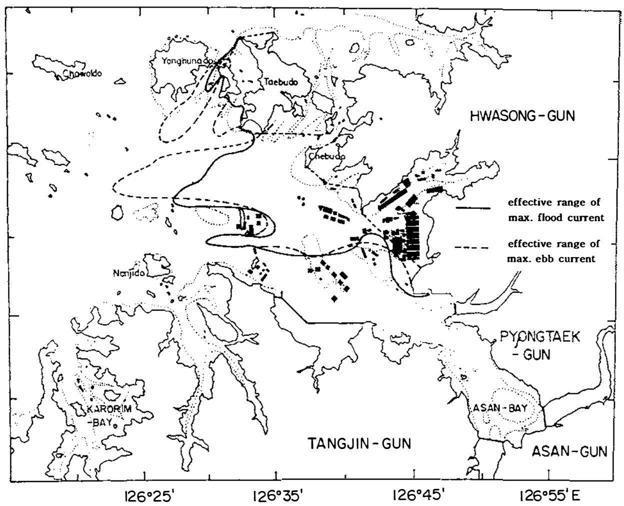

Figure 7. Effective ranges of current-speed changes on aquafarms around site E.

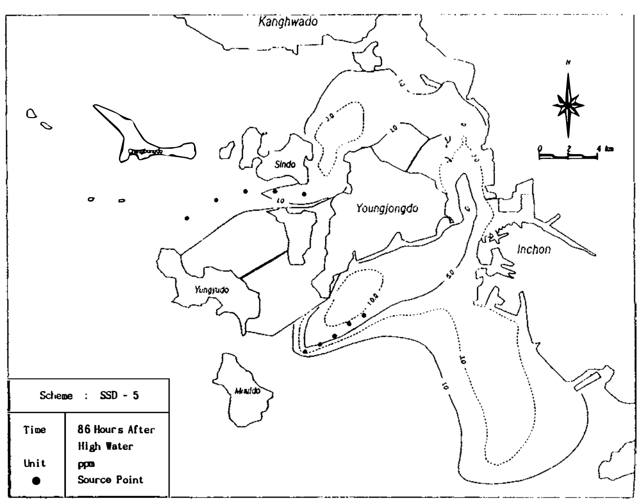

Figure 8. Increase of s.s. concentration due to dredging (with silt protector, MOT,1991).

CONCLUSION AND RECOMMENDATIONS

Coastal development activities have been increased in Kyonggi Bay which is located close to Seoul the capital of Korea, because the government decentralizes population from Seoul and encourages regional developments. The development projects include mostly land reclamation, dike and airport constructions on tidal flats and across the mouth of small bays. Extensive coastal developments are made in the bay under the Central or regional governments, which will cause over-development of the coastal zone and substantial impacts on the marine ecosystems.

Given the importance of the coastal areas in the Kyonggi Bay to the nation and regional society, managing their social and economic uses in a sustainable fashion should be a principle of government policy. With increasing population and economic growth, concern is growing in particular about the destruction of natural ecosystems of the Bay by the associated demands. It is the time to apply ICZM (Integrated Coastal Zone Management) to coastal marine developments in Kyonggi Bay. The ICZM tries to find the optimum balance between those uses based on a given set of objectives, which are restoring and maintaining the ecological integrity of coastal ecosystems and also maintaining important human values and uses associated with those resources. One of the comprehensive processes of ICZM, which may be applicable to Kyonggi bay, can be found in NRC report (1993).

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A MANAGEMENT INFORMATION SYSTEM FOR THE ASEAN-AUSTRALIA LCR DATABASE

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ABSTRACT

The ASEAN-Australia Living Coastal Resources (LCR) Project involved researchers from throughout Southeast Asia in a series of comprehensive surveys of tropical coastal ecosystems. Subsequently, the LCR Database was developed to provide an integrated system for assembling and storing the data obtained during these surveys. This database is currently being used as a basis for the development of a Coastal Zone Management Information System for the region.

The utility of any Management Information System (MIS) is ultimately dependant upon the quality of the underlying data. This paper reviews the major problems that have been encountered in the development of the LCR Database and discusses these problems in terms of the proposal to establish a MIS. Most of these problems are of a generic nature (for natural resource assessment databases) and therefore, the solutions which have been employed in developing the LCR database, will be suitable for general application in similar systems elsewhere.

INTRODUCTION

Throughout the world coastal resources represent one of our most valuable, and at the same time one of our most threatened, resources (El-Hinnawi, 1992). Effective management of these resources, which provides for their continued use whilst sustaining their functional integrity, remains a priority. Management of these resources requires that relevant information is made available and that this information is presented and interpreted appropriately. Two major problems exist with regard to accessing this information; firstly it is widely scattered both within and between countries and secondly mechanisms for integrating and displaying this information are not well developed (Bradbury, 1992).

In South East Asia, the ASEAN-Australia Living Coastal Resources project (LCR project) has been pivotal in establishing a mechanism for obtaining and analysing data concerning the status of coastal resources in the ASEAN region. Studies under this project have covered mangrove, seagrass and coral reef systems (including both the benthos and associated fisheries) and have provided information on what species are present, where they are located and what their current status is. Five countries, Singapore, Thailand, Indonesia, Malaysia and the Philippines have participated in the project which ran in two 5 year phases between 1985-1994.

The Living Coastal Resources (LCR) database and associated data management systems, were developed to support the field research programs (Licuanan *et al.*, 1989). The database comprises a series of data tables which provide a mechanism for integrating the data collected across the region (Table 1). Associated routines for summarising these data enable analysis at either the component or ecosystem level. Such routines may report, for example, the distribution and abundance of commercially important fisheries species across the region or provide information about individual sites or locations including a detailed inventory of the status of the ecosystems at these locations. An important feature of the LCR database is that the data have been collected over a 10 year time frame. This allows for detailed time-series analyses of the change in the status of these resources. Such information enables us to understand what is happening to resources; specifically, whether they are being degraded, whether they are stable or whether they are improving.

Table 1. The Living Coastal Resources database comprises data collected over 10 years (1985-1994) from a variety of different ecosystems in five ASEAN countries.

Ecosystem type	Data type	Number of data records	Number of locations
Coral reefs	Benthic lifeform	170,000	40
Coral reefs	Fisheries	50,000	40
Seagrasses	Vegetation	10,000	10
Seagrasses	Fisheries	2,000	10
Mangroves	Forestry	1,500	20
Mangroves	Fisheries	1,500	20
Soft-bottoms	Infauna	5,000	15

Whereas the development of the LCR database is a significant achievement in that it represents a successful model for a regional natural resource assessment database, there are still a number of problems to resolve before this approach can be universally adopted. A major difference exists between being able to establish a regional database and being able to use this database as a basis for the development of a regional Management Information System (MIS). The principal problem is in assuring the quality of the data.

In this paper we aim to provide an overview of future directions for the information technology component of the LCR project and to relate this to the needs of similar projects elsewhere. The problems associated with the regional integration of data are discussed in the context of the development of regional scale syntheses.

DEVELOPING A MANAGEMENT INFORMATION SYSTEM

The proposal to develop a Management Information System (MIS) from the LCR database evolved from the database management project. During the final 3 years of the project, as changes in computing technology and a better understanding of the needs of managers in the region developed, a conscious effort was made to revise the structure of the database in order to provide the basis for developing a MIS. These developments followed along the lines of those discussed by Bradbury (1992) who identified both the need for such a system and identified the major components (Table 2).

Table 2. Aspects of a Coastal Zone Management Information System (after Bradbury, 1992) and their relationship to the development of the LCR database. In developing such a system (Bradbury, 1992) suggests that the primary objectives should be to present information so that the individual researchers can see their specialised information in the context of the whole problem and so that decision makers can comprehend the whole problem free from the constraints of any one discipline. In order to achieve this there are six stages in the flow of information from acquisition of the raw data to visualisation of the final syntheses (Bradbury, 1992). The development of the LCR database has already resulted in significant progress in all these areas although clearly much remains to be done.

Management Information Sub-systems	**Current status of the LCR database system**
Acquisition	A system is in place for obtaining and updating research data as it is collected by field based groups.
Managing	A database structure has been designed and is being used to store the incoming data. Procedures are in place for the backup and validation of these data.
Accessing	Routines have been designed to summarise data and to extract subsets for analyses.
Integrating	Relational structures (Figure 1) provide for the cross-referencing of data tables and allow the introduction of data from other sources. This process needs to be augmented by explicit documentation of why the data were collected in order to clearly identify the nature of biases and potentially confounding influences associated with the data collection protocol (see below).
Enhancing	Analysis routines have been developed to provide summary information such as indices of reef health through the evaluation of standing stock, live coral cover and species diversity.
Visualising	Routines to provide graphical displays of data and integration with GIS systems (Figure 2) are being developed to assist in the development of interpretations. Much more work is needed in this area.

The original objective in developing the LCR database was to provide an information exchange network which facilitated the integration of baseline data on the status of representative coastal and continental shelf ecosystems (Dartnall and Jones, 1986). In order to achieve this objective the database was structured to ensure that it could provide basic information about a number of different aspects of these systems including:

1) A resource inventory comprising information on the distribution of major or important species and/or communities.
2) A library of assessment methodologies, data management, data analysis and interpretation routines which can be used to provide practical guides and monitoring protocols for inclusion in management programs.

Having incorporated these basic functions a great deal more has been achieved through the ongoing development of the database and associated programs. These developments include an ability to:

3) Integrate data from a variety of additional sources with appropriate references to geographic location and ecosystem type.
4) Produce reports on the status of ecosystems by providing indices of health and information on the distribution of important species. Important species may include economically valuable, ecologically significant or endangered species.

To fully realise the benefits of a Management Information System some aspects still need to be further developed, these include:

5) A system to provide predictions of ecosystem responses to intervention (through the use of formal models) against which management proposals can be tested.
6) A capacity to provide assessments of the quality of the data. This will provide the basis for identifying uncertainties and inferring the relative confidence that can be placed on results from analyses or predictions.

Figure 1. Logical structure of the LCR database illustrating the relationship of the various database tables in terms of the scale of information (ecosystem vs. component) that they contain. The central 3 columns (Sample information, Biological data and Taxonomic information) represent the primary tables defined in the LCR database. The remaining tables represent additional data included to support the development of the MIS.

Ecosystem level information			**Component level information**	
Environmental information	**Sample information**	**Biological data**	**Taxonomic information**	**Economic value**
What is the condition of the site at which the data were collected? - major impacts - existing management practices	Where and when were the data collected? - location latitude, longitude - date sampled	What taxa are present and in what quantity? - abundance or amount of given species	What are the taxa and how are they related? - systematic classification of species	What are the various taxa worth? - $ value of target species

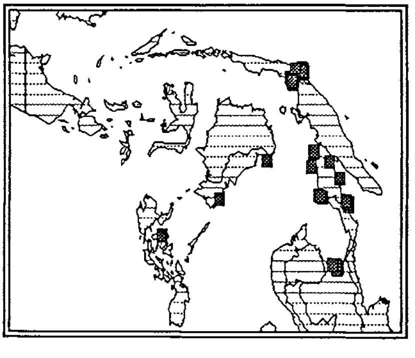

Figure 2. Extract from the PC-based GIS system (MapInfo®™) showing the locations of selected LCR coral reef study sites in South-East Asia. This plot was produced by taking information directly from the coral reef sample database and plotting it onto a commercially available digitised map.

PROBLEMS OF DATA QUALITY

In order to develop a MIS the underlying database needs to be error free. Problems of data quality cannot be underestimated as they propagate throughout all subsequent systems and ultimately determine the value of any Information System. In developing the LCR database a variety of data quality issues were encountered (Table 3) some of which had relatively simple causes and associated solutions. In the main however, the major problems arose due to differences in training and understanding between field based researchers who collected the data and the computing professionals charged with the task of managing the data.

Table 3. Summary of problems and recommended solutions

Type of problem	Source of problem	Solution
Data entry errors	Mis-keying, incorrect interpretation of methods.	Validation and reasonableness checks.
Integration errors	Methodological differences associated with the data collection.	Standardisation routines. Calibration of methods.
Internal bias	Differences in expertise or interest between groups.	Orthogonal designs or clear documentation of purpose.
Spatial resolution	Differences in perspective of geographical relationships.	Define standards in relation to definition of "locations".
Taxonomic inconsistencies	Differences in the sources and application of taxonomic information.	Standardised system for resolving taxonomic relationships and systems.

Data entry errors are the most common and there are many standard approaches to minimising errors from this source. These approaches include double entry of data or checks of computer entries against the original data sheets. Alternative approaches include defining criteria for validating data (ensuring logical consistency) and performing "reasonableness checks" upon the data as it is entered.

Reasonableness checks differ from checks of logical consistency in that they address the question of whether a given data value is reasonable "in the circumstances" as opposed to consistent given a set of hard and fast rules. This has proven to be an important distinction in dealing with biological systems which are highly variable and in which there needs to be some recognition that rules are often broken. Reasonableness checks highlight potential problems in the data where extreme or unlikely values are reported. The decision to accept or reject those values is then left to the researcher. Reasonableness criteria need to be defined a priori by the researchers and incorporated into the data management systems.

An example of the use of reasonableness checks for ensuring data quality was encountered in the analysis of the LCR coral reef fish database. On the first attempt to analyse this database it was found that only one third of data records could be utilised. The remaining two thirds of the data were considered to be in error for a variety of different reasons. One source of error was in the coding of data on fish abundances. In developing this database researchers were given two alternatives for coding data. The first used an actual count of the number of fish (of a given species) encountered on a sample transect; the other involved estimating the total abundance on a $\log^4$ scale. The latter alternative is used to address the problem of counting fish that school; in these cases abundances are categorised as 1-7 representing a situation where there were 1, <4, <16, <64, <256, <1024 or <4096 fish of a given species on a sample transect.

In compiling the data these alternative methods were, on occasions, clearly confused. Data records with a $\log_4$ abundance between 9 and 12 (indicating an actual count between 6.5×10^4 and 4.2×10^6) were clearly incorrect (especially as the species in question were sometimes known to be large and solitary). In general the correct interpretation of the data was that these figures represented an actual count which had been incorrectly coded as a $\log_4$ abundance value. Whereas a trained fish biologist would immediately recognise this as an error the computing professional developing a summary system for the database would not. After developing a series of reasonableness checks and addressing the taxonomic problems (see below) the error rate in this data set was reduced to less than 3%.

Problems with taxonomic databases

Natural resource assessment databases aim to gather together information on the status of ecosystems by integrating data on the distribution and abundance of indicator species or taxa. Such information is critical if we are to develop regional strategies to effectively manage the conservation and utilisation of these natural resources. Furthermore, they are crucial if we aim to quantify critical attributes of the ecosystems such as biodiversity, the degree of endemism, or the distribution and relative abundance of unique and endangered species.

The taxonomic database is a critical component of the Living Coastal Resources data management system in that it provides a basis for summarising data at both regional and local scales. The system also allows us to summarise the data at any given taxonomic level which is a fundamental requirement for regional scale analyses.

In compiling taxonomic data from field surveys a number of problems may arise which will confound attempts to summarise the data and extract relevant information (Cheshire, 1994b). Such problems are likely to be much more significant if the surveys cover a large geographical area (such as those undertaken as part of the LCR project). These problems can be summarised as follows (Cheshire, 1994b):

1) Inconsistent naming of taxa will lead to incorrect conclusions being drawn about major processes such as connectivity between ecosystems. Across the region a species may be given a variety of different names depending upon local conventions. Similarly, the same name may be used in different regions but applied to species which are in fact quite different.

2) Taxonomic revisions are constantly being undertaken and there is an ongoing need to incorporate such revisions into the database to ensure that information is up to date and of the best possible quality.

3) Human error is possible either during the initial identification of species or subsequently during the coding of the information into the database system.

The first problem arises principally because different areas across the region are likely to be surveyed by different people. Unless these people have a common background and access to similar resource information (such as published taxonomic reference texts) it is very unlikely that there will be an overall consistency, between locations, in the use of species names. These problems manifest themselves in a variety of ways. Typically, analysis of data collected during such regional surveys may give rise to quite erroneous conclusions about biogeographical processes, degrees of endemism and levels of biodiversity. For example, if the same species is given a different name in each of the areas surveyed this would result in the conclusion that each area has a unique species and that this contributes to the dissimilarity between areas. Conclusions about the exchange processes between these areas would reflect the "apparent" differences and estimates of biodiversity and endemism would be incorrect. Alternatively, conclusions about changes in communities through time may in fact be a reflection of revisions in the nomenclature and not to any real changes in the ecosystem.

In all cases the apparent differences are artefacts of the data management system. If not recognised as such they may result in changes to ecosystem management approaches or priorities which are, at best, not necessary and at worst are truly detrimental to the system under consideration.

Problems of bias

On the surface the LCR database would seem to provide a good basis for a MIS. Data have been collected across the entire region using standard methodologies and these data have been entered into a common system. Unfortunately, there are numerous other biases that manifest themselves in a database of this sort. Such biases arise because the data were collected for different purposes (even though the collection methodologies were identical).

In the LCR project collection biases can be seen in many of the data sets. Seagrass data, for example, have been collected in Thailand, Indonesia and the Philippines. To a large extent the methodologies used to collect the data are the same. The problems arise in the choice of sites. In Thailand sites have been chosen based on criteria such as the relative impact of coastal eutrophication or the impacts of various fishing methodologies. In Indonesia, sedimentation and coastal landfills are a major threat whereas in the Philippines factors such as the impact of effluent waters from mining operations have been the focus of studies.

Establishing a series of studies across the region, which focus on the range of problems and impacts on the systems, is a justifiable approach when resources to support the studies are limited. It causes a problem however, in that regional syntheses of these data are likely to be based upon a search for common indices by which to compare sites or locations. There is a significant chance that this process will lose sight of the fact that regional differences embodied in the database will reflect not only biogeographic trends (ie. real regional differences) but also the differences in the interests and concerns of the researchers. In the final analysis, the influence of "researcher interests" is likely to be more important in defining the results of regional scale analyses and consequently will mask any real "regional signals" in the data.

Recognition of these biases is critical if the database is to realise its full utility and therefore we need to include an explicit process of identifying and coding the purpose which underlies the collection of every data subset in the database. This will ensure that the data used in any subsequent comparisons are truly representative and comparable.

DISCUSSION

The overall objective of ecosystems management is to improve quality of life through the maintenance of a healthy living environment. In this respect the development of Management Information Systems will result in a number of benefits including the improved use of resources through sustainable development and the better management of ecosystems for the future.

Management of natural systems can be focussed in a number of different ways. In the broadest terms a distinction can be made between the management of an ecosystem or the management of the components. This distinction is particularly relevant when dealing with commercially significant, migratory or endangered species. Typically these species are either resident in any given system for only a short time or are so important in their own right that they demand direct and individualised management attention.

The LCR database is structured (Figure 1) so that information can be extracted using either of these broad themes allowing inquiries to be initiated at either the ecosystem or the component level. If, for example, there is a need for information on any taxa (or group of taxa) then the approach would be to enter via the component level and link across, via the abundance data, to find all of the locations where the taxa are found. Alternatively, it may be necessary to investigate specific locations. In this case the inquiry is initiated with the site information and summaries of the status of resources may then be developed. These summaries may include a variety of indices including information on the relative biomass or abundance of important species, the biodiversity of the site and the degree of commonality or connectivity between locations throughout the region.

Linkage of the existing biological data to external data sources such as those which provide data on demographics or environmental factors and impacts (inputs of toxins and pollutants or destructive fishing practices) will provide information on the response of these ecosystems to such pressures. Ultimately this information will be invaluable in determining approaches to correct these problems and should lead to improved management practices.

The distinction between ecosystem vs component level management is now a fundamental consideration in the ongoing development of the database. The embodiment of this structure within the database was initially directed towards facilitating the collation of information collected during field studies. There was little regard for the broader significance of this approach. However, through the linkage of additional information (to the site and taxonomic database tables) we are now able to address questions that go beyond the more circumscribed biological questions that the database was originally designed to address. As an example, the introduction of information on the economic value of given taxa would allow for an assessment of the value of given sites by cross-linking the relevant tables.

The inclusion of a geographic referencing system for all data (via naming of study locations and specification of the latitude and longitude) allows the information to be analysed in geographic terms. The data are easily incorporated directly into Geographic Information Systems (Figure 2) allowing for the application of a much broader suite of analytical approaches and subsequently more sophisticated interpretations.

CONCLUSION

The Living Coastal Resources database was developed to provide a common system for the storage and exchange of data during the LCR project. Subsequent development of this system has provided the basis for a much more sophisticated Management Information System. It is envisaged that with further development, particularly of the visualisation components, this system could evolve into a fully fledged Coastal Zone Management Information System which would provide significant support to managers and decision makers in the ASEAN region.

ACKNOWLEDGMENTS

The authors would like to thank all members of the LCR database management team for their much valued discussions in the development of this paper.

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NEW APPROACHES TO MANAGING TOURISM IMPACTS IN THE GREAT BARRIER REEF MARINE PARK

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ABSTRACT

Tourism is the largest industry in the Great Barrier Reef, and its value to the region is estimated at over A$1 billion per annum. There are currently around 500 tourist operations within the Marine Park. While a small proportion involve aircraft, most operations are vessel-based using vessels ranging in size from less than 10m to ocean-going cruise ships. In recent years there has been an increasing trend towards the use of permanently moored tourist facilities such as pontoons. The majority of tourist activities in the Marine Park are non-extractive although some involve fishing and collecting.

Within less than a decade there has been a tenfold increase in the number of permitted tourist operations in the Marine Park, and the industry continues to grow rapidly. The permit system remains a valuable and flexible tool for the assessment and management of impacts associated with tourist constructions and facilities, and those activities with potential for substantial environmental impact. However, it has become increasingly complex and even cumbersome in the context of managing the majority of tourist programs without associated structures.

Management of tourism impacts is now in the process of moving away from a system largely driven by permits, to one in which greater emphasis is placed on the use of Zoning Plans, Management Plans and Regulations combined with more user education and self-regulation. This approach has clear advantages in also providing better and more equitable control of impacts caused by private users, whose activities generally do not require permits.

TOURISM IN THE GREAT BARRIER REEF REGION

The Great Barrier Reef consists of some 2900 individual reefs including more than 70 fringing reefs. There are around 900 islands in the region; one third of these are coral cays, the majority however are continental islands many of them with fringing reefs. This magnificent system of reefs and islands provides a major tourist attraction nationally and internationally, and tourism has overtaken commercial fishing as the region's principal industry and is currently estimated to be worth about A$1 billion per annum. Tourism is now expanding at a rate of around 10% per year; during the 1980s growth rates as high as 30% per year were recorded in the Cairns region. Visitation to the reef is estimated to be 2.2 million people per annum, and is expected to double by the year 2000. The majority of visitors are carried by commercial tour operators. However, private recreational use is also increasing substantially, reflecting growth in coastal development and regional populations.

Tourism activities in the Great Barrier Reef Marine Park are predominantly nature-based, focusing on enjoying the natural beauty of the resource and settings. Most tourist activities are non-extractive and typically include (Kelleher and Dinesen, 1993):

- Viewing marine life from glass bottom boats, semi-submersibles, underwater observatories
- Snorkelling

- SCUBA diving
- Reefwalking
- Scenic cruises and flights
- Whale watching
- Sailing and windsurfing
- Motorised watersports such as waterski-ing and paraflying

Extractive activities include recreational fishing (eg. linefishing, spearfishing) and collecting (eg. for shells). Most of the activities are conducted in vessels ranging from small craft to high-speed multi-hulled vessels and large cruise ships, but a smaller number of visitors view the reef by aircraft. The impacts of tourism in the Marine Park have been discussed by Carey (1993) and by Kelleher and Dinesen (1993), and are likely to include:

- Anchor damage to coral
- Removal of mangroves and other natural features for tourism developments
- Land reclamation
- Excavation and dredging
- Effects of fixed and moored structures on corals, fish communities
- Recreational fishing and collecting
- Damage to coral from intensive diving and reefwalking
- Waste discharge and littering from vessels
- Effects of fish feeding on fish communities
- Amenity impacts, eg. displacement of 'low key' recreational use of sites (private and commercial) by more intensive tourism
- Cultural impacts particularly in relation to Aboriginal and Torres Strait Islander people

In general, much of the tourism use is concentrated in the areas near the major centres of Cairns and the Whitsunday Islands, and is located primarily in the more accessible sites and safe anchorages. While most tourist activities are considered relatively benign and do not pose a threat to the well-being of the reef ecosystem, increasing pressure on a limited number of reefs and associated islands underlines the need to maintain such locations in good condition and to ensure the quality of visitor experience is sustained.

Of much greater concern to management of the Great Barrier Reef are the more significant environmental impacts which may arise from the construction of tourism infrastructure such as marinas, and cumulative effects of coastal development (including clearing of mangroves) to meet growing demands of tourism and regional development generally. While many of these developments occur outside the World Heritage Area, a co-operative approach by various levels of government is essential to ensure effective environmental impact assessment and mitigation (Kelleher and Dinesen, 1993).

MANAGEMENT OF THE GREAT BARRIER REEF MARINE PARK

The Great Barrier Reef Marine Park was established by the Australian government in 1975. It is a multiple use Marine Park managed by the Great Barrier Reef Marine Park Authority. Day-to-day management of the Marine Park is carried out by the Queensland government (principally by the Department of Environment and Heritage), who are also responsible for management of adjacent island national parks and State marine park areas. The Authority's primary goal is to provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park. Since its inception, the park has been managed for conservation and wise use, consistent with the principles of what is currently known as Ecologically Sustainable Development.

Management tools include Zoning Plans; Management Plans at varying levels of detail; Regulations; Designated Areas (eg. Reef Appreciation Areas and Special Management Areas); permits; and education. These tools have been described in numerous publications (eg. Craik, 1994). Zoning Plans take at least 2 - 3 years to develop with substantial public participation. To date they have focussed on zoning for varying levels of extractive use and protection, from general use through to preservation (no access) zones. The recently updated Cairns Section Zoning Plan also includes a No Structure Subzone with a view to providing for and keeping some areas free from permanently sited structures and facilities. Zoning Plans also specify which activities require permits; these include tourist facilities and operations.

The Great Barrier Reef World Heritage Area Strategic Plan is a 25 year plan developed by joint decision-makers and all interested parties and users. It sets a long term vision for the World Heritage Area and identifies how that vision might be achieved.

Management Plans have been developed for individual reefs or larger groups of reefs. The Whitsunday Region and Cairns Offshore are two areas for which tourism pressure needs careful consideration in the management plans currently being developed. Such Management Plans are jointly developed with the Queensland Department of Environment and Heritage, and because of the level of public and stakeholder consultation required take almost as long to prepare as Zoning Plans. The kinds of prescriptions contained in Management Plans include provision for no anchoring areas, limits on levels of use, and siting of infrastructure and facilities. To date, the number of Management Plans which have been formally completed and adopted is limited. Management of tourism impacts has relied substantially on the permit system, either in the absence of completed Management Plans, or indeed to implement the provisions of Management Plans as they apply to activities such as tourism operations which require permits.

Special Management Areas, to control fishing and collecting or anchoring, have been developed with public input to enhance protection and management of heavily used parts of reefs, or at individual bays.

Permits for tourism operations were introduced with zoning of the first Section of the Great Barrier Reed Marine Park in 1981, and have remained a requirement ever since. Use of permits has allowed flexibility, since the impacts of tourist activities - initially considered to be not well understood - could be individually assessed and permit conditions developed to mitigate those impacts. Most Marine Park permits are joint permits covering use of Commonwealth (Federal) and adjacent State Marine Park areas; this arrangement promotes complementary management of areas under different jurisdiction.

Factors which must be considered when assessing permit applications are set out in the Regulations and include conservation, objectives of the zone, cultural and heritage values, likely impacts on future uses and amenity, and provisions to make good possible environmental damage (especially in relation to structures and constructions). Use of the Marine Park by Aboriginal and Torres Strait Islander people, and the question of native title to marine areas, have become increasingly important in the consideration of tourist permit applications, particularly for those involving permanently sited facilities or structures.

In the early 1980s, there were only a handful of tourist program permits, and the permits themselves consisted of a single page and few conditions. The zoning of the entire Great Barrier Reef Marine Park, the growth in tourism, and increased complexity in use especially at popular visitor destinations, have led to a huge increase both in the numbers of permits and in the length and complexity of the permit documents. This situation has developed not only for tourism program permits, but also for other types of permits such as research permits. The number of tourist program permits issued in 1993/94 was 319, compared with 156 in 1992/93, despite the fact that most tourist permits are now issued for a longer period (generally 6 years).

The escalation in numbers and complexity of permits has been of concern to the park management agencies and to applicants for a variety of reasons, including: time taken to assess permit applications;

increased demands on resources as permits workload continues to increase; duplication and delays associated with permits being jointly assessed by Federal and State agencies; difficulty in interpreting the meaning of permit restrictions; and inequities in conditions applying to different users, particularly in terms of constraints applying to commercial tourism operations (which require permits) and private recreational users (whose activities do not require permits).

Under the Great Barrier Reef Marine Park legislation and Australian administrative law, decisions regarding permit applications are subject to appeal. This means that if an applicant is refused a permit or is not satisfied with the conditions on the permit, he/she may apply to the Authority for a reconsideration of the permit decision. If the appellant is not satisfied there are further avenues of appeal, principally through the Administrative Appeals Tribunal, which can be a lengthy and costly process. In the past couple of years, there has been a huge increase in the number of appeals relating to decisions about permits for tourist programs. For example, in the past year the Authority received 12 formal applications for reconsideration regarding permit refusal or conditions, and there were two appeals to the Administrative Appeals Tribunal both of which were subsequently withdrawn.

The following factors have further contributed to the rise in the number of appeals and other problems with the permit system: insufficient resources being applied to development of formally endorsed policy regarding many permitted activities such as tourism and therefore over reliance on case-by-case decisions; a flexible approach regarding some of the restrictions placed on proponents resulting in some inconsistency in permit decisions; and the fact that Management Plans have not had a statutory basis and have largely relied on permits for their implementation.

REVIEW OF MARINE PARK PERMIT SYSTEM

During past few years it has become clear that the permit system in its current form is no longer an effective way of managing the impacts of the majority of tourism activities conducted within the Marine Park.

Some of the reasons for this have been discussed above, including the increasing number of appeals, and the growing complexity of permits (there has been a tendency to increase the constraints imposed through permits as a 'quick fix' to solving a variety of management problems). There have also been serious concerns that the permit system has imposed unnecessary inequities in the management tourism operations, as similar activities may be conducted by other park users such as private recreational users without the need for permits or the constraints commonly applied through permit conditions. Furthermore, Zoning Plans have generally provided very limited guidance for management and appropriate siting of tourism activities, and the number of area-specific Management Plans (addressing tourism issues) completed to date has been limited. While the numbers of tourist programs and permit applications continue to grow, resources for assessing and processing permits under the present system cannot be expected to increase accordingly. Stream-lining the permit assessment and administration procedures, while reducing the time and workload involved in issuing permits, cannot resolve many of the underlying problems. Alternative management approaches are necessary, such as statutory plans which are kept simple but address management of tourism and recreation impacts, and greater use of regulations to impose any necessary restrictions on all park users.

In late 1983 the Authority established a Working Group to review the permit system and recommend appropriate fundamental changes, focussing, as a priority, on tourist program permits. The Working Group consisted of a senior representative from the Great Barrier Reef Marine Park Authority, the Queensland Department of Environment and Heritage, the Queensland Department of Tourism Sport and Recreation and the Association of Marine Park Tourism Operators, with the Australian Littoral Society providing substantial input especially on conservation issues.

The Working Group's recommendations were accepted by the Authority and proposed actions endorsed as being of the highest priority. The Working Group proposed the following principles for management of tourism use:

- There should be greater emphasis on management of impacts and sites rather than regulation of users.
- Any necessary constraints on use should be applied, as far as possible, to all user groups.
- In general, management should ensure a high level of protection for sites of especially high conservation value, with minimal risks being accepted in their management. Access to most other sites should be largely unrestricted but subject to some general management provisions, monitoring of use levels, and monitoring of impacts at at least some sites.

In respect of the permits and management planning, the Working Group recommended that to maintain adequate protection for the Great Barrier Reef World Heritage Area, the permit system should be retained including thorough impact assessment procedures for constructions, structures, etc. with potential for significant impact. However, procedures should be clarified and streamlined wherever possible, and reflect the knowledge gained from previous experience. Permits should be retained as a means of granting permission to operate to particular sites. A very basic permit or licence system should be retained for other commercial tourist activities, on the grounds that some kind of permit is needed for control and for information-gathering/monitoring purposes.

The Working Group urged that for activities unlikely to cause significant environmental impacts, management should make greater use of statutory measures (Zoning Plans, Regulations, Management Plans), rather than the discretionary permit system. Restrictions should be kept to the minimum necessary to achieve management objectives. Consistent with Great Barrier Reef World Heritage Area Strategic Plan objectives to provide for ecologically sustainable use, the Authority should ensure that Zoning and Management Plans provide for a diversity of use opportunities appropriate to the area. However, detailed management arrangements should be confined to a small number of heavily used or sensitive sites.

The Working Group also stressed the need for more emphasis on tourist operator self-regulation and training and recommended that Codes of Practice, training and accreditation should be used to foster and acknowledge environmentally responsible behaviour by tourist operators. The Authority and the Queensland Department of Environment and Heritage should actively work with industry to develop those aspects of the Codes relating to Marine Park and island management. Restrictions applying through Codes should be presented in an attractive and easily understood form, and management agencies should foster the development of Codes of Practice for private users. In association with the Code of Practice training for operators (including trip managers and interpretive staff) should be phased in - such training is considered to greater self-regulation and of decreased reliance in the permits system.

FUTURE DIRECTIONS

Consistent with the Working Group's proposals, the Authority and the Queensland Department of Environment and Heritage are implementing short-term and long-term programs both to improve the existing permit system and to shift emphasis away from permits as the principal tool for management of most tourism activities. The same approach will also be applied to other activities, notably in the Marine Park.

As a matter of priority, substantial changes are being made to standardise and greatly simplify many of the tourist program permits. At the same time the Authority is working closely with the tourism industry to encourage greater self-regulation; and to jointly develop Codes of Practice to promote environmentally responsible use and behaviour. A training strategy and on-going training program are being drawn up.

The purpose is to ensure that all tourist operators and their staff understand key features of the reef and island ecosystem, and the purposes of management, particularly the rationale for Codes of Practice and those restrictions on use which may need to be applied.

At the same time, greater resources will be put into development of statutory Management Plans and Regulations. This will ensure that necessary constraints on use are applied equitably to all user groups and that such constraints are not imposed thorough a discretionary permit system. It is expected that for the majority of reef areas, Management Plans and Regulations will need to provide, in the simplest possible way, for the protection of the resource (eg. protecting coral from anchor damage) and for the requirements of a range of user groups, especially in respect of access to moorings and anchorages. More complex management arrangements (including booking systems), such as those for Green Island and Low Isles, are resource-intensive and realistically can only be implemented at a limited number of heavily used or sensitive sites.

Finally, whilst permits will in due course be reduced to simple licences for the majority of tourist operations, there remains a need to ensure that full environmental assessment and impact controls are in place for developments and activities with a real potential for significant environmental impacts. In this context, permits continue to provide a useful and flexible tool for protecting the environment while providing for reasonable use and appropriate development.

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MARINE TOURISM IN INDONESIA

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ABSTRACT

Tourism is a fast growing sector of the Indonesian economy. Overseas visitor numbers have risen rapidly in recent years. Domestic tourism is also increasing rapidly, although reliable data on participation rates are unavailable. These trends are expected to continue and may even accelerate during the next decade as a wider range of tourist destinations within Indonesia become more accessible and better known.

Not surprisingly, in view of the archipelagic nature of Indonesia, marine and coastal areas are a primary focus for tourism activity. For the purposes of this study, marine tourism was defined as all activities involving tourists in marine (ie. predominantly saltwater) environments. The study involved surveys of the 47 medium to large scale (>12 employees) marine tourism operations in Indonesia in 1993.

These operations are of considerable economic, social and environmental significance. They cater for >105 000 tourists (mainly inbound), employ more than 1000 staff and operate throughout the archipelago, although Bali is the primary node.

Operators report high growth rates and view the future with considerable optimism. They are concerned about environmental degradation caused by fisheries and industrial activities and recognise the need for careful planning if their own activities are to be sustainable. The survey results underpin the importance of planning, education/extension and co-ordination if marine tourism ventures are to be successful and sustainable.

INTRODUCTION

"Indonesia is the least known of the world's best dive locations. The introduction of SCUBA gear and the beginning of dive operations here is barely a decade old, and new locations are still being opened and explored, albeit slowly. It will be years before diving in Indonesia reaches its full potential..." (Muller, 1992).

The above quote emphasises the undoubted potential of dive tourism in Indonesia and, in many ways, could be regarded as indicative of the country's wider marine tourism potential. Indonesia has the world's longest tropical coastline (81,000 kms) and the third largest Exclusive Economic Zone (EEZ) (5.5 million square kilometres). The archipelago comprises more than 17,000 islands and has a sea to land ratio of 3:1. Not surprisingly, the archipelago is a global centre for biodiversity, containing more than 17% of all species in the world (Caldecott, 1992). Indonesia's marine biodiversity is particularly rich (McManus, 1992; Alder and Dutton, 1994).

The archipelago is home to more than 185 million people (the world's fourth most populous nation), although settlement is unevenly distributed between the major islands, with more than 60% residing on Java. Traditionally, Indonesians have a long history of marine resource exploitation (Sya'rani and Willoughby, 1986). Most marine resource exploitation activities are based in the shallow water, near coastal zone and primarily focus on fisheries, oil/gas and mineral resources. A 1987 BAPPENAS (National Planning Agency) study estimated that marine industries account for some 22% of total GNP and that tourism activities comprise about 23% of total economic activity in marine regions.

Tourism is now a rapidly growing force in the national economy with recent annual inbound growth rates of up to 20%. Most tourism activity is focused on Bali, Java and North Sumatra - these destinations account for 70% of visitor destinations (Anon., 1994). Information on domestic tourism numbers and sectoral distribution are, however, limited. In view of the diversity of tourism opportunities possible within marine areas of Indonesia, high rates of economic growth and growing recognition of the potential for tourism to contribute to conservation of marine biodiversity (Schoen and Djohani, 1992), it was considered timely to investigate the present status of marine tourism in Indonesia.

The following sections describe the findings of the first national survey of marine tourism operators in Indonesia. For the purposes of the survey a wider definition of marine tourism was adopted than that used in other, similar recent regional studies (eg. Lefroy, 1993). Marine tourism was defined simply as those activities undertaken by tourists in marine (predominantly saltwater) environments.

TOURISM IN INDONESIA

The Economic Intelligence Unit (EIU) (1991) considers Indonesia to be one of the "success stories" of international tourism in the past decade, despite the relatively modest (in global terms) total number of visitors (around 3.1 million in 1992-93). Inbound tourism growth rates peaked at around 20% per annum in the mid 1980s (the highest growth rate amongst ASEAN countries) and are still continuing strongly into the 1990s, with recent (1993-94) growth averaging 11% per annum (Anon., 1994). These growth rates are nearly four times the global rate and double the regional average. They represent a dramatic turn-around for a country which in the mid 1960s was experiencing negative tourism growth and had a base market of less than 15, 000 visitors (Francillon, 1979).

In a review of tourism in Southeast Asia, Hobson (1994) observes that, "not only have tourist arrivals increased rapidly, but more importantly, so have tourism receipts". The regional share of global tourism receipts has doubled from 8% in 1990 to 15.5% in 1992. A number of key factors have underpinned this growth, especially factors such as the large population base within the region (56% of the world's population), the high rate of regional economic growth (5.5% per annum as against 2.2% for the rest of the world), the easing of travel restrictions and finally a rapid increase in air traffic and related infrastructure.

This strong growth level is expected to continue for the rest of this decade at least (Euroconsult, 1988), although as Hobson (1994) observes, a number of factors could affect the capacity of major destinations such as Indonesia to absorb new growth. Notable amongst these are infrastructure, environmental resources and human resources. All three issues are of concern in Indonesia at present.

Despite significant investment in tourism infrastructure, an increasingly strategic approach to meeting future demand via development of Master Plans for key destination regions (eg. Rhenda, 1989) and industry sectors (eg. Euroconsult, 1988) and strong national government support for tourism development, many regions within the archipelago remain under-supplied with air transport, accommodation or ground travel infrastructure necessary to fully exploit potential opportunities. In locations where tourism development has been rapid, notably Bali and Lombok, environmental concerns are mounting (Kaweeka-Lee, 1992), mirroring the experience of much of coastal Asia (Dutton and Saenger, 1989; Wong, 1991). Finally, there are critical skills shortages in many hospitality and tourism management sectors and regions - these are often compounded by the lack of formal training opportunities (IDP, 1994)

MARINE TOURISM INDUSTRY SURVEY

Definition and limitations

Like most marine industries (eg. communication, transport, etc.) it is often difficult to delimit the boundaries of marine tourism - many marine-dependent activities are based primarily "on-shore" with only some elements of the operation (usually the resource dependent ones) occurring in marine areas. As noted earlier, for the purposes of this study, marine tourism was therefore defined as those activities undertaken by tourists in marine environments. This definition is somewhat restrictive, but enables the specific significance, extent and impacts of marine tourism to be isolated from the wider tourism industry. In practice, however, it must be emphasised that marine tourism is inextricably linked with the wider industry and can not be managed in isolation - the definition simply provides a convenient frame of reference for the purposes of an industry study.

Context and objectives

The Government of Indonesia is currently placing considerable strategic emphasis on development of marine resources and industries. One initiative in this context has been the development of a Marine Science Education Project (MSEP). This project (supported by the Asian Development Bank) is designed to "assist in achieving optimal utilisation of living marine resources in Indonesia under sustained yield conditions. This will be achieved by (1) helping to meet demand for professional and high-level marine science manpower through the establishment of comprehensive educational programs and (2) improving the national capability to manage the marine environment through a program of training and research" (Pasaribu and Kensler, 1991).

The MSEP initiative will accelerate the supply of marine science from around 70 per year in 1990 to 2600 per year in 1998. While most of these will work in easily identified industry sectors (eg. fisheries and aquaculture), it was considered important (for curriculum development purposes) to evaluate potential employment opportunities in fields such as marine tourism.

This study was thus designed to address two inter-related objectives:

(a) to ascertain the present status of marine tourism industries in Indonesia (no comprehensive research had previously been undertaken on this sector of the tourism industry); and

(b) to identify whether the MSEP could assist in meeting the human resources/training needs of marine tourism operations.

For the purposes of this paper, details relating to objective (b) are presented in general terms only.

SURVEY METHODS

Target selection

One of the major constraints faced by most national-scale studies of any tourism sector is the lack of information on operations. This problem was compounded in the context of this study by:

- the decentralised nature of marine tourism (information about remote areas is hard to obtain and communications between areas often difficult);

- the lack of a peak industry body (there are no national associations relevant to this sector specifically); and
- incomplete knowledge of the types of operations which may be classified as a marine tourism operation.

To overcome these constraints, MSEP staff liaised with government agencies, tours operators and NGOs and consulted travel directories, telephone books and tourist guides to identify candidate organisations for inclusion in the survey. In all, some 47 potentially relevant operators were identified - these were distributed throughout the archipelago, although most were based in Bali (22/47).

Survey instrument and sample

Because of the limited time and budget available to survey each operator, a mail back questionnaire was selected. This technique offers a number of advantages (low cost/unit, standardisation of variables, etc.), but also has a number of drawbacks, especially in relation to being able to pursue topics of specialised interest (Yegidis and Weinbach, 1991).

A draft of the questionnaire was translated into Bahasa Indonesian and tested with local tour operators and amongst University staff and students. The revised questionnaire was then distributed to the 47 operators with a reply-paid envelope. The questionnaire addressed 12 principal topics ranging from basic operational characteristics (eg. location, staff, age, etc.) to assessments of industry needs and observations on trends.

Survey response

Of the 47 questionnaires mailed out, 16 direct returns were received and advice received that two survey targets were no longer in business. A further return was received from an additional operator who was not on the original mailing list (targets were asked to identify any additional operators in their local area). The effective response rate was therefore 37% - a rate which is about average for this type of instrument, but which raises concern about potential bias due to non-response (Stinson and Beed, 1987).

As the information provided from the initial response proved adequate in the context of the survey objectives no follow up mail out was undertaken as was initially proposed. Completed returns were retranslated into English before processing of survey results, a process which is potentially fraught with difficulty, however, was aided by the input of expert translators - none of the returns posed any unresolvable translation problems.

SURVEY RESULTS

The following sections summarise the major findings of the survey. For reasons of brevity, only key findings are presented.

Distribution of operations

The majority of operations are based at a range of locations in Bali (47%), with other important bases in West Nusa Tengarra (Lombok and Sumbawa), Irian Jaya, East Nusa Tengarra (Timor - Flores) and West Java. Several operators (17%) base their operations throughout the archipelago.

Choice of destinations

Most respondents observed that their choice of destination reflected constraints such as climate, vessel capacity and cost rather than opportunity factors such as market preferences and lack of competition. In this respect, marine tourism seems to be supply led rather than demand driven.

Operational characteristics

Most operators surveyed are relative new comers to the industry - 53% have been established less than three years. Only 23% had been in business for more than seven years. The majority of operators had previously worked in a marine tourism business, usually in dive training or related businesses such as charter boats.

The operators surveyed employed an average of 21 staff per operator including two companies who employ 102 and 70 staff respectively. By discounting these larger employers, the average number of employees per operator declines to 12.5.

Overall employment in the industry was extrapolated from these results (by stratifying multipliers) and is believed to be around 1000 people. This figure does not include the many small businesses who were not included in the sample (and who typically employ <6 staff).

Nature of operations

Figure 1 outlines the range of activities undertaken by marine tourism operators. There is obviously some overlap between the types of services provided. For example, "Travel/transport" and "Cruising/Tours" - these are separable by factors such as length of trip and geographic focus of operations - "Cruising /Tours" are generally extended tours (>1 day).

Interestingly, as indicated in Figure 1, despite the predominance of dive operators in the sample, only 23% provide dive tourism services exclusively. Some 88% of operators, however, provide for SCUBA diving activities as part of their broader operations.

Other major activities provided (and aggregated within general categories in Figure 1) include snorkelling, boat charter/rental, fishing, parasailing, waterskiing, expeditions, nature tours and history studies. The majority of operations (40% are day trips or overnight), followed by 3 day trips (33%), extended trips (16%) and medium length trips (11%). The maximum trip length reported was 15 days for a cruise operation through the eastern archipelago.

New activities

Most (60%) of operators plan to introduce new types of recreation opportunities in the near future. While the majority of these are designed to match services provided by competitors, a quarter of all operators propose to introduce entirely new marine tourism activities such as:

- semi submersible and possibly fully submersible coral viewing vessels;
- surfing tours;
- fly diving (sea plane based);
- sea canoeing/kayaking tours;
- bareboat charters in the eastern islands; and
- regional guided yacht tours as part of an ASEAN-Australia network.

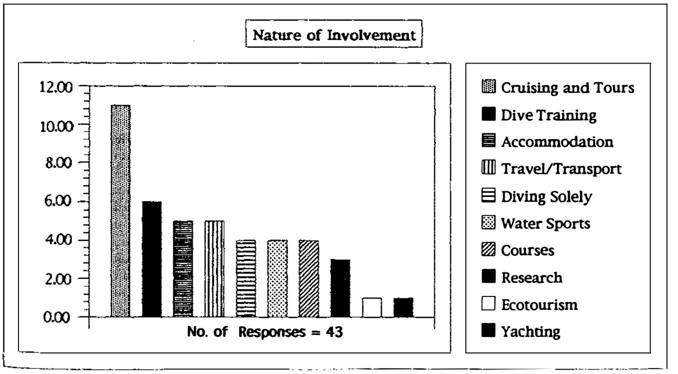

Figure 1. Activities provided by marine tourism operators

Tourist characteristics

Each operation caters for around 2100 tourists per year, although the actual numbers handled by each of the respondent operations varies enormously (from <150 year to >3500). Interestingly, one operator responded that "they never bother to count"!

Extrapolating the sample data to all marine operations yields a gross participation level of around 105,000 tourists per annum. As most of these are foreign tourists (see below), it is clear that marine tourism is a significant part of the overall national tourism industry, with more than 3% of all tourists specifically seeking out commercial marine tourism products.

Tourism trends

The majority of operators (60%) indicated that tourist numbers are increasing at rates of between 10 and 60% per annum. The highest rates of increase were reported for operations around Lombok and West Java. The two operators who reported a decline (of between 5 and 20% per annum) attributed this largely to the effects of increased competition in Bali (both with other marine tourism operations and land-based operations).

Tourist origins

The overwhelming majority of tourists (94%) engaged in commercial marine tourism operations are from overseas - the major source markets are (in order) the USA, Australia, Japan and Europe. Of the remainder, 3% are Indonesian nationals and 3% expatriates (foreigners resident in Indonesia). These data appear reasonably uniform for all operators, although an operator based in Irian Jaya noted that Indonesian residents comprised 20% of all clients.

There are no detailed data on domestic tourism trends in Indonesia, nor could any recent studies be located on leisure behaviour, however, several operators suggested that there has been a slight increase in domestic tourism participation in marine activities in recent years and believed that there was considerable potential to increase that part of the market.

Evaluation

More than 90% of operators undertake some type of evaluation of services provided - 60% by interview/informal feedback, 30% by questionnaire and 10% by a visitor log book. Respondents reported that the majority of clients are "satisfied" (60%) or highly satisfied" (40%) with their experience, however, in view of the 'double filtered' nature of these comments (tourist>operator>operator>survey), such assessment should be interpreted cautiously.

Seven of the respondents (40%) mentioned that tourists did express concerns to the operators about aspects of their experience. The most common complaint related to litter...

> "plastic and Coca Cola cans in coral reefs destroyed the coral colonies"; and
>
> "too much garbage in the area"

Other complaints related to the need for better air transport links (to remote areas) and better facilities (boats) and the need for higher levels of operator professionalism (including marketing).

Destination characteristics

The majority of operations (70%) are based on sites which have primarily natural environment values (dive sites, drop offs, big fish, unusual marine life, etc.). The remainder focus on sites with cultural values (traditional fishing, dance, village life, etc.) and historical values (especially World War II wrecks).

Operators noted that many current and potential sites are highly constrained for a number of reasons, the most commonly cited ones being damage to coral reefs due to use of explosives or poison, inadequate infrastructure (moorings, etc.), bureaucracy, lack of accommodation, etc.

Some 60% of Operators noted that sites in use are in the same or better condition that they were five years ago, while 40% reported a decline. All respondents identified a range of strategies for better site management, the most common of which was for improved education and extension practices, followed by greater regulatory action (especially at the local level), increased conservation management and the introduction of rules on anchoring.

Future of marine tourism

A clear majority of operators (76%) are optimistic about the future of marine tourism in Indonesia. Reasons cited in support of this view include:

- the wide variety of potential destinations available;
- the high level of biodiversity and endemism in the archipelago - these are likely to be major attractions in view of current global interest in environmental issues; and
- Indonesia is a largely unknown destination and the potential for tourists to make new discoveries is high.

The small number (11%) of operators who were pessimistic about the future of marine tourism cited concerns about overpopulation, unchecked resource exploitation and coral reef destruction. In terms of necessary actions to improve marine tourism, most operators emphasised the importance of action at the local/regional level. A summary of their proposals is presented in Figure 2.

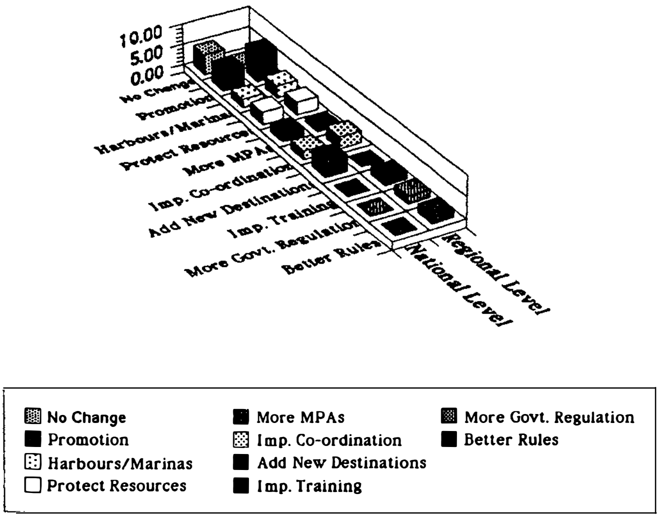

Figure 2. Actions needed to improve marine tourism in Indonesia

Education links

When asked about the potential contribution of universities to marine tourism operations, most operators indicated that they had had little previous contact with Universities and most were sceptical about the type of assistance which could be provided. Only 12% of the sample believed that Universities could definitely be of assistance to their operation, although a strong majority (82%) believed that further training (at whatever level is appropriate) would be beneficial to their operation and industry.

Priority topics for further training included marine ecology, resource management, dive safety, sea safety, education/interpretation skills and general skills (especially photography).

DISCUSSION

While most of the survey findings are reasonably self-explanatory, two key issues deserve particular comment. These relate to strategic planning and the role of marine tourism in environmental management.

Strategic planning

The current national emphasis on marine resource management, including recent initiatives in marine conservation and education (Alder and Dutton, 1994) appears appropriate and timely. As indicated in this survey and stressed in recent studies of the importance of biodiversity conservation in Indonesia (eg. Caldecott, 1992; Cochrane, 1993; Hutomo, *et al.*, 1993) the natural systems of Indonesia are under mounting pressure from a range of marine and land-based activities.

These systems form the major marine tourism attraction in Indonesia and are closely interwoven with cultural and historical attractions. Although marine tourism per se appears to be a relatively small niche market within the overall context of Indonesian tourism, it is of considerable local economic significance, especially in remote locations where few alternative industries may exist. Additionally, as several reviewers have suggested, the opportunity to engage in marine tourism is an explicit part of the attractiveness of many coastal destinations and is likely to become increasingly important over time. Survey respondents observed that Indonesia's vast EEZ is one of the few areas of Southeast Asia which has the potential to provide new opportunities for discovery experiences in marine environments.

A key question which must be addressed is, as operators themselves propose, that of the sustainability of tourism and the integration of marine tourism with other development initiatives. The survey suggests that lack of co-ordination both within the marine tourism sector and between tourism and other sectors is a pressing problem which needs to be more fully addressed. To date, most emphasis in this regard has been given to only selected regions (eg. Rhenda, 1989) or to selected types of tourism development such as resort development (eg. Euroconsult, 1988).

Dutton and Hall (1989) argue that sustainable tourism development requires a commitment to strategic planning and recognition of the wider market system in which any tourism enterprise operates. The marine tourism industry has yet to receive the benefit of such commitment and appears to be largely supply driven in isolation from potentially relevant sectoral initiatives in tourism, education and regional development at this stage. As industry operators suggest, this must change if marine tourism is to reach its undoubted potential.

Environmental management and education

There is growing recognition of the nexus between tourism and the potential for improved environmental management in Indonesia (eg. Sekartjakrariri, 1993). There is also growing recognition of the potentially adverse impacts of inappropriate tourism development, especially in coastal areas and amongst indigenous communities (eg. Dutton and Saenger, 1989; Wong, 1991; Lea, 1993; Sofield, 1993). This survey has indicated the considerable potential for tourism to make a positive contribution to local economic development and better environmental management.

In a related, but separate study of the Karimunjawa Islands, a large Marine Park and a potential marine tourism development area near Central Java (Dutton, *et al.*, 1993), the practical difficulties of developing a viable and sustainable marine tourism industry were described as considerable. The Karimunjawa islands are typical of many marine areas in Indonesia - highly productive, ecologically rich and very scenic. They are potentially an ideal tourism node. However, they are also being increasingly exploited at unsustainable rates for fisheries and local subsistence activities; activities which, in turn, are diminishing the tourism development potential of the islands.

The marine tourism operator survey noted that most operators make astute judgements about the suitability of sites and are increasingly concerned about the attractiveness of potential sites. Up to the present time it seems that Indonesia has enjoyed a seemingly limitless array of tourism development opportunities. If one site becomes degraded, then it has been a reasonably simple task to move to a new site. These options, however, are now being reduced, particularly for sites near destination regions which have adequate support infrastructure.

As the operators themselves now suggest, greater emphasis needs to be given to "husbandry" of sites. In this regard, the operator recommended emphasis on improved education and extension practices within the tourism industry appears to offer considerable promise. These approaches are working well in marine tourism operations in the Great Barrier Reef region (Alcock, 1992; Hockings, 1993) and have already been proposed for parts of Indonesia (see. eg. Schoen and Djohani, 1992), but are awaiting implementation in most areas. Local application of these practices in areas of conservation significance and/or marine tourism potential such as the Karimunjawa Islands thus appears to be an urgent priority need and one which could be met more proactively by Universities and other training bodies (see, eg. Dutton, 1992; Alder and Dutton, 1994).

CONCLUSION

Indonesia, as Muller (1992) suggests, is one of the world's most attractive and least well known marine tourism destinations. While inbound tourism to Indonesia is growing rapidly, most current tourism activity is focussed in relatively confined areas of the archipelago and is predominantly land-based.

Marine tourism is emerging as a locally significant niche market, especially in areas not integrated with other forms of tourism development. It is also an important complementary industry in the main Indonesian destination areas such as Bali and West Java.

For strategic economic, environmental and social reasons, there is considerable merit in supporting current industry requirements for improved co-ordination of marine tourism development throughout Indonesia. The results of the first national survey of marine tourism operators described in this paper will form a useful benchmark for further industry monitoring and development in this regard.

ACKNOWLEDGEMENTS

The survey described in this paper was undertaken by the author whilst on secondment to the Indonesian Marine Science Education Project (MSEP), based at Universitas Diponegoro (UNDIP) in Semarang, C. Java. The assistance of MSEP staff at UNDIP is gratefully acknowledged, particularly the invaluable help provided by Ms V. Savrani, Dr B. Ludvianto and Ir. A. Hartoko with survey administration and translation of responses.

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INTEGRATED COASTAL MANAGEMENT EDUCATION: THE EXPERIENCE OF THE CENTRE FOR COASTAL MANAGEMENT

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ABSTRACT

Management of the Australian coastal zone is important to all Australians - a fact emphasised in the recent National Coastal Zone Inquiry (RAC, 1993). Not surprisingly, the Inquiry noted that historical management practices in the coastal zone have been ineffective and often inappropriate and that far greater vision is required if Australians are to continue to enjoy the many values associated with coastal resources.

These conclusions reinforce the importance and relevance of coastal management education and mirror similar concerns in the Asia-Pacific region. While there have been many initiatives in environmental science at the tertiary level in Australia over the past decade, few have given specific attention to coastal management education. A notable exception is the coastal management program at Southern Cross University which was introduced in 1986.

The Centre for Coastal Management at Southern Cross University acts as a dedicated multi disciplinary research, teaching, consultancy and advocacy unit within a Faculty of Resource Science and Management. Some 500 graduates of the Centre now work in the entire spectrum of professional coastal management in Australia and the Indo-Pacific region and the Centre provides global educational and advisory services.

This paper reviews the history and experience of the Centre for Coastal Management and its programs. Particular emphasis is given to factors which have been instrumental in the success of the Centre, including integration of disciplines within the curriculum structure, close liaison with industry and community agencies, emphasis on applied research and continuing monitoring of program and graduate performance. The experience of the Centre is likely to be of considerable relevance to other educational institutions within the Asia-Pacific region.

INTRODUCTION

The Centre for Coastal Management (CCM) at Southern Cross University is the largest and longest-established provider of undergraduate level coastal management education in Australia. The recent National Coastal Inquiry (RAC, 1993), observed that the coastal management program at Southern Cross University is one of only three resource management (education) programs nationally which do not relegate human activity to a "secondary consideration" in their curricula. Given the proliferation of environmental management/studies courses in Australia since the late 1970s (Thomas, 1993), the RAC observation is clearly an indictment of the failure of mainstream tertiary education programs to appreciate the nature of complex, multi dimensional disciplines such as coastal management.

Milbrath (1990) suggested that the failure of tertiary education programs to give such interdisciplinary areas of inquiry "mainstream status" lies in the dominating nature of traditional academic pursuits, in which primarily technological solutions are paramount. In a review of Australian experience with tertiary environmental education, Thomas (1993) argued that such courses are, in general, "being maintained on the margins of institutional activity", thus supporting Milbrath's argument.

What then makes the Southern Cross University coastal management program different ? Clearly, the first and most substantial characteristic of coastal management education at Southern Cross University is that it began and has been supported to develop as a "mainstream" institutional activity. The coastal management program at Southern Cross University was the first degree level course in science at the Northern Rivers College of Advanced Education (NRCAE was the institutional predecessor of Southern Cross University). This institutional support has been instrumental in both the success of the coastal management program and in the successful evolution of the CAE to University status. In 1994, the Committee undertaking the first national quality assurance audit of Australian Universities (CQAHE, 1994) noted that "the Centre (for Coastal management) stands out....the level of performance of this Centre within a short period of time has been significant". The CCM was the only academic program area at Southern Cross University singled out for such praise and its influence was a major factor in Southern Cross University being ranked within the same national quality band as much longer established institutions such as James Cook University of North Queensland.

Later sections of this paper elaborate on factors which have influenced the design and evolution of academic programs within the Centre, however, it is also significant to note that the coastal management program at Southern Cross University has a much broader focus than just the delivery of undergraduate and postgraduate courses. The Centre acts as a multi-functional unit within a broader Faculty structure - its mission embraces research, consultancy, advocacy, professional development, training and communication. Each of these activities is undertaken on an integrated basis at various geopolitical scales (i.e. from local to continental levels) and within the broadest context of contemporary coastal management practice (i.e. involving a wide range of biological, physical and social sciences).

Such span of interest is rare within the confines of current academic practice in the Asia-Pacific region (see, e.g., AFS, 1988; UNESCO, 1987; Dutton and Sutterlin, 1993; Hay and Chou, 1993) and yet is increasingly necessary if the many complex and insidious problems associated with sustainable utilisation of coastal resources are to be resolved.

OVERVIEW OF CCM PROGRAMS

Undergraduate courses

The Coastal Management program at Southern Cross University (SCU) formally commenced in 1985 with the preparation of a course accreditation proposal for a new undergraduate (Bachelors level) degree course in coastal management. Such proposals were a requirement for all new course proposals in Colleges of Advanced Education (CAE) and were intended to demonstrate the industry and market relevance of such developments. At that time, the Northern Rivers CAE offered two resource science courses - a two year Associate Diploma and a three year Diploma.

After comprehensive review of educational needs and with input from a range of industry, government and academic sectors, the Coastal Management course was accredited for commencement in 1987. The course structure consists of 24 Units, to be undertaken over three years. A list of course units is provided in Table 1 - this is the current course, as revised following a formal course review workshop in 1991 (the first of a planned five yearly review program).

There are two features of the coastal management degree structure of particular note. Firstly, as is apparent from Table 1, the course places a strong emphasis on a blend of resource science and resource management subjects. From a grounding in basic sciences in the first year, students progress to more diverse, but specialist, courses in years 2 and 3. Such progression is a basis for development of often complex management concepts which require an adequate scientific knowledge base. Secondly, the final unit in the course is a double unit course entitled "Integrated Project". As the title implies, this unit is the capstone element of the overall curriculum and requires students to undertake an applied research project which demonstrates their competence in applying multi disciplinary resource science skills in a management context.

Table 1: SCU Coastal Management Course Structure

Year	Semester	Unit *	Status **
1	1	Biology	Core Unit
	1	Chemistry	" " " "
	1	Geology	" " " "
	1	Resource Assessment Techniques I	" " " "
	2	Ecology	" " " "
	2	Quantitative Analysis (Statistics)	" " " "
	2	Hydrology and Climatology	" " " "
	2	Resource Assessment Techniques II	" " " "
2	3	Computing in Applied Science	" " " "
	3	Marine Biology	" " " "
	3	Soil Processes	Elective Unit
	3	Aquatic Ecosystems	" " " "
	3	Environmental Chemistry	" " " "
	4	Coastal Plant and Animal Communities	Core Unit
	4	Coastal Resources and Their Management	" " " "
	4	Coastal Geomorphology	" " " "
	4	Legislation, Administration and Communication	" " " "
3	5	Land Use Planning	" " " "
	5	Natural Resource Economics	" " " "
	5	Protected Area Management	Elective Unit
	5	Remote Sensing and GIS	" " " "
	5	Coastal Engineering and Oceanography	" " " "
	5	Aboriginal and Torres Strait Islander Studies	" " " "
	6	Integrated Project	Core Unit
	6	Project Planning and Management	Elective Unit
	6	Recreation and Tourism Planning	" " " "
	6	Applied Geology	" " " "
	6	Environmental Impact Studies and Assessment	" " " "

* The normal workload for a full time student is 4 units per semester.

** Coastal Management students are also able to substitute elective units in other streams of the Resource Science Program or from other Faculties within the University, or externally, to satisfy the 24 Unit requirement.

Figure 1 traces the history of student enrolments in the coastal management program (both postgraduate and undergraduate) and the growth in staff resources. Students enrolled in the previous (pre 1987) Diploma course were provided with the opportunity to upgrade to the new Bachelor's degree, however, the first intake of new students to the course did not commence until 1987. Demand for the new course is strong, with some 10 first preference applicants for every place available. This strong demand has continued into the 1990s, with the Tertiary Entrance score for the course rising from 38.9 in 1987 to 61.35 in 1993.

A final development of note was the introduction of new undergraduate course streams based around the coastal management program in 1991. Following concern about employment opportunities for the increasingly large numbers of graduates and recognising the opportunities for diversification into complementary study areas, two new course "streams" were introduced in 1991 in "Conservation Technology" and "Fisheries and Aquaculture".

Both new streams share a common first year curriculum with the coastal management program and then provide students with the opportunity for specialist training, often based around elective study units of the coastal management program. The development of these streams has proven extremely cost-effective and has been well received by both students and employers.

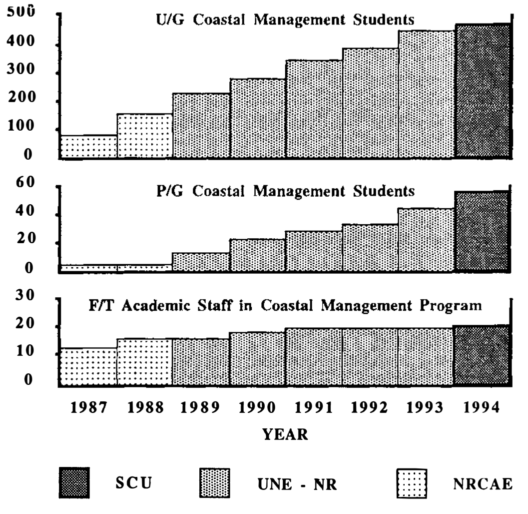

Figure 1. Coastal Management Program Trends

Opportunities for postgraduate course development were limited in the CAE sector, however, as part of national tertiary education reforms, CAEs were incorporated into an "unified National system" of Universities. In 1989, the NRCAE became part of the University of New England network (UNE-NR) - a change which brought access to a wider range of postgraduate and research opportunities.

The amalgamation also had the effect of providing staff with increased access to research funding, particularly under the Australian Research Councils "Mechanism B" initiative which provided access to significant research infrastructure. Specialist laboratory and computing equipment worth more than $1 million has been provided to the coastal management program on a competitive bidding basis under this program - this equipment has been instrumental in development of research programs in fields such as GIS, Molecular Biology, Plant Ecology, Electron Microscopy, Marine Biology and Pollution Studies.

In 1989-90, new postgraduate programs initially at Honours level, and later at Masters and doctoral levels, were developed by the CCM. All are currently research-based, however, further postgraduate course work programs are currently under development. Figure 1 indicates the relatively rapid growth in post graduate student numbers.

Other program activities

Since its inception, the CCM has consistently emphasised the importance of integrating education programs with community, industry and professional service activities. This link works in three ways. Firstly, the Centre has a corporate commitment to ensuring that its graduates are exposed to up-to-date information on market needs and contemporary issues and trends in coastal management. Thus, for example, when the House of Representatives Standing Committee on Environment, Recreation and the Arts (HORSCERA) was conducting a national coastal inquiry (HORSCERA, 1992), the Centre conducted a workshop on coastal management issues and approaches for the Committee.

Secondly, as a means of contributing to "best practice" environmental management, the Centre makes available staff and facilities to industry, regulatory and community groups. This has the additional benefit of keeping staff informed of "on ground" developments and, in many cases, provides additional resources to underpin research and educational programs. For example, since 1987, the Centre has undertaken more than 80 consultancy projects, each of which has contributed to the acquisition of information and support facilities and many of which have provided employment opportunities for coastal management students and graduates.

Thirdly, these activities enable the Centre to establish networks and opportunities for promoting the importance of coastal management. For too long, coastal management has been considered as either too difficult or as a secondary activity by government and the community at large.

Brown and Burke (1993) in a national survey of Australian agencies with an interest in coastal management issues describe the all too common view of one planner (for a coastal area) who described his status in terms of " I'll know I'm a coastal manager when my Council treats me as if I am". This quote highlights the lack of institutional recognition and support for professional coastal management and provides a stark contrast to the high recognition enjoyed by other professionals.

The Centre has consistently maintained that, until there is widespread acceptance of the extent and nature of coastal management issues and needs, there can be little political will to address them. By raising coastal management issues in the public arena (CCM activities are regularly reported in both academic and popular media) and by developing networks of informed decision-makers (the Centre publishes "Coastlines", a newsletter for coastal managers twice yearly), the Centre promotes the importance of coastal management as a professional activity.

All of the above activities have played a major part in the development of the Centre, both nationally and internationally. They have also served a valuable role in ongoing performance monitoring and evaluation - information generated during engagement in consultancies, public debate, training activities and field studies is constantly reviewed and used in all spheres of CCM operations. For example, during preparation of a Conservation Strategy for the Jervis Bay region (Dutton, *et al*, 1994), the GIS database developed was prepared under a licence agreement which required that the client agencies make the database available for subsequent undergraduate training use. In return, the client agencies were provided with access to database information at a reduced cost.

RELEVANCE TO OTHER INSTITUTIONS AND PROGRAMS

Limitations of some current approaches

There have been many historical initiatives in marine science, coastal management and related academic fields internationally (ESCAP, 1985). For example, Maynard (1987) describes the proliferation of marine-oriented courses in North America in the 1960s and 70s (developments which he links with the popularity of Cousteau at the time). In the Asia-Pacific region in the recent years such developments have enjoyed a strong resurgence of interest (e.g. Maynard, et al, 1990; Chua, 1991; Hay and Chou, 1993), with numerous large scale institutional development projects (e.g. the Indonesian Marine Science and Education Project described by Brick, et al, 1993) and short course training courses (see, e.g., Hay and Chou, 1993) being implemented.

In most cases there is clear recognition of the limitations of traditional, often reductionist, academic approaches to training and development of professional coastal managers. However, as McManus (in Hay and Chua, 1993) observed, a strong disciplinary bias still exists in many institutions. To compound this problem, there is often a thematic or cultural bias inherent in the way which educators and institutions view coastal management issues and needs. For example, many of the idealised curricula for coastal and marine resource management education presented in international forums in the past decade continue to emphasise the perspective of developed nations at the expense of locally-derived solutions (Lemay and Zale, 1989).

Lessons from the CCM program

The experience of the Centre for Coastal Management at large indicates that there is far greater room for innovation in tertiary education program design than is generally recognised. The following sections summarise some principles which have been instrumental in the successful development of the coastal management program at SCU and which may be transferable to other programs, both existing and under development.

Principle 1: Coastal management should be given disciplinary status

As discussed earlier, coastal management programs must be given "mainstream" disciplinary status if we are to develop integrated programs which instil in students and the wider community an adequate understanding of the importance and nature of the subject. The success of the coastal management program at SCU is attributable primarily to the distinctive identity and direction given to the program from its inception.

Principle 2: Coastal management education must be flexible and responsive.

Unlike many academic pursuits, coastal management is characterised by a relatively short formal tradition of research and education. Coastal management is also characterised by rapidly changing socio-political needs and by a need to deal with a comparatively large body of knowledge (spanning the humanities to earth and biological sciences). To deal with such a broad range of subjects, and to keep abreast of change, requires a commitment to monitoring trends in industry, society and other spheres of academia. The Centre for Coastal Management uses a range of monitoring and performance appraisal techniques, prominent amongst which is a system of maintaining close links with program graduates - their feedback is constantly sought and incorporated in program scope and content.

Principle 3: Integrated coastal management education must reflect the environment within which it occurs.

As with any systematic activity, education is intermeshed with a wide range of social endeavours. One of the first proponents of a systematic approach to environmental planning, McLoughlin (1969) argued that for planning to be effective, it must "mirror the environment within which it occurs". The Centre has applied the same philosophy in the planning and development of its activities. At the outset of course development, the Centre took the unusual step of defining the coastal zone in very broad terms as "the land/sea interface extending from the upper limits of catchment areas to the seawards limits of terrestrial influences" (NRCAE, 1986). Such a comprehensive view of the coastal zone is only now being formally recognised in institutional arrangements for coastal management (e.g. CCNSW, 1994). This broad-ranging definition creates additional potential complexity, however, as Holmes et al. (1992) observed, such philosophical commitment must underpin the development of integrative approaches to resource management.

Principle 4: Formal education courses are only part of an integrated program

Whilst formal courses are the core business for most tertiary institutions, there are ever increasing demands on them to provide additional services and to establish more active links with industry, government and community bodies. As indicated above, the Centre for Coastal Management has long recognised these needs and has allocated considerable efforts to research, consultancy, training and advocacy activities which both complement and underpin its formal course programs. While these "extra curricula" activities can represent a significant cost to the institution (e.g. in terms of commitment of staff time serving on advisory committees, etc.), the benefits of involvement far outweigh the costs and represent an outstanding opportunity to proactively contribute to better coastal management practice locally and globally.

Principle 5: There is no substitute for 'hands on' experience

Coastal management is an applied science. As such, it must integrate professional practice with academic theory. This requirement is articulated in several ways in the programs of the Centre for Coastal Management. In academic programs, for example, the Centre places considerable emphasis on field experience - one of the most highly regarded components of the undergraduate program (based on graduate exit surveys) is an annual fortnight-long excursion to the Great Barrier Reef Region during which students are exposed to a range of coastal management issues during site inspections with developers and managers. The excursion culminates in the conduct of interdisciplinary field research leading to the preparation of management plans or impact assessment statements for coastal development projects. A further example is the Discovery Ranger program, a joint initiative of SCU and the NSW National Parks and Wildlife Service in which some 15-20 students are trained to provide educational service in national and marine parks during periods of peak visitation.

This principle is also apparent in recruitment and professional development of academic staff involved in the Centre's programs. In setting up the academic team, considerable emphasis has been placed on selection of staff with a blend of academic and industry experience - this, in turn, has contributed to the market acceptance of the Centre and its programs. The ongoing market relevance of academic programs is further enhanced by active support for staff engagement in consultancy practice which is typically a more accurate measure of industry relevance than, for example, research. Unlike many traditional academic science programs, the Centre gives equal recognition to consultancy and research activities across its span of activities.

Principle 6: Coastal management must be addressed at a range of temporal and spatial scales

As with any integrative discipline, coastal management applies to resources and activities over a diverse range of temporal and spatial scales. It is not sufficient to develop coastal management programs which address issues and change at only one location, or within the context of one epoch of human history. Thus, while the Centre for Coastal Management enjoys a highly favourable location (in a sub-tropical ecotone, with access to a wide range of coastal ecosystems and industry types) its programs are designed to cultivate understanding of national and international perspectives on coastal management.

The success of this commitment is evident by the ready acceptance of graduates into workplace settings throughout Australia and the Pacific region. Equally significantly, the Centre has successfully anticipated numerous trends/issues which are now of concern in particular regions or industries. For example, in 1988, Centre staff were instrumental in developing a tourism program (within the same Faculty as the Centre for Coastal Management) which, although initially hospitality focussed, is now collaborating actively with the CCM on projects in emerging fields of concern such as ecotourism and marine protected area management.

CONCLUSION

Coastal management is now enjoying unparalleled community and governmental recognition as a field which must be better addressed if the many values and uses of coastal resources are to be sustained. Numerous recent national (e.g. HORSCERA, 1991; RAC, 1993) and international (e.g. Hay and Chou, 1993) programs and inquiries now recognise the importance of education as a key element of coastal management practice.

The experience of the Centre for Coastal Management as an Australian leader in the field deserves closer scrutiny as its wide ranging and often innovative programs are potentially relevant to many parts of the Asia-Pacific region and elsewhere. That the Centre has continued to successfully grow and evolve despite disruptive institutional change, and within the context of a market place where coastal management has not historically been recognised as a mainstream academic activity, is attributable to the adaptive nature of the Centre and its programs.

The Centre possesses a high level of resilience, is linked on a range of scales with key stakeholders and is opportunistic. These attributes, combined with an overriding commitment to excellence provide a strong basis for continued growth and sustainable development of the coastal management program. For example, as a means of overcoming current institutional inertia in conducting integrated coastal management research and delivering the results to practitioners, the Centre has recently initiated proposals for a national Co-operative Research Centre in Coastal Management and a national Key Centre for Teaching and Research.

The Centre is firmly committed to supporting similar initiatives elsewhere in the Asia-Pacific region and believes that its experience can be usefully applied internationally. Only by explicit recognition of the importance of coastal management education is it likely that the emerging global coastal crisis can be meaningfully addressed.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support and assistance of all members of the Coastal Management team at SCU in developing the programs described in this paper.

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CONJOINT ANALYSIS FOR PRODUCT DESIGN OPTIMIZATION: TRIDACNID CLAMS IN THE AQUARIUM MARKET

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ABSTRACT

The aquarium market for exotic tridacnid clams has increasing potential worldwide. Beautifully convoluted shells and brightly colored mantles enhance any saltwater aquarium. In order to reap maximum profits from this market, tridacnid clam producers and aquarium distributors need information about the preferences of saltwater aquarists. Time series information from the retail market is rare for tridacnid clams. Therefore, conjoint analysis, a stated preference technique, is used to identify the value of clams of various sizes and colors. Values were obtained by asking Hawaii aquarium distributors, who handle a great portion of seawater aquarium organisms, for their preference tradeoffs between clam wholesale price, shell size and mantle color.

An estimate of the value of the clam attribute is determined for each distributor using a binomial model. An aggregation of the data for distributors provides a partial demand curve for each attribute. The marginal revenue for each attribute is determined giving the addition to clam total revenue for each increase in size or color enhancement. Conjoint analysis provides estimates of the cost to produce each attribute. In addition, the marginal costs to enhance these attributes in tridacnid clams are provided. The equation of marginal revenue to marginal cost determines the most profitable attribute combination for tridacnid clams in the aquarium trade. Results of this study for clams in the aquarium market suggest optimal production decisions, product designs and marketing strategies. The aquaculture industry can then design the most optimal tridacnid clam product and species for sale in the saltwater aquarium market.

INTRODUCTION

In the last two years, the mainland US demand for saltwater aquariums or "mini-reef" systems has grown and now accounts for 20 percent of the value for the national aquarium trade (Heslinga, 1990). The U.S. trade in ornamental fish, invertebrates and supplies had an estimated value of over $700 million in 1989 (Winfree), while, outside the U.S., the value for marine aquarium fish and invertebrates, excluding supplies, was estimated to be $100 million in 1985 (McLarney, 1985). The use of spectrum actinic and metal halogen lights in "mini-reef" aquariums make it possible to keep tridacnid clams in closed-cycle tanks for long periods of time. With the technologies currently available, tridacnid clams can be transported to aquarium markets worldwide (Heslinga 1990). Tisdell (1989) and Deese (1989) indicate that the demand for these clams in the aquarium market has the potential to increase.

In order to realize the full profit potential of giant clams in the aquarium markets, producers must understand the tradeoffs buyers are willing to make for the attributes of the product (Anderson, 1987). This information can be used to guide producers production and marketing decisions (Steencamp, 1986). While economists often determine the value of a product's characteristics by fitting hedonic price models using revealed preference data, giant clams have not been sold in aquarium markets long enough to generate sufficient time series information to make the estimation possible. In addition, because the preferences of aquarium owners change rapidly, such models may not be useful for predicting the future (Miklius and Leung 1990). Conjoint measurement is a quantitative research method useful in a number of marketing studies to determine the tradeoff between product attributes using experimental information (Beilock *et al*., 1986).

This paper uses conjoint analysis to estimate the value of size and color for *Tridacna derasa* among the aquarium distributors in Hawaii. First, is a discussion of the theoretical basis of estimating the value of characteristics using stated preference techniques. Then, a description of the experimental techniques used to elicit the stated preferences of aquarium distributors in Hawaii and a presentation of the results of the experiment. The final section presents a discussion of the implication of this research for other researchers interested in determining the value of product attributes.

THEORETICAL FRAMEWORK FOR CONJOINT MEASUREMENT

Conjoint analysis intends to infer estimates of willingness to pay from the stated preferences among alternative bundles of product attributes evaluated simultaneously using statistical techniques to quantify how much each attribute contributes to the overall utility given the bundles ordinal ranking (Carroll *et al*., 1989). The choice of one variation of a product over another is decomposed into a set of attributes (x) and the attributes are assigned weights (w) such that an index I, $I=f(wx)$, is a monotonic transformation of the original ordinal data. The index I is interpreted as an ordinal utility function. The analysis is a two step process (Beilock *et al*., 1986).

First, information must be collected from individuals about their preferences. To accomplish this, respondents participate in an experiment require them to rank a number of alternative product with different attributes. Concerns with the external validity of conjoint experiments center on the use a series of artificial choices, rather than actual market situations, as a basis for estimating the value of attributes. Louviere (1988) provides evidence that if stated preference experiments, which include the use of conjoint measurement and contingent valuation, are properly designed and administered, no bias will result.

The ranking data for each individual can be analyzed using maximum likelihood techniques to estimate an ordinal utility function. If the rank order information is converted to binary data, a probability model such a logit or probit can be used to estimate the ordinal utility function. The ranks (R) will range in value from 1 to N and the values are assumed to be functions of the attributes x then the following equations of the form $N*(N-1)/2$:

$$R_i - R_j = F_i(x_i) - F_j(x_j) \tag{1}$$

for all i and j, given $i>j$

This equation can be transformed to a Bernoulli of value one if $R_i - R_j > 0$ and zero otherwise. The paired comparisons are assumed to be probabilistically independent. This means that to make the first choice all bundles are compared to each other. Then, after the first choice, the bundle that is ranked first is then removed from the choice set and the remaining bundles are then compared to independently to each other. This process repeats until all the bundles are ranked.

According to McFadden (1987) the following indirect utility function can be estimated from the converted data:

$$C = \alpha + \beta_1 x_1 + \beta_2 x_2 + ..+\beta_n x_n \tag{2}$$

where $C = exp[u/1-u]$ and u is the utility individuals obtain from consuming the product. Because (2) represents an indirect utility function, price is includes as an attribute of the product. This is possible because utility is assumed to be maximized given income, savings and the price of other goods. However, income, savings, and the price of other goods are assumed to remain constant leaving the price of the product as a variable in the indirect utility function (Hensher et. al., 1988).

In order to determine the value of the attributes given an indirect utility function, the total derivative of the equation (2) gives:

$$\delta C = \delta\alpha + \delta\beta_1 x_1 + \delta\beta_2 x_2 + ... + \delta\beta_n x_n \quad (3)$$

which is equal to:

$$0 = 0 + \beta_1 \delta x_1 + \beta_2 \delta x_2 + \ ... + \beta_n \delta x_n. \quad (4)$$

Because the indirect utility level, C, is assumed to remain constant the derivative remains equal to zero. Assuming x_1 is the price of a product and x_2 is the attribute that is changing while the levels of all other attributes remain, then solving equation (4) for $\delta x_2 / \delta x_1$ gives:

$$\delta x2 / \delta x1 = \beta 2 / \beta 1. \quad (5)$$

The expression on the left side is interpreted as the change in attribute 2 for a change in product price which is equal to, on the right hand side, β_2 / β_1. The same procedure can be used to determine the value of the other attributes in the function.

SURVEY METHODS AND DESIGN

While it would be desirable to estimate the indirect utility function of final consumers in the aquarium market, the monetary and time cost of such an activity is prohibitive. Aquarium distributors demand is derived from the demand of final consumers and the size of the experimental group makes it much less costly to survey. Therefore, aquarium distributors were the target group for the survey. Further cost constraints made it impossible to survey all aquarium distributors or even a random sample. While this group is not a randomly drawn sample of distributors, the fact that 58 percent of the $5 million of saltwater fish and equipment is exported to the mainland U.S. by this group means that the group represents the final demand of various U.S. consumers.

In order to determine which characteristics of clams are desirable and over which ranges these attributes are desirable (Anderson, 1987), some preliminary work with the distributors was required. Live *T. derasa* (7 to 12 cm shell size) from the Micronesian Mariculture Demonstration Center (MMDC) in Palau were purchased and supplied to the distributors. Clam color varied; some appearing unenhanced with brown and translucent mantles, while others looked enhanced with neon green and blue color patterns. Enhancement involves the addition of ammonium nitrate as a fertilizer for the zooxanthellae algae in the clam's mantle, resulting in enhanced mantle coloration (Heslinga, 1990). Follow-up interviews with distributors were conducted to determine their feelings about these clams and how much they would be willing to pay for them.

Enhanced clams with more color were preferred to the unenhanced clams by all distributors. The distributors also said they were willing to pay more for the larger animals; however, this preference for larger animals may not be because of size alone. Larger animals are rare in the market and color variations are more apparent.

Stated preference data was obtained by personal interviews of aquarium distributors. Each survey participant was provided twelve cards, with each card describing four clams with a combination of three attributes. The three attributes were color, price and size. Distributors were asked to indicate which clams they would by first, second, third and fourth on each card. Clam size ranged between six and fifteen centimeters in one centimeter increments, the price ranged between $1.50 and $15.00 in $.25 increments, and color ranged between enhanced or unenhanced. Photos of unenhanced and enhanced animals, along with shells of each clam size, were shown to remind each distributor of the actual variation between the clams.

The attribute combinations used on for the four clams on each card always gave a higher price to a larger clam and to an enhanced clam. The desired attributes must be more expensive in order to force a trade-off between that attribute and price, otherwise the respondent's rankings would be perfectly predictable (Anderson, 1987). The cards were designed so that the desired attributes would become progressively more expensive, eventually causing the respondent to switch to a cheaper clam with less desirable attributes. This point at which the higher price causes this switching behavior identifies the maximum value of the attribute to the respondent. The twelve cards and the four clams within each card were arranged in a randomly assigned order. Thus, no order bias should result because every distributor was administered the choice in a different sequence.

EMPIRICAL RESULTS

The indirect utility functions were estimated using the logit algorithm in SHAZAM (White, 1978). The estimates of indirect utility function using price, color and size as the product attributes are presented in Table 1. The percentage of right predictions (%RP) indicates the number times the estimated model predicted the choice made by the respondent. Enhanced clams were preferred by all respondents. However, although the focus group results indicated that larger clams were preferred, the stated preference data indicated that not all respondents actually do. As indicated in Table 1, four respondents preferred larger clams and three preferred smaller clams. This result required that the choice given participants in the conjoint experiment be altered for those distributors preferring smaller sizes to ensure the utility function could be estimated for this group

Figure 1 gives the partial demand curve for the color enhancement for *Tridacna derasa* as derived from the utility functions presented in Table 1. The curves indicate the amount of money these distributors are willing to pay for enhanced clams as compared to unenhanced clams. The x axis on the graph shows the number of distributors willing pay for the enhanced clams. This partial demand curve does not indicate how many clams each distributor is willing to buy.

The partial demand curves for a one centimeter increase and decrease are shown in Figures 2 and 3, respectively. Figure 2 represents how much distributors who preferred larger animals in Table 1 are willing to pay for a one centimeter increase in size. Figure 3 represents how much distributors who preferred smaller animals in Table 1 are willing to pay for a one centimeter decrease in size.

Another problem was encountered when another group of distributors did not value color as much as the focus group indicated. Therefore, the estimated function for these respondents, as shown in Table 2, includes size only. These distributors may differ from the others because understood the enhancement process and could enhance clams themselves. Therefore, they were no willing to pay much for an enhanced clam as compared to an unenhanced clam.

Table 1. Utility functions for distributors valuing tridacnid clam size and color.

Distributor	Intercept	Size	Color	Price	%RP[a]
D1	1.37**[b]	0.34**	2.70**	-0.77**	72
	(0.46)[c]	(0.19)	(0.69)	(0.30)	
D17	-0.12	1.64**	3.59**	-1.49**	86
	(0.55)	(0.47)	(1.01)	(0.54)	
D4	0.71**	0.64**	0.72*	-0.23*	74
	(0.33)	(0.15)	(0.41)	(0.13)	
D6	0.25	0.31**	1.10**	-0.11	67
	(0.21)	(0.08)	(0.33)	(0.09)	
D22	0.27	0.64**	2.08**	-0.37	81
	(0.38)	(0.23)	(0.74)	(0.26)	
D16	0.88**	0.42**	0.34	-0.21*	64
	(0.34)	(0.13)	(0.49)	(0.12)	
D3	1.21**	0.66*	1.28*	-0.54	61
	(0.54)	(0.34)	(0.72)	(0.41)	
D24	0.34	0.26	0.55	-0.05	60
	(0.29)	(0.11)	(0.46)	(0.11)	
D8	-0.41	0.62	-0.83	-0.25	79
	(0.36)	(0.26)	(0.63)	(0.33)	
D7	0.27	-0.07	0.55*	-0.32**	72
	(0.18)	(0.06)	(0.32)	(0.09)	
D5	1.41**	-0.89**	2.45**	-1.73**	94
	(0.54)	(0.28)	(0.85)	(0.65)	
D2	0.35	-0.48**	3.22**	-0.37	92
	(0.49)	(0.19)	(0.90)	(0.33)	
D20	0.99**	-0.29**	1.43**	-0.66**	82
	(0.30)	(0.12)	(0.52)	(0.22)	
D21	0.86*	-0.71**	2.31**	-0.92**	92
	(0.46)	(0.22)	(0.78)	(0.44)	
D15	0.33	-1.02**	4.25**	-0.20	93
	(0.87)	(0.44)	(1.70)	(0.60)	

Note: [a] Percentage correct predictions
[b]*Coefficients are statistically significant using 90% confidence interval, ** for 95%
[c] Asymptotic standard errors

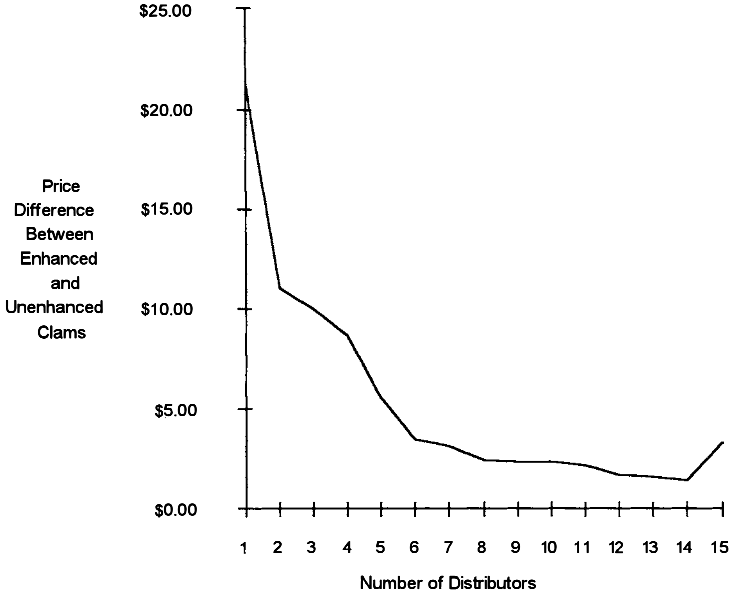

Figure 1. Partial demand curve for enhanced tridacnid clams.

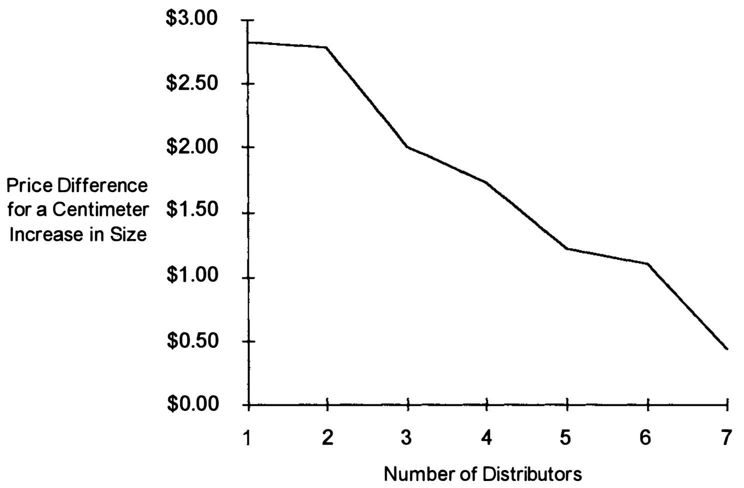

Figure 2. Partial demand curve for a one centimeter increase in size of tridacnid clams

Table 2 shows the estimated functions of the respondents who valued enhancement and smaller animals. This group was not consistent with the hypothesis formed from the focus group results that larger animals were preferred. These distributors will have to be surveyed again in order to determine how much they are willing pay for a smaller animal. This group represents a large portion of the Hawaii distributors who ship to smaller retail stores in which the average sizes of aquariums are 55 gallons. Figure 4 shows the partial demand curve for this group indicating how much this group is willing to pay for an enhanced clam as compared to an unenhanced clam.

Table 2. Utility functions for distributors valuing tridacnid clam color

Distributor	Intercept	Color	Price	%RP[a]
D12	0.19 (0.29)[c]	1.50**[b] (0.44)	-0.34** (0.12)	75
D11	0.25 (0.37)	3.85** (1.03)	-0.21* (0.13)	82
D10	-0.04 (0.31)	2.05** (0.51)	-0.32** (0.12)	79
D9	0.94* (0.52)	5.86** (1.47)	-0.83** (0.28)	96
D13	0.94** (0.38)	3.35** (0.80)	-0.32* (0.17)	88
D14	0.34 (0.40)	4.12** (1.07)	-0.52** (0.21)	90
D18	0.97** (0.27)	0.20 (0.43)	-0.24* (0.15)	74
D19	-0.53 (0.39)	0.24 (0.50)	-1.16 (0.27)	88
D23	0.65 (0.34)	1.48 (0.47)	0.331 (0.13)	70
D25	-0.46 (0.40)	3.8 (1.06)	0.38 (0.16)	88
D26	0.45 (0.56)	1.62 (0.70)	0.71 (0.32)	82

Note: [a] Percentage correct predictions
[b]*Coefficients are statistically significant using 90% confidence interval, ** for 95%
[c] Asymptotic standard errors

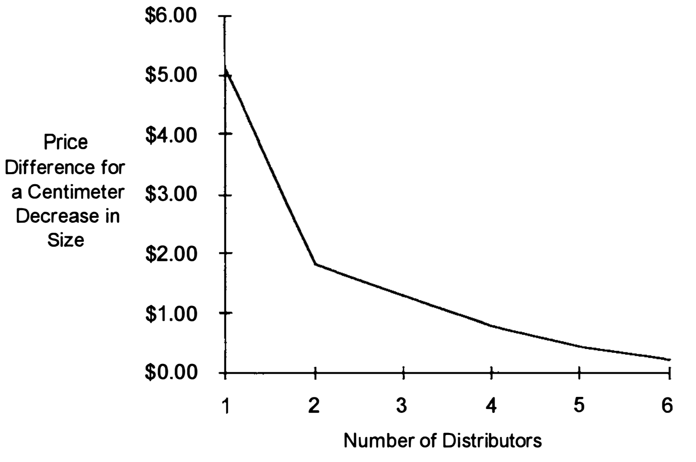

Figure 3. Partial demand curve for a one centimeter decrease in size of tridacnid clams

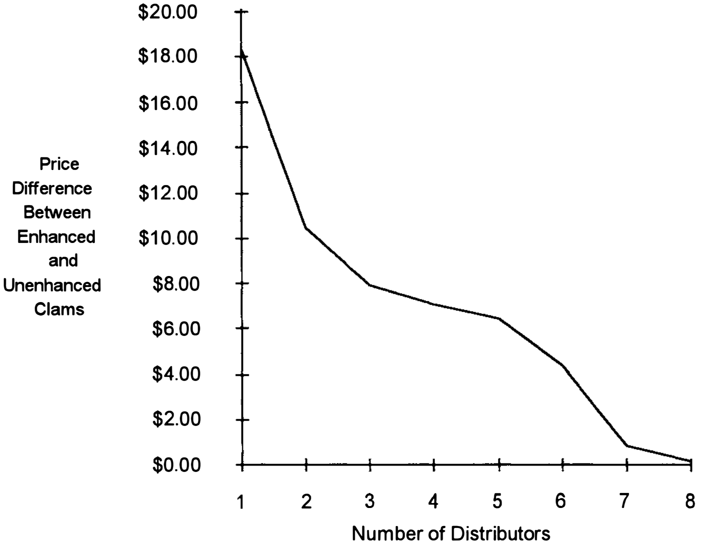

Figure 4. Partial Demand Curve for Enhanced over Unenhanced Tridacnid Clams

CONCLUSIONS

The attribute preferences of aquarium distributors in Hawaii for tridacnid clams fall into three different groups. Those who value color enhancement and larger size, color enhancement and smaller size, and larger size. The factor that appears to determine which group a distributor will fall into is the volume handled by the distributor, the type of market they buy products and the type of markets they serve. One distributor may purchase aquarium products from a large export market with a wide selection; another may deal with a local supplier marketing one product line. Concerns with this survey include the primary hypothesis from the distributor focus group indicating a preference for larger clams. The conjoint cards were designed as though all distributors preferred larger clams. To rectify these concerns, conjoint cards can be designed with the hypothesis that smaller clams are preferred. This conjoint technique allows separation of markets when estimating utility functions as utility is not always consistent among groups.

The conjoint experiment is a useful market tool designed for any aquaculture operation; be it seafood or the aquarium market. This conjoint approach can also be used to compare species of Tridacnid clams to determine which species a clam hatchery should invest time and money to produce. It is a method by which a producer can get timely results on the existing market as to the interests of his consumers for product attributes and the relative weights of those attributes. In this case, the conjoint methodology was used in the Hawaii aquarium market for *Tridacna derasa*. It was used to identify and quantify the attributes sought in the aquarium market for *T. derasa*. The attributes of size and color enhancement were investigated and estimated for their part-worth to the overall utility of the distributors. This information is useful to the producer who can estimate costs for producing the clams with desired attributes and seek the optimal production strategy to maximize profits in the aquarium market.

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MODELING ECONOMIC AND ECOLOGICAL EFFECTS OF MARINE PARK MANAGEMENT

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ABSTRACT

Hawaii's most popular underwater recreation area is the Hanauma Bay Nature Park on Oahu. To protect its valuable marine resources, the waters of the bay are designated a Marine Life Conservation District. Marine parks provide access for public enjoyment and accommodate all interested groups. Marine park managers strive to balance the immediate demands for ocean recreation with the long term conservation of resources. The ideal management plan protects the marine environment as the most important consideration but also recognizes the needs of different user groups. In Hanauma Bay, however, managers' face challenges in controlling the amount of users the bay can withstand. Overuse has caused degradation of the water quality, death of coral species and overcrowding, making the park less enjoyable. In 1990, the Department of Parks and Recreation initiated restrictions to further protect the resources from overuse and ensure long term use of the site. This study combines results from scientific studies and direct observations to develop a conceptual model that reveals the dynamic relationship between recreational use and the coral reef ecosystem in Hanauma Bay. The model describes how the present use of the bay may be heavily discounting potential future values. The paper examines management objectives and the effects of the recently imposed restrictions of the park. Applications of the model are used to determine the effects of coral reef protection and recovery through: education, further restrictions on the number of users, user fees, and restricted areas. The model can ultimately improve park management decision-making and help to ensure the protection of resources for the future.

INTRODUCTION

Marine park management at Hanauma Bay, Hawaii requires skilled personnel flexible to change and capable of standing by their convictions. Enlightened management comes from an understanding of coastal systems allowing managers to balance the pressures as well as minimize risks (Carter, 1988). Present issues facing coastal managers require background scientific knowledge of Hanauma Bay before they can be addressed efficiently. Scientific research has provided baseline physical parameters in water quality that are necessary for coral growth. The nearshore reefs and abundant marine life at Hanauma Bay provide coastal ecosystems that are in great demand by both vacationers and conservationists. Conservationists have a long term interest in ensuring the resources will exist for future generations to enjoy. The economic status in Hawaii depends on this influx of vacationers so intent on visiting Hanauma Bay where the visitors expect adequate access to the shore with esthetically pleasing views and recreation amenities. All water based activities require water management plans to allow optimal use as well as protection. This paper attempts to show how the understanding of both the biological and economic models along with their various components can be used by managers in establishing goals and carrying out policy for the best use of marine parks such as Hanauma Bay.

MANAGEMENT CONCERNS

Hanauma Bay Nature Park and Recreation Area enclosing a Marine Life Conservation District and Underwater State Park is a remnant of a volcanic crater. The most popular natural attraction in Hawaii attracts nearly 3 million visitors per year and over 50% of all tourists. By 1967, in recognition of the unique features and dwindling fish populations, the Department of Land and Natural Resources, Division of Aquatic Resources (DLNR) designated Hanauma Bay a Marine Life Conservation District. In the 1970's, concerns over the non consumptive uses prompted the City and County of Honolulu (DPR) to fund a study that concluded the park was overcrowded, and gave a maximum daily figure for beach use as 1,363 people (Okomoto *et al.*, 1977). By 1983, beach occupancy continued to increase to nearly 8000 visitors per day.

Studies in 1989 found the average number of users of the park on a daily basis as 6,707 people (Reynolds, 1990). Visitors complained of overcrowding, limited parking, traffic and overused facilities. Marine resources in the bay are subject to a decline in water quality from body oils and inappropriate fish feeding, trampling and sediment transport from swimmers and snorkelers, and runoff from showers and septic leaks. In response to this overuse, DPR developed and initiated their *1990 Hanauma Bay General Plan including Rules and Regulations* to decrease the number of visitors and relied on controlling access as a method of reducing park usage and impact to park resources (Okomoto *et al.*, 1992). Parking was limited to the available 325 spaces, tour buses restricted to a 15 minute stay, and park hours reduced. Positive steps to further develop the Hanauma Bay Educational Program were established (L. King, 1991). The educational program is available at the bay for interpretive hikes, marine flora and fauna information, fish feeding alternatives as well as the proper precautions swimmers should heed to protect coral resources.

In 1990, when the restrictions were introduced, there was a significant decrease in the number of visitors to the bay. By 1991, the Hanauma Bay Nature Park had approximately 2 million visitors, a one third reduction in visitor numbers from 1989 figures. In 1992, the figures indicate this reduction in the range of 1.6 million visitors. The expected restoration costs for a place as unique as Hanauma Bay are very high, as are the expected losses if the bay becomes so degraded it must be closed for its protection. Management concerns and actions to protect the park and its resources outline the relationships which can be used as management tools. This research addresses the environmental degradation at Hanauma Bay and expands the conceptual model developed by Lee and Gallagher (1992) by introducing the dilemma for marine park managers with present and potential management policies and their effects on the functional relationships in the bay.

MODELLING FRAMEWORK

The coral in Hanauma Bay is a draw to the visitor and a necessary component of the marine reef ecosystem. The coral condition indicates the health of a reef system, dependent on chemical water quality, turbidity and impact from waves and physical contact. The growth of corals is fundamental to understanding reef development (Grigg and Dollar, 1980). Corals are important as habitat, shelter and food for most species that inhabit the reef ecosystem. This research uses the amount of living coral in the bay as one indicator of the recreational value of the bay. The model also includes visitors who provide a major source of value to the bay when present, but who can also cause environmental degradation. The model for Hanauma Bay assumes that the recreational value of the bay increases with the amount of live coral in the bay as well as the number of visits to the bay. The marine park manager must choose how many people the park can handle to get the best recreational return, but not allow so many people that it will destroy the marine resources in the park.

The mathematical model for Hanauma Bay, uses symbols to represent changing conditions and states representing both recreational and management activities at Hanauma Bay. The model outlines the resource management problem for Hanauma Bay and is characterized by two state variables and one control. The value of the bay is then expressed as a function of the two states. One state being the amount of surface area of live coral coverage in the bay, expressed as x_{1t}. The other state is the number of visits to the bay, expressed as x_{2t}. The control variable for Hanauma Bay is the limited number of cars allowed in the park at any one time as determined in the 1990 DPR rules and regulations. This is expressed as u_t, and uses annual number of visitors to the park. The letter f represents the value of the bay at a designated time that is characterized by using the letter t. Because the value of the bay will decrease over time due to its intensive use, the letter r then represents the social discount rate. Combining these forces on the bay, the model for the net present value of the bay as expressed in Lee and Gallagher (1992) as Equation 1:

$$V = \int_0^T e^{-rt} f(x_{1t}, x_{2t}, u_t)dt \qquad (1)$$

In terms of the model, coral growth x_{1t} increases with the amount of live coral coverage in the bay and likewise decreases with recreational use. Coral has a direct or positive relationship with more live coral and an indirect or negative relationship as more and more visitors use the bay and cause stress and destruction to the coral resources. It can then be determined that the change in coral coverage over time is a function of the amount of coral coverage x_{1t} and the number of visitors x_{2t}. Equation 2 represents the first order condition or the first derivative for the change in coral coverage over time[1].

$$\dot{x}_{1t} = g_1(x_{1t}, x_{2t}) \qquad (2)$$

The model also gives a symbolic relationship for the recreational demand of the bay. Recreational demand, x_{2t} , increases with the amount of live coral in the bay as more and more people want to experience the beauty of the underwater environment. This recreational demand decreases when the park becomes overcrowded with visitors. The change in visitor numbers over time is then expressed as a function of the amount of live coral in the bay x_{1t}, the number of visitors at the bay x_{2t} and the level of control of visitors into the park, u_t. Equation 3 represents the first order condition or first derivative for the change in recreational demand over time.

$$\dot{x}_{2t} = g_2(x_{1t}, x_{2t}, u_t) \qquad (3)$$

The objective, and choice for marine park managers, is to choose the number of visitor numbers to admit into the park to maximize the net value of the bay (Equation 1). That is to choose to meet the highest amount of recreational demand possible (highest present value to the bay), but not allow overcrowding and coral degradation to reduce the value of the bay to the user and resources over time. The problem, as further developed by Lee and Gallagher (1992), is to choose u_t to maximize a present value Hamiltonian equation. The Hamiltonian equation represents the combination effect of the social discount rate and the net present value of the bay with the effects of both state variables: the coral coverage and number of visitors to the bay. The Hamiltonian is subject to values of the state variables $x_{1,0} = x_1^0$ and $x_{2,0} = x_2^0$ to determine a reference point indicating the initial state of the bay when the

[1] Where $\dot{x}$ is an abbreviation for $\delta x / \delta t$ the marginal condition.

management initiatives are enacted. The first derivative of the Hamiltonian with respect to the control variable, u, set equal to zero, gives the optimality condition.

The optimality condition evaluates the marginal conditions and interprets the first order conditions. It implies that at the optimum, the value to the bay that would be gained by allowing just one more person into the park (increasing the value of the bay) will just equal the present value of future losses to the park. Losses from degradation of coral resources and visitor dissatisfaction from overcrowding caused by allowing this last person into the park. The multiplier effects of this management strategy show the changing conditions on coral growth and recreational demand by increasing or decreasing the objective function or present value Hamiltonian that must be maximized at some optimum level for recreational use and protection.

PHASE DIAGRAM

An illustration in the form of a phase diagram is provided to show the dynamic relationships between coral production and visitor numbers. Information for this diagram was obtained through direct observations at Hanauma Bay and existing literature on coral biology and growth. Figure 1 shows the special cases of the state equations (2) and (3) where $\dot{x}_1 = 0$ and $\dot{x}_2 = 0$. The diagram displays a series of arrows positioned at right angles to indicate the horizontal direction of movement along the x axis in response to the effects on the coral coverage and vertical direction of movement along the y axis in response to the effects on visitor numbers. These arrows are in response to the location of the curves and policies.

The curve labeled $\dot{x}_1 = 0$ in the diagram represents the combinations of coral coverage and visitor numbers in which the rate of coral destruction due to recreational use just equals the rate of coral production from the existing living coral in the bay. This concave curve is typical of economic models displaying biological growth models that show increasing production at a decreasing rate until a maximum coral production is reached where the acceleration in producing coral coverage declines. Above this curve, visitor numbers are higher as shown along the vertical or y axis, therefore the coral is degraded at a faster rate than it is produced or than it can recover. The values that fall in this area represent this condition and the horizontal directional arrow points to the left (←). Below this $\dot{x}_1 = 0$ curve, the visitor numbers are lower and the coral can grow at a greater rate than it is degraded giving a positive net coral growth. Values which represent $\dot{x}_1 > 0$ have horizontal directional arrows pointing to the right (→).

The curve labeled $\dot{x}_2 = 0$ represents the combination of coral coverage and visitor numbers in which the annual number of visitors remains the same over time. This convex curve has an intercept above zero to indicate that even if there were no coral at Hanauma Bay, people would still visit the park. This is an exponential curve in response to the historically increasing numbers of people who have visited Hanauma Bay until the 1990 restrictions placed an upper limit on visitors. This limit is represented by the horizontal line of the curve once the maximum amount of people are allowed in the park (x_2^{max}). In response to values on the left of this $\dot{x}_2 = 0$ curve where $\dot{x}_2 < 0$, visitor numbers will decrease over time as shown by the vertical arrow directed down (↓). This is attributed to the lack of coral coverage which affects interest in underwater exploration or the overcrowding which reduces water clarity or space on the beach. Values found on the right side of this curve will correspond to a better coral condition and a lower number of people in the park. The values where $\dot{x}_2 > 0$ show an increase in visitor numbers over time as shown by the vertical arrow directed up (↑).

Figure 1 shows a combination of two management strategies and their response to the model as displayed in the diagram. These points are labeled A and B. Point A represents an initial state that is currently the practice at Hanauma Bay under DPR 1990 rules and regulations. This includes the limitations to visitor numbers through parking restrictions and is characterized in the diagram as u^a. The directional arrows act as a guide causing strategy A to continue along a spiral path which results in a net loss of coral resources and a lower number of visitors to the bay.

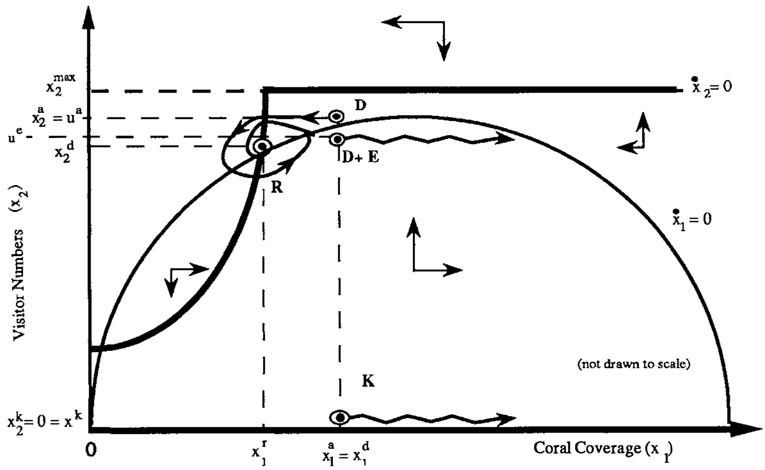

Figure 3. Relationship Between Visitor Numbers and State of the Coral under Education, Further Limits on Numbers of Visitors in the Park and Restricted Areas.

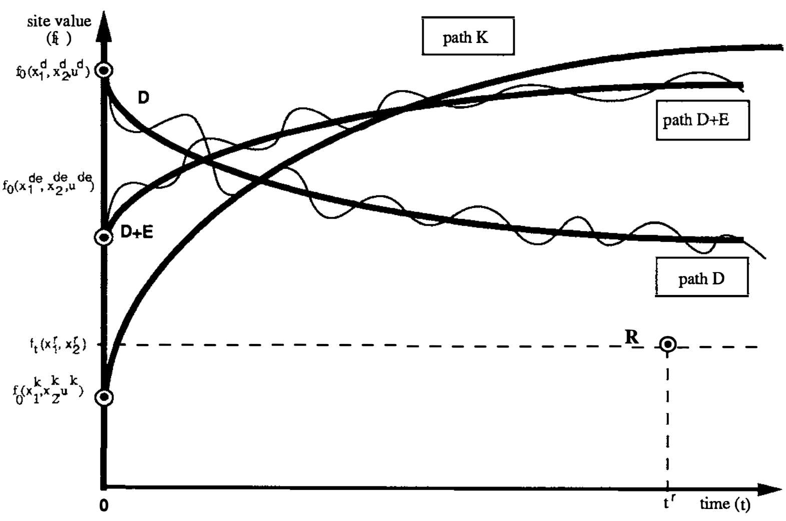

Figure 4. Site Value over Time under Alternative Management Strategies for Education, Further Limitis on Numbers of Visitors at the Park and Restricted Areas.

This management strategy is on a downward path and will reach a stable equilibrium which is labeled Point C. Point C indicates a steady state where the coral is in a degraded condition at x_1^c and the number of visitors is well below the restriction limits to the park. An alternative management scheme is proposed by Strategy B. This approach to management begins with the coral coverage in the same state as strategy A, a shown by $x_1^a = x_1^b$ on the horizontal axis, but clearly places a stricter limit on the amount of users by placing the control at u^b. Under this situation, the net coral growth is expected to increase as greater protection is placed on the resources and the visitor numbers cannot increase due to restrictions but may ensure there is live coral in the future.

Continuously changing economic values resulting from the above management strategies are provided in Figure 2. This diagram displays the value of the resources at Hanauma Bay over time. Strategy A begins at time zero indicating the enactment of the 1990 management rules and regulations. Strategy A has initially higher site values than Strategy B as more people are allowed into the park under the u^a control scheme with the same initial coral conditions. The fluctuations along path A continuously cycle downward until it reaches the stable state at point C indicating a decrease in the value of the bay over time as the coral becomes degraded and fewer people visit the park. Path B on the other hand has lower initial values of the bay due to the strict enforcement of control limits at u^b, but eventually surpass the values under management strategy A as the coral is able to recover and the entire reef ecosystem improves. Diagrams can be useful to marine park managers to illustrate the costs, benefits, and risks of achieving environmental goals under various management practices. These practices can be used to investigate existing or potential future management plans. It also allows for alternative strategies to be compared such as A and B by summing the areas under the curves and discounting the future values over time as in Equation 1. This methodology for management is useful for managers and policy makers alike but requires that the functional relationships are understood and can be placed into the model.

MODEL APPLICATIONS

The existing management Plan for Hanauma Bay Nature Park has outlined specific management goals (Okomoto et al, 1992): to preserve and enhance the natural qualities and opportunities unique to Hanauma Bay, to optimize the use of Hanauma Bay as an important recreational resource, and to promote public education. While this Plan does an excellent job of identifying the concerns and outlining goals, objectives and policies for the future management of the bay, it does little to show the functional relationships involved in the interests of the Park. It is important to test the effectiveness of the management plans and the management models. Park managers think the numbers at the beach are still above ecosystem capacity for recovery or maintenance as stressed coral is more likely to be trampled than pristine coral (A. Hong (1991), L. King (1991)).

Baseline biological and ecological information is needed on coral growth, reproduction, and establishment to determine the amount of impact the marine resources can withstand. A single inexperienced person can destroy more coral and marine life by standing, sitting, and walking on the coral than an entire group of conscious skin divers. Figure 3 illustrates Strategy D as the beneficial effect of the Hanauma Bay Educational Program. The Program is responsible for decreasing the negative impact of users resources by curtailing intentional and involuntary destructive behavior. A shift in the $\dot{x}_1 = 0$ curve indicates a greater number of visitors can use the bay before the water quality is degraded and coral is affected. The path of policy D is affected by changes in the rate of coral destruction above the $\dot{x}_1 = 0$ curve. The reduced rate of coral destruction is shown by a shorter horizontal directional arrow indicating it will take longer at a high visitor level before the path crosses the $\dot{x}_2 = 0$ curve when the coral is degraded enough to discourage visitors. Education as a management tool can result in coral growth x_1^r much improved from the level x_1^c shown in Figure1.

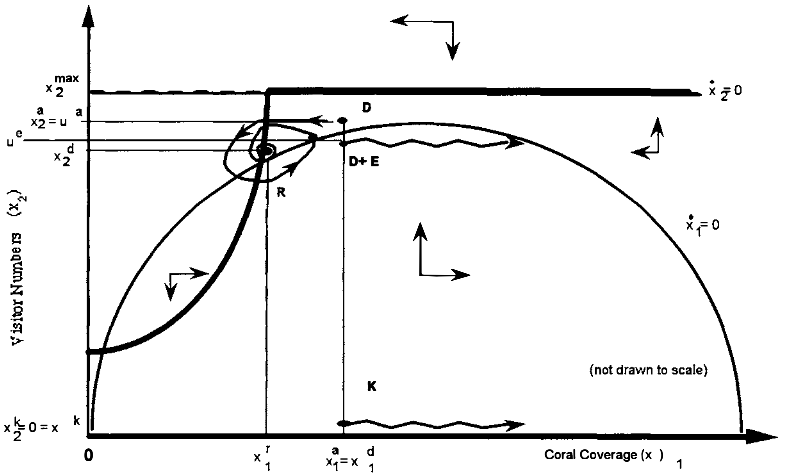

Figure 3. Relationship Between Visitor Numbers and State of the Coral under Education, Further Limits on Numbers of Visitors in the Park and Restricted Areas.

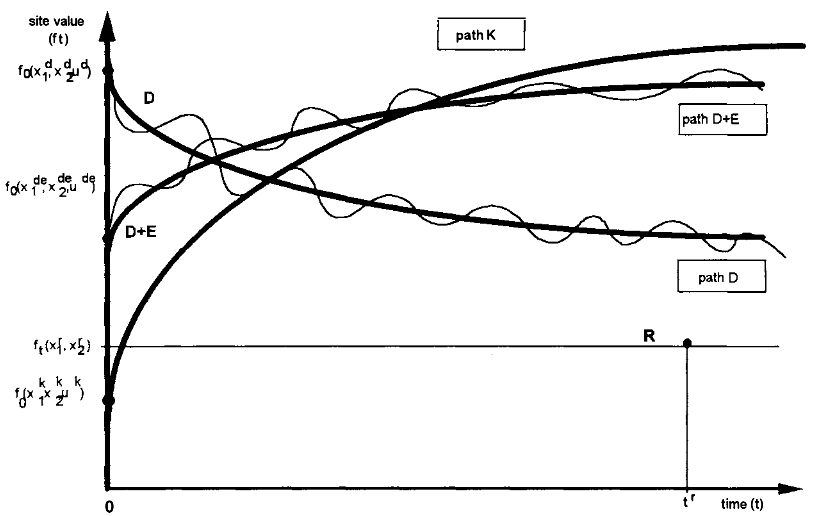

Figure 4. Site Value over Time under Alternative Management Strategies for Education, Further Limitis on Numbers of Visitors at the Park and Restricted Areas.

Hanauma Bay managers may continue to restrict entry. A combination of management strategies is displayed in the diagram as Strategy D+E. The upward shifted $\dot{x}_1 = 0$ curve along with an additional reduction in visitor numbers at control level u^e can protect coral resources. The initial reduced level of users places the point under the $\dot{x}_1 = 0$ curve where the coral growth is positive. The demand for recreation is positive but regulated by the control at u^e. The result of such combinations of strategies displays improved long term preservation of the park.

Managers considered restricted areas in the bay. This would encourage coral settlement and growth in optimal conditions. This is Strategy K and is represented by removing the $\dot{x}_2 = 0$ curve as there would be little impacts from visitors with the control level at zero where $u^k = 0$. Scientific information would be collected on coral re-establishment and the social discount rate r. In addition, daily user fees were considered which may increase revenues and may deter people to reduce visits to the bay. The disadvantage of such a program is that residents of Hawaii would be most negatively affected. Visitors, who have spent a great deal of time and effort to visit the Hawaiian Islands, have been willing to pay as much as $30-$40 per visit to Hanauma Bay (Leong (1990), A. Hong (1991)).

EMPIRICAL INFORMATION NEEDED

Marine parks are commonly subjects of research, from baseline biological and archaeological to social and economic studies that ensure continuing tourism. A variety of research topics warrant information on all aspects of Hanauma Bay that can identify the critical functional relationships to target in management decisions. It is imperative for the marine park manager to understand these functional relationships and their importance to the protection of the bay's natural resources. Such relationships involve the impact of users on the resources of the bay. Also important are the effects that resource degradation have on user's satisfaction of the bay. Further information on the effectiveness of resource modeling as a management tool is needed. Information on the long term capacity for recreational use of the bay has been the directive of marine park managers. Field and trial accounts of modeling the econmic effects of marine park management have yet to be tested. The information gained from research specific to the management concerns at Hanauma Bay will further guide park managers and policy makers in long term use of resource management tools and protection of Hanauma Bay Nature Park.

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ENVIRONMENTAL MONITORING FOR OFFSHORE OIL AND GAS DRILLING IN BASS STRAIT, VICTORIA

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ABSTRACT

BHP Petroleum is conducting exploratory offshore drilling activities in the Otway Basin off the western Victorian coast. Environmental monitoring of the drilling activities of one well, Minerva 2a, has to date consisted of one baseline sampling event and two post-drilling events. Direct effects of drill cuttings discharge (smothering effects) have been monitored using frames deployed on the seabed at 11 sites within 200 metres of the well head location. Cuttings buildup is estimated via *in situ* underwater video footage of the frames. Secondary effects of drill cuttings discharge (chemical contamination) are being monitored at 18 sites within 6.4 kilometres of the well head location via laboratory analysis of sediment samples. Parameters being investigated include: total metals, bioavailable metals, radionuclides, and total hydrocarbons. In addition, sediment particle sizes are being measured at selected sites and infauna samples from each site are sieved and archived for subsequent faunal analysis. An S2 logging current meter was deployed above the sea floor near the well head location during the month long drilling activities. The magnitude and direction of current flow will be used to help determine the fate of discharged drill cuttings and to correlate any measured secondary effects with subsequent movement of cuttings (and contaminants) along the seafloor. Preliminary results indicate no evidence of cuttings buildup around the frames and despite significant increases in some of the measured parameters at sites less than 800 metres from the well head, levels do not approach ecologically significant thresholds.

INTRODUCTION

In 1992 BHP Petroleum commenced exploration drilling programs in the Otway Basin off the west coast of Victoria, Australia.

Very few studies have been conducted in Australia with regard to the environmental assessment of offshore drilling activities. Most studies have been conducted overseas in the United States and Europe (refer to a review by Hinwood *et al.*, 1994, also Coats, 1994; Hyland, *et al.* 1994; Steinhauer, 1994). These overseas studies must be applied to Australian situations with caution as environmental and ecological conditions are often extremely different.

The need for reliable and accurate environmental impact assessment is currently a key management issue for the petroleum industry. Firstly, the industry needs to know the real effect of its activities so that it can react to minimise or mitigate the effect. Secondly, it needs information which can be provided to environmental and public interest groups. Thirdly, it needs evidence to satisfy regulatory authorities about the impact of exploration drilling and to support future applications for exploration for, and production of, petroleum in new and potentially sensitive locations.

The Minerva-2 well Marine Environmental Program (MMEP) was initiated by BHP Petroleum in order to quantify impacts of its offshore activities and to provide local Australian monitoring results upon which environmental management strategies can be based. The MMEP is ongoing and this paper presents some of the interim results and provides initial conclusions from the study.

Background

The main impact potential of offshore petroleum drilling activities result from the discharge of drill cuttings and used drilling fluids to the marine environment.

Cuttings are fragments of crushed rock removed from the drill hole by the movement of drilling fluids circulating within a closed system. Cuttings may contain heavy metals and other contaminants - the exact composition depending on the geology of the region. Cuttings are separated from the drilling fluids and continuously discharged overboard during the drilling process.

Drilling fluids are specially mixed relative to the downhole conditions and may contain a variety of components which are specifically added and which may contain metals such as barium, chromium and zinc and also any number of trace contaminants such as arsenic, cadmium, copper, mercury, nickel and lead. Fluids are recycled and discharged overboard only when they are changed to meet new downhole requirements or when drilling is completed.

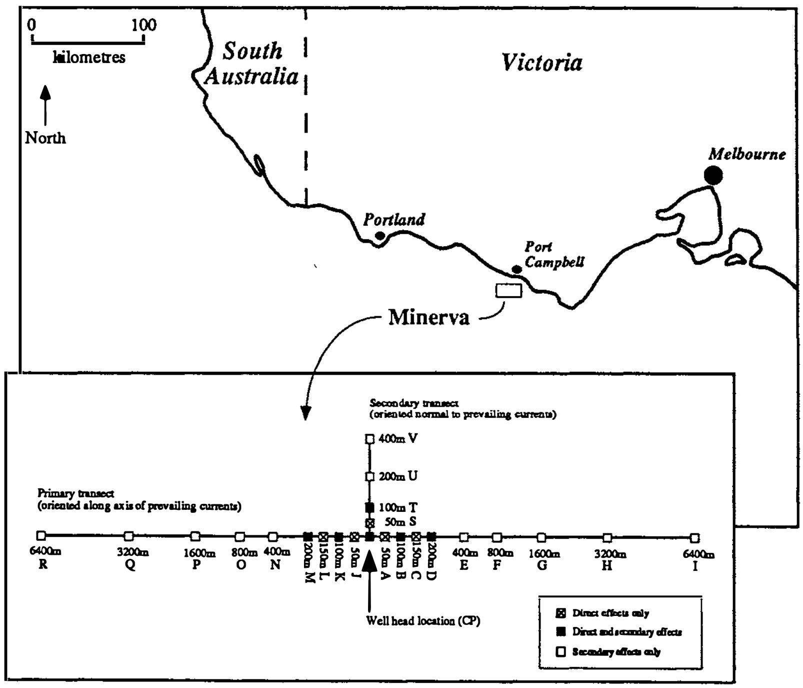

Figure 1 Locality map showing position of Minerva-2 drill site and layout of sampling sites

The Minerva-2 drill site is located 11 kilometres off the coast in 60 metres of water (Figure 1). This area is known for its rugged scenic beauty and as an important area for local fishing industries that include crayfish and abalone. This coastline is also visited annually in winter by calving Southern Right Whales (*Eubalaena australis*).

The Minerva-2 well was drilled to a depth of over 2000 metres in September 1993 resulting in the discharge of an estimated 500 cubic metres of cuttings to the marine environment.

METHODS

The MMEP was designed to assess both direct effects of cuttings/fluids discharge on the seabed (smothering) and secondary effects from chemical contamination of the sediments and/or modification of the sediment grain-size distribution.

Two transect lines were established (Figure 1). The primary transect runs west-east through the well location and is oriented parallel with the prevailing current flow. Nine sites are located each side of the well head position (Site CP) extending out to 6.4 kilometres in both directions. A secondary transect extends perpendicular to the primary transect for a distance of 400 metres inshore from the well head site and contains 4 sites.

An S2 logging current meter was deployed above the seafloor near the well head location prior to commencement of drilling activities. The current meter remained in position until the post-drilling sampling event when it was recovered and downloaded. Analysis of oceanographic data is incomplete at this stage and will not be referred to in this paper.

Direct effects

Smothering effects of cuttings/fluids discharges were monitored at 11 sites within 200 metres of the well head position (see again Figure 1). Prior to commencement of drilling, a weighted metal frame was deployed onto the seabed at each site. Each frame had a single two metre upright pole marked at 20 centimetre intervals by horizontal bolts. After drilling activities had been completed, a remotely operated vehicle (ROV) with video was used to relocate each frame and to record the depth of sediment overlaying the metal frame relative to the height of upright pole exposed. In addition, a five minute video survey of the seabed surrounding each frame was conducted to determine the extent of visible sediment modification and cuttings presence.

Severe weather delayed the timing of the post-drilling ROV videoing so that it was three weeks after completion of drilling before the frames were videoed.

Secondary effects

Chemical contamination and/or sediment grain-size distribution changes are assessed by collecting three replicate sediment samples at each of 18 sites (refer Figure 1). Sites are located using a differential global positioning system (DGPS) with an accuracy of less than 10 metres. Sediment samples are collected using a Smith-McIntyre grab and from each grab sample a single one litre sub-sample is collected in a solvent washed glass jar which is immediately frozen (-20°C).

Sub-samples are analysed for a variety of contaminants including total and bioavailable forms of arsenic, barium, cadmium, chromium, copper, mercury, nickel, lead and zinc and levels of radionuclides and total hydrocarbons. Chemical contamination results of both post-drilling sampling events are compared to pre-drilling contaminant levels using one-way analysis of variance (ANOVA), $p = 0.05$. The sediment grain-size distribution pattern is also determined to assess possible changes due to drilling impacts.

The sediment remaining after acquisition of each subsample, is weighed and wet sieved (1 mm mesh size), preserved in 10% buffered formalin and archived for infauna analysis. Infauna analysis is being conducted by the Victorian Fisheries Research Centre and involves sorting of 100% of each preserved sample with identification of fauna to species level.

To date, a single pre-drilling sampling event (September 1993), a post drilling event (October, 1993) and a three month post-drilling event (February, 1994) have been conducted.

RESULTS

Direct effects

Six of the eleven frames were relocated using the ROV and additional video footage in the vicinity of the non-relocated frames was obtained.

No evidence for extensive build-up of cuttings at any of the sites was observed. Sparse drill cuttings were evident on the sand in some areas but no mounding. Four of the six relocated frames were completely exposed above the seabed. The other two frames (at Site D, 200m east and Site S, 50m north) were partially buried by an estimated 10 centimetres of sediment but with only sparse cuttings visible.

The well head structure was also located and videoed using the ROV. A shallow, 20 to 30 centimetre depression was evident around the well cap to a distance of approximately 2 metres but no other seabed modification or cuttings build-up was visible in the vicinity. Several fish (*Pseudophycis sp*) were observed amongst the well head structure.

In all areas videoed, the seabed exhibited heavy rippling suggesting the presence of strong bottom currents.

Secondary effects

Chemical contamination

Bioavailable metal concentrations are not fully analysed at this time and the following discussion refers to total metals only. Bioavailable metal concentrations are less than those discussed.

Results of the sediment analysis exhibit a variety of trends. Cadmium, mercury and total hydrocarbons were consistently below detection limits of 0.1 ppm, 0.05 ppm and 20 ppm respectively.

Arsenic, chromium and lead post-drilling concentrations (Figure 2) were, on the whole, not significantly different from pre-drilling concentrations (ANOVA $p > 0.05$).

Barium, copper, nickel and zinc (Figure 2) exhibit post-drilling concentrations significantly different from pre-drilling concentrations (ANOVA, $p < 0.05$). Each of these contaminants is discussed in more detail below.

Barium concentrations increased substantially at sites within 100 metres of the well head site in the first post-drilling sampling event. Levels had decreased by three months after drilling but remained significantly elevated within 100 metres of the well head to the east (Site B), 200 metres to the west (Site M) and 100 metres to the north (Site T).

Copper concentrations were significantly elevated at Site CP at the time of the first post-drilling event ($p < 0.05$). Levels had resumed to background by three months post-drilling.

Nickel concentrations exhibited high variability with apparent increases at several sites distant from the well head in the first post-drilling event (Sites N, 400m west and Site G, 1600m east). The concentration increase at Site CP is significant ($p < 0.05$) for the post-drilling event but had decreased to background levels by three months post-drilling.

Nickel concentrations at all sites have resumed background levels by three months post-drilling ($p > 0.05$).

Zinc concentrations were significantly elevated only at the well head (Site CP). Concentrations increased ten-fold by the first post-drilling event but had reduced by half after three months. The concentration of zinc at Site CP was still significantly elevated at the time of the three month post-drilling survey ($p < 0.05$).

Seven radionuclides were measured in sediment samples from Sites CP, B (100m east) and K (100m west). While levels did not ever reach "radioactive" thresholds as defined by government guidelines, several radionuclides exhibited statistically significant changes after drilling activities.

U, Th, Th^{228}, K^{40} exhibit no significant changes after drilling (Figure 3) although all show increases in the first post-drilling samples. The high level of variability between replicates exceeds the variability between successive sampling events. K^{40} and Th^{228} exhibit 8-fold and 3-fold increases in mean levels respectively but these are non-significant.

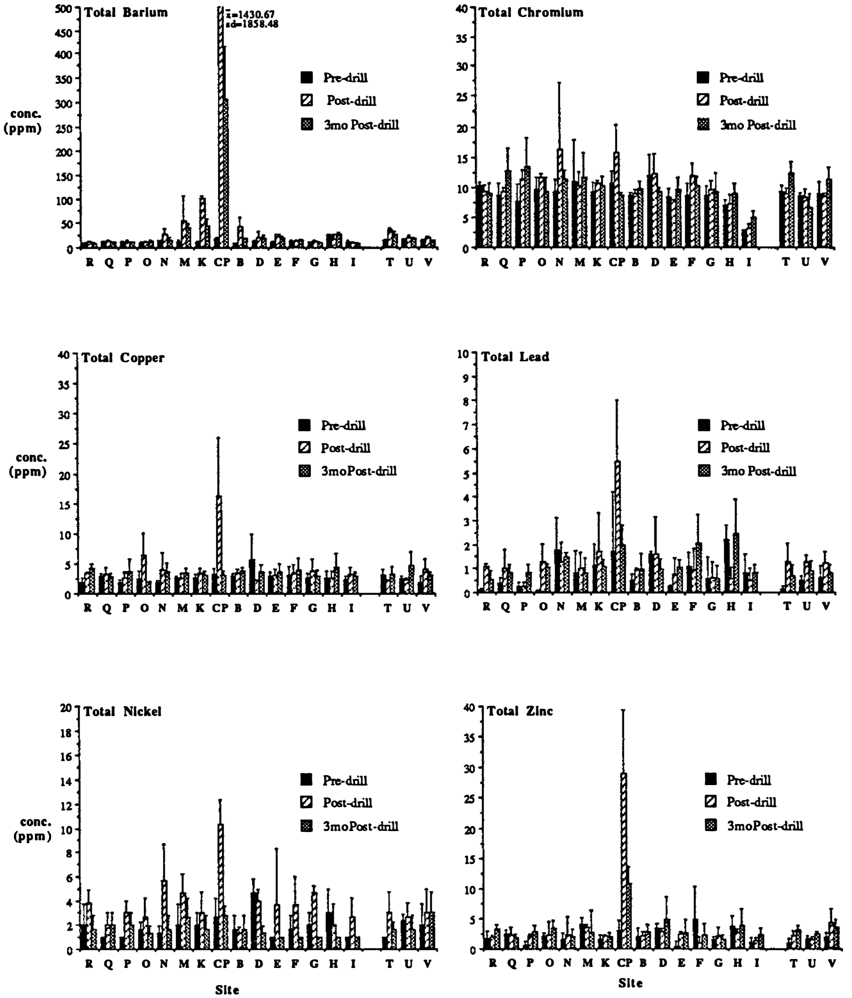

Figure 2. Contaminant concentrations in sediment samples collected before, immediately after and three months after drilling operations. Error bars represent one standard deviation.

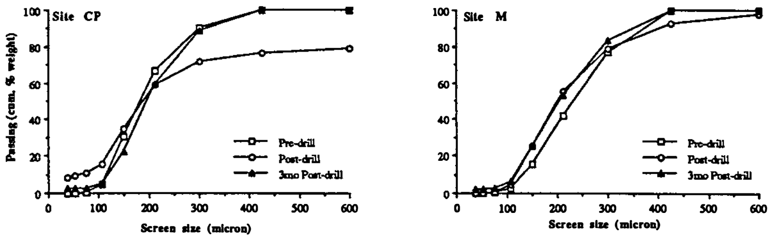

Figure 3. Radionuclide levels in sediments collected at the drill site (CP) and Site B (*measurement units for U and Th are ppm).

Ra^{226} and Ra^{228} exhibit statistically significant increases at Site CP between pre- and post-drilling sampling events with subsequent decreases to near-background levels by three months post-drilling.

Pb^{210} exhibited a statistically significant decrease from background levels at Site CP between post- and three month post-drilling events. This is probably a reflection of the natural variability at the site.

Sediment grain-size analysis at Site CP (Figure 4) shows that between the pre-drilling event and the post-drilling event, the distribution of grain-size has shifted so that a higher percentage of fines and a higher percentage of coarse particles are present after drilling. The fine particles may be a result of drilling fluids while the coarse particles are almost certainly a result of drill cuttings which were visible in the sieves during fauna sample preparations. By three months post-drilling, the grain size distribution at Site CP had returned to background. Grain size distribution at Site M (200m west) remained unchanged between all three sampling events (Figure 4).

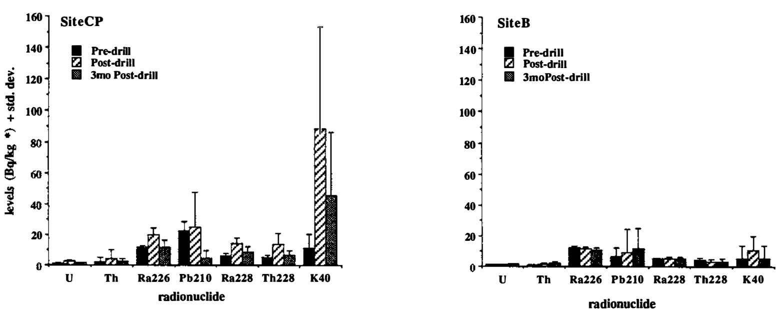

Figure 4. Grain-size analysis distribution plots for Sites CP and M.

Infauna analysis

Only very preliminary results are available on the analysis of infauna communities from the sampling sites. At Site CP, 22 species (n = 46) were identified in pre-drilling samples, 7 species (n = 10) in post drilling samples and 10 species (n = 16) in three-month post-drilling samples.

While firm conclusions are not possible, the initial results suggest that the diversity of infauna species at Site CP has altered since drilling activities although no adequate baseline data is available to account for possible seasonal biases.

DISCUSSION

Direct smothering of cuttings and drilling fluids discharge are minimal or at least short-lived within the high energy environment of Bass Strait. The time of ROV video surveys, three weeks after drilling ceased, was immediately after a period of rough weather which postponed sampling. It is not possible to confidently state whether mounding of cuttings did not occur at all due to bottom currents or whether mounds were rapidly dispersed by inclement weather during the three weeks prior to sampling. In either case, the potential smothering impact at the Minerva-2 well is negligible.

Other studies have recorded visible cuttings mounds beneath discharge points (EPA 1985; Menzie *et al.*, 1980; Dustan *et al.*, 1991) although Ray and Meek (1990) state that cuttings mounds can be rapidly dispersed during storm activity.

Chemical contamination of benthic sediments at the Minerva-2 well appears to be restricted to within 200 metres of the well head at the worst and in most cases, restricted to the well head site itself. Elevated levels of contaminants recorded after drilling had generally resumed background by three months post-drilling, the exceptions are barium and zinc. Even at the highest concentrations recorded, no contaminant is likely to affect benthic communities.

Barium is one of the most sensitive indicators of drilling activities and despite the detection of significantly elevated concentrations in surface sediments during the examination period, the highest recorded concentration of 3576 ppm is well below ecologically significant levels. Laboratory studies have shown that barium concentrations less than about 10 000 ppm do not cause measurable impacts on benthic infauna (Neff *et al.*, 1985).

There is no evidence from the current study to suggest that elevated contaminants at the well head site are resuspended to create "hot spots" of contamination further afield. The decrease in contaminants over time at sites close to the well head is most likely due to dispersion by bottom currents but at a rate which prevents detection of significant contamination elsewhere in subsequent sampling events. Contaminants could also be filtering down through surface sediments to a depth below the level of maximum grab penetration. There is no scope in the current study to document that possibility.

Sediment grain-size distribution has been shown to have altered between pre-drilling and the first post-drilling surveys, although resumption of background distribution was attained by three months post-drilling. This phenomenon may relate to the preliminary faunal analysis results which suggest that the diversity of infauna species at the well head site decreased to a third after drilling operations. A shift in the grain-size distribution could affect infauna species to the extent that those species favoured by the new sediment environment become more common while other species may decrease in abundance and/or disappear altogether.

At this stage, the shift in infauna community structure is speculation as very few samples have been fully analysed and biases due to seasonality have not been accounted for. Therefore, any impacts of drilling activities on benthic fauna cannot be confidently documented at this stage.

In conclusion, the MMEP has shown that in the high energy environment of Bass Strait, the impacts of offshore drilling activities on the marine benthic environment are probably localised to within several hundred metres of the well head at most and are likely to be short-lived (< 3 months). No contaminants were detected in ecologically significant levels in surface sediments anywhere within six kilometres of the well head and no smothering of benthic communities was observed.

A final sampling event will be undertaken in October 1994 to assess the levels of contamination 12 months after drilling activities.

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SUSTAINABLE USE OF COASTAL AND MARINE RESOURCES IN THE UNITED STATES AND AUSTRALIA

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ABSTRACT

The final report of the Australian Resource Assessment Commission's Coastal Zone Inquiry is a potentially significant milestone in the discussion of institutional arrangements for sustainable coastal resource use in Australia. The United States government has yet to initiate such a focussed inquiry. However, sustainability is receiving increasing emphasis in some U.S. regional, state, and local coastal management efforts. Those experiences could prove useful if and when the recommendations of the RAC Coastal Zone Inquiry are implemented.

For marine areas, the world's most fully developed regional multiple-use management program is Australia's scheme for the Great Barrier Reef carried out cooperatively between the national government and the Queensland state government pursuant to 1975 national legislation. Multiple-use marine sanctuaries established under the U.S. Marine Sanctuary Act tend to emphasize sustainable resource uses over unsustainable ones. Recently designated sanctuaries include some intensely used areas of the U.S. exclusive economic zone and provide an important test of the program's capabilities. Unfortunately, many U.S. and Australian fisheries which in theory are to be managed sustainably appear in fact to be managed unsustainably. In the U.S. emergency actions taken under the Endangered Species Act may result in major changes in the management regime for some fisheries.

Within both nations, considerations of federal-state relations continue to affect the management structure for sustainable use of coastal and marine resources significantly. Those considerations must be weighed heavily in the design of national institutional arrangements promoting sustainable resource use within the very general international parameters so far established.

AUSTRALIAN EFFORTS TO ACHIEVE SUSTAINABLE USE OF MARINE AND COASTAL RESOURCES

Introduction

Australia seems to have grasped sustainability as official national government policy about as firmly as any developed nation with respect to both marine and terrestrial resources. (Zarsky, 1990). Operationalizing sustainability in the use of Australian natural resources remains a major challenge. (Westcott, 1993). An adequate institutional and legal framework is a necessary but not sufficient condition for achieving sustainability. The following sectorial review evaluates the Australian framework for sustainable use of coastal and marine resources.

Marine protected areas: The Great Barrier Reef Marine Park

The world's most fully developed regional multiple-use ocean management program appears to be Australia's scheme for the Great Barrier Reef. The Barrier Reef program contains elements of sustainability, polluter pays, and the precautionary principle. (Kenchington, 1991). In theory it is integrated in the sense that the Marine Park Authority has specific federal statutory authorization to regulate upland activities which have adverse impacts on reef resources; however, the authority has felt politically constrained to not use that authority despite mining, grazing, resort development, and other vegetation clearing activities which seem to be having adverse impacts on parts of the reef ecosystem. Instead, a voluntary agreement has been reached with Queensland coastal sugar cane growers to reduce fertilizer use and soil erosion in the watersheds of rivers flowing into the Great Barrier Reef Marine Park. (Mercer, 1991).

The biggest pollution threat to the reef may be from land-based sources such as dumped wastes, discharges from outfalls and pipelines, and non-point source pollution entering coastal rivers and estuaries, problems currently inadequately dealt with in Australia. However, the constitutional basis for Commonwealth intervention to deal with these problems is weak due to the absence of an international convention dealing with land-based sources. Furthermore, while the Commonwealth-state 1980 Offshore Constitutional Settlement preserves Commonwealth management authority over the reef itself, the Australian states certainly view land-based pollution as a matter within their jurisdiction pursuant to settlement understandings that the states controlled discharges into the territorial sea and the Commonwealth controls discharges beyond. Thus, regulation of point-source discharges remains entirely a matter of state regulation in Australia to date, as no pipeline at present extends beyond three miles and state water pollution statutes control discharges into rivers or estuaries which end up in the ocean. Australia is not alone in its problems of dealing effectively with land-based ocean pollution sources. Around the world they contribute by far the largest proportion of ocean pollutants but frequently are ineffectively regulated by source nations. (Hildreth, 1991a).

Federalism and Australian offshore oil and gas development and seabed minerals mining

In the absence of any comprehensive Australian EEZ resource management legislation, management of offshore oil and gas development from a multiple-use perspective appears to have been limited to the drilling prohibition in the Great Barrier Reef Marine Park, a ten-year drilling moratorium offshore from the Cape York Peninsula in Queensland's far north, and 500-meter safety zone established around Australian offshore installations in accordance with article 5(3) of the 1958 Geneva Continental Shelf Convention. Additional steps would appear to be possible under existing legislation as the Commonwealth Offshore Petroleum Act authorizes the imposition of necessary measures to prevent "unjustifiable interference" with the conservation of living resources, control waste, and repair seabed damage.

Regarding pollution from seabed minerals mining operations, the Commonwealth Offshore Minerals Act authorizes the imposition of liability insurance, waste control, and seabed restoration requirements and mandates that "unjustifiable interference" with the conservation of living resources be prevented. (Minerals (Submerged Lands) Act 1981, 60(2); 70(b), (c)(ii), (iii); 75; 105). Under the Great Barrier Reef Marine Park Act, mining is prohibited in all areas of the park. (Section 38).

Fisheries management

Australia's Fisheries Act has been amended to conform to the obligations imposed on coastal nations by UNCLOS to allow access to surplus fish within the EEZ, prevent over-exploitation through conservation measures, and generally ensure that optimum utilization of EEZ fishery resources takes place. Optimum utilization also is the concept governing domestic fisheries management in Australia. Australia has used limited entry (including industry-funded vessel buy-back schemes) as a domestic fisheries management technique extensively. For Australia's major domestic fisheries, complex management plans which attempt to balance Commonwealth, state, and industry interests have been evolved over the years under joint Commonwealth-state management authorities. State fisheries acts in Australia tend to focus on nearshore fisheries and provide a range of licensing schemes and management techniques including the establishment of marine parks and aquatic reserves for habitat and species preservation purposes. (Hildreth, 1991a).

Australian sustainable development policy and the Australian resource assessment commission's coastal zone inquiry

The Australian National Strategy for Ecologically Sustainable Development was endorsed by Australian federal, state, and territory governments in December 1992. The strategy was developed based on the work of nine sector groups including fisheries and tourism. In their work the sectorial groups identified the number of cross cutting issues including the need for integrated management of the Australian coastal zone. (Australia, 1992; Australia, 1993; Kenchington and Crawford, 1993, pp118-119).

A specific objective of the Australian National Sustainable Development Strategy was the development of coastal policies consistent with ecologically sustainable development principles by each of the endorsing governments. Nationally this task was performed by the Coastal Zone Inquiry of the federal government's statutorily established Resource Assessment Commission. (Australia, 1993b). The Inquiry's report focuses on coastal as distinguished from marine issues for the most part. The Inquiry's final report proposes the enactment of a Commonwealth Coastal Resource Management Act. Similar to the U.S. CZMA, the proposed act would link Commonwealth funding of activities in the coastal zone to activities consistent with nationally agreed coastal management objectives; activities inconsistent with those objectives would be ineligible for Commonwealth funding.

The Inquiry's eight proposed national objectives include several related to sustainable development such as: (1) coastal zone resources should be available for fair and equitable public and commercial use that optimizes long-term benefits; (2) biological diversity of marine and terrestrial ecosystems should be maintained for future generations; and (3) coastal water quality should be maintained or restored to avoid any detrimental impacts on the integrity of coastal ecosystems and their ability to support a range of beneficial uses. A proposed National Coastal Action Program would be based on federal, state, and local development of more detailed objectives consistent with the eight nationally agreed objectives by 1995.

With the submission of the Coastal Zone Inquiry report to Prime Minister Keating at the end of 1993, the current Resource Assessment Commission and staff were disbanded and absorbed by other government departments; however, the commission legislation was left in place for possible future use. Whether the Inquiry's report will join 25 previous Australian coastal zone management reports prepared at the federal and state level during the last 25 years as largely unimplemented recommendations remains to be seen. Concrete steps for improved Australian coastal zone management are discussed in many of those reports as well as the academic literature. (Hildreth, 1992a, 1992b).

UNITED STATES EFFORTS TO ACHIEVE SUSTAINABLE USE OF MARINE AND COASTAL RESOURCES

Introduction

The single most U.S. mechanism for development of a U.S. national strategy for sustainability is the President's Council on Sustainable Development created by President Bill Clinton on June 14, 1993. Under recent previous administrations, some federal agencies were instructed confidentially not to use the term "sustainable development," and the concept was not explicitly embraced by President Bush at the 1992 Earth Summit. With the formation of the council, President Clinton has placed the concept of sustainable development on the official national agenda. However, the council's current funding is only $400,000 per year and its executive director was not appointed until October 1993. Furthermore, its lines of authority with respect to other federal agencies are unclear. Meanwhile, many regional, state, and local governments, institutions, and citizens groups have begun to work toward defining strategies for sustainable resource use and identifying important economic, environmental, and social indicators for progress toward sustainability. (Lesh, 1994).

Marine protected areas: The United States marine sanctuaries program

The U.S. National Marine Sanctuaries (NMS) Program was created in 1972 as part of the Marine Protection, Research, and Sanctuaries Act. The purpose of the program is to identify marine areas of special national or international significance due to their resource or human-use values and to provide authority for comprehensive conservation and management of such areas where existing regulatory authority it inadequate to assure coordinated conservation and management.

During the first phase of the NMS program, designation was a slow process, and sanctuaries included relatively small areas of ocean space within their boundaries and were managed for narrowly defined purposes. Eight sanctuaries were designated during this period: the U.S.S. Monitor, Key Largo and Looe Key off Florida, Gray's Reef off Georgia, the Channel Islands, Point Reyes, and Cordell Banks in California, and Fagatele Bay in American Samoa. (Hildreth, 1991b).

The designation process for marine sanctuaries has been streamlined, but Congress has also accelerated the process by designating or ordering the designation of certain sanctuaries. During this second phase of sanctuary designation, the Florida Keys, Monterey Bay, Stellwagen Bank, Hawaiian Islands Humpback Whale, Washington Olympic Coast, and the Flower Garden Banks national marine sanctuaries have been created. These sanctuaries differ from those designated earlier in two ways: 1) their size, and (2) their management approach. (Kalo *et al.*, 1995). The newest marine sanctuaries encompass extensive ocean areas of both federal and state jurisdiction. Designation of large ocean areas allows management of more of the activities that affect sanctuary resources and provides the opportunity to develop a sustainable ecosystem approach to resource management.

Federalism and offshore oil and gas development

Oil and gas development in state ocean waters is governed principally by state law. Some state statutes apply to both onshore and offshore development and otherwise are quite outdated and overdue for revision. Other state statutes have features such as larger tract sizes and higher royalty rates worthy of consideration in legislative revision and regulatory implementation of the federal Outer Continental Shelf Lands Act (OCSLA) which governs oil and gas development beyond state ocean waters. The significance of coastal state dissatisfaction with the current legal structure for OCS oil and gas development is indicated by President Bush's June 1990 decision postponing for at least a decade most OCS oil and gas development off California, Florida, Oregon, Washington, and the New England states, and congressional decisions postponing OCS development in most other areas except the Gulf of Mexico and Alaska.

Fisheries management

The major objectives of the United States Magnuson Fishery Conservation and Management Act (MFCMA) are to minimize foreign fishing within the U.S. EEZ and territorial sea and to establish comprehensive fisheries management plans (FMPs) governing domestic fisheries where appropriate. Through the MFCMA, federal fisheries management has been imposed on the zone extending beyond state ocean waters from three to 200 nautical miles offshore by limiting foreign access and catch to any surplus unharvested domestically, and by limiting domestic catch of specified stocks through zones, closures, gear restrictions and catch quotas mostly adapted from state fisheries management. The states remain primarily responsible for fisheries management within three miles, except for fisheries engaged predominantly beyond three miles, where MFCMA section 306(b) authorizes federal pre-emption of state actions which adversely affect a federal fishery management plan.

The MFCMA's provisions for allocation of unharvested surplus to foreign fishermen generally seem consistent with international norms. Other federal statutes link foreign fishing privileges to international whale conservation and driftnet regulation efforts. The MFCMA also asserts jurisdiction over United States-origin anadromous fish throughout their range and until 1990 exempted highly migratory tuna from any domestic management.

U.S. fisheries management appears to be evolving from single species management toward multi-species management of related fisheries. The next steps toward sustainable marine resources management will be to integrate fisheries management with management of marine mammals, some of which are listed as endangered or threatened under the Endangered Species Act, and other marine species including some non-marine mammal species also listed as endangered or threatened. With adequate budget and personnel, some of the more capable regional fishery management councils could be authorized to prepare regional marine ecosystem management plans as an extension of the multi-species fishery management plans they currently prepare (Jarman, Hildreth, and Marthaler, 1994).

Coastal zone management

Without a comprehensive land component, Australia's Great Barrier Reef scheme and the U.S. marine sanctuaries program are incomplete models for integrated management of marine and coastal areas. As one study of sustainable development puts it, "in terms of marine resources, sustainable development begins in the coastal zone, not the edge of the EEZ." (Beller, 1990). For a more integrated approach, one model is the United States Coastal Zone Management Program funded at the federal level and carried out at the state level. For more sustainable resource management offshore of the U.S., several coastal states have taken the lead in expanding their coastal zone management programs seaward. The programs now include provisions directed at federal offshore activities enforced under the federal consistency provisions of the U.S. CZMA based on the impacts within state ocean waters that federal ocean resource management decisions can have.

Australian states could be encouraged with similar legislation and funding support to take a greater interest in the sustainable management of multiple offshore ocean resource usage, including managing the coastal zone impacts of offshore resource uses as well as the coastal impacts of upland watershed resource uses. Given the framework provided by the 1980 offshore constitutional settlement which is quite sensitive to international law of the sea (LOS) considerations, there is relatively little risk that increased Australian state involvement in multiple use management offshore would run afoul of LOS limits on the exercise of national authority offshore. Rather, such state involvement would assist Australia in carrying out its stewardship responsibilities under LOS and other international agreements.

CONCLUSIONS

On the terrestrial side, sustainable resource use in Australia and the U.S. is complicated by mixed private and public ownership of land. Even on the marine side where that factor is not present, significant difficulties exist due to the mobility of the marine species of concern, the fluid nature of their environment, the mixed record of the federal, state, and provincial agencies charged with their protection and management, and congressional and parliamentary inability to legislate in other than a piecemeal fashion.

Fisheries are managed by both countries under principles related to sustainability such as optimum yield, but in practice many important fisheries have been overfished in unsustainable ways. Furthermore, from a "polluter pays" perspective, some important external costs of fishing such as bycatch of non-target species are only beginning to be internalized. For most fisheries, no attempt is made by governments to capture a portion of the economic rent through royalties or fees, and this may be a contributing factor to both the overfishing and the externalities problems. A precautionary rather than an optimistic approach to setting fisheries catch quotas could help reduce overfishing.

In some fisheries, bycatch of non-target species threatens biodiversity. In the U.S. major legal pressures to reduce such threats are generated under endangered specie and marine mammal protection laws. However, without improved protection for habitat important to both commercially valuable fish species and non-target bycatch species, both overfishing and bycatch problems may be expected to continue. An important function of the Australian and U.S. marine protected areas programs is protection of marine habitat. However, these marine protected area programs are relatively limited in geographic coverage.

In Australia and the U.S. the management regimes for offshore oil and gas drilling and seabed minerals mining are beginning to reflect the "polluter pays" principle, primarily by imposing compensation requirements when drilling or mining conflicts with other marine resource uses, the most dramatic example being oil spill compensation requirements. Offshore oil and gas and seabed minerals are nonrenewable resources, but current legal and institutional arrangements governing their exploitation do not address the difficult question of how to handle exploitation of nonrenewable resources under sustainability principles.

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WAVE-INDUCED MOTION OF A SUSPENDED CAISSON

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ABSTRACT

A platform suspended by hoist cranes has been used to launch large caissons for breakwaters on the northern Pacific coast of Japan. Prior to this operation a hydraulic experiment was made, which revealed that the caissons were swung by long-period waves beyond the allowable clearance of the facility. In order to reduce the caisson's motion, a new fender system was developed and the motion of the new launching system was predicted by an analytical model considering the collision between the caisson and the fender. The validity of the model was examined by the site measurement. As it was confirmed that the analytical model had the practical accuracy, the model was applied to the managing system for the safe and efficient launching operation.

INTRODUCTION

Because of economic growth, the demand for large harbours is increasing in Japan. However, as the bays near urban areas are fully developed, they have to be constructed on the coast facing open seas where wave conditions are harsh. To accommodate the severe conditions, caissons used for a breakwater tend to be larger and heavier. As the caisson gets larger, launching it into water becomes a difficult and important task in harbor construction. Various caisson launching systems have been used such as a slip-way, a floating crane, a floating dock and a dry dock. Among those are DCL (Draft Controlled Launcher) and Platform-type launcher (a launching system using a platform suspended by hoist cranes)- relatively new systems, as shown by Okayama (1993).

A Platform-type launcher was chosen, after studying various factors, to launch 99 caissons for the breakwaters at Tohoku Electric Power Co. Inc. Haramachi power station on the northern Pacific coast of Japan. The system had been used to launch caissons at sites on the coast of the Sea of Japan where wave conditions are relatively calm. However the waves coming to the Pacific coast are severer and more likely to contain swells. Taking into account the wave condition at Haramachi site and the dynamic characteristic of the launching system, a hydraulic test was conducted, concerning the behavior of the suspended caisson subjected to relatively long waves. Since it was clear from this test that a caisson moved beyond an acceptable range, a counter-measure to reduce the motion of a caisson was designed. A predictive model of caisson's motion was developed to provide the criterion on the workable wave condition and to be used for management of the launching operation. Then site measurements were conducted to ensure the accuracy of the model. The measured movement of the caisson agreed fairly well with the prediction.

SITE CONDITION

Haramachi power station is located on the northern part of Japan facing the Pacific Ocean as shown in Figure 1. On this coast, swells are predominant all the year round and the dominant wave direction is ENE.

Figure 2 shows the lay-out of the power station harbour. The harbour is being made after dredging a

Figure 2 shows the lay-out of the power station harbour. The harbour is being made after dredging a sand beach. There are two breakwaters under construction : a north breakwater projecting to the east to protect from the waves in the principal direction, and a south breakwater. They are composite breakwaters consisting of 99 caissons. The caissons are made and launched at the southern area of the harbor. The launching site is protected by a temporary breakwater made of concrete blocks.

Caissons, which are made in 6 bases, are dragged sideways on bogies, which move onto the launcher's platform as shown in Figure 3. There are two decks supported by steel piles along two sides of the platform. The platform is suspended by 18 wires of the hoist cranes that are placed on the decks. After a caisson is transported on the platform, the platform is lowered into water as all the wires are unwound at the same rate until the caisson becomes afloat due to its buoyancy, as shown in Figure 4.

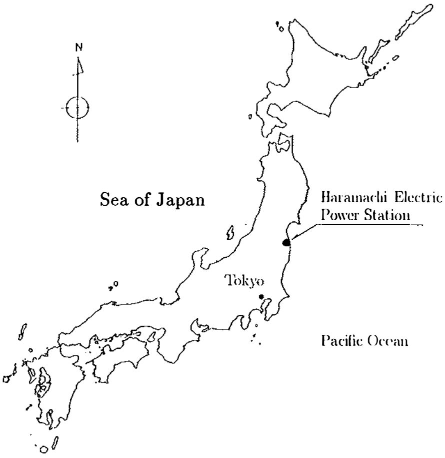

Figure 1. Location of Haramachi power station.

HYDRAULIC EXPERIMENT

This is the first time the launching system has been used on the Pacific coast, where long period waves always attack. At the design stage, a hydraulic experiment was conducted to investigate how much a caisson moves due to long period waves. The model scale was 1/20 and Froude similarity law was applied to the model. The incident wave angle, components of the caisson's motion and the caisson's draft are defined in Figure 5.

The caisson's natural periods at various draft were measured in still water, and shown in Figure 6. Note that all results from the experiment were converted to those for the prototype. The natural period for each motion increases with the draft, suggesting that the long waves become more influential on the caisson with the deeper draft. It is also observed that the caisson has almost the same natural period for surging and swaying motions. The caisson's motion in one directional random waves was measured in the wave channel. Two typical waves were selected by the statistical analysis of the site wave condition.

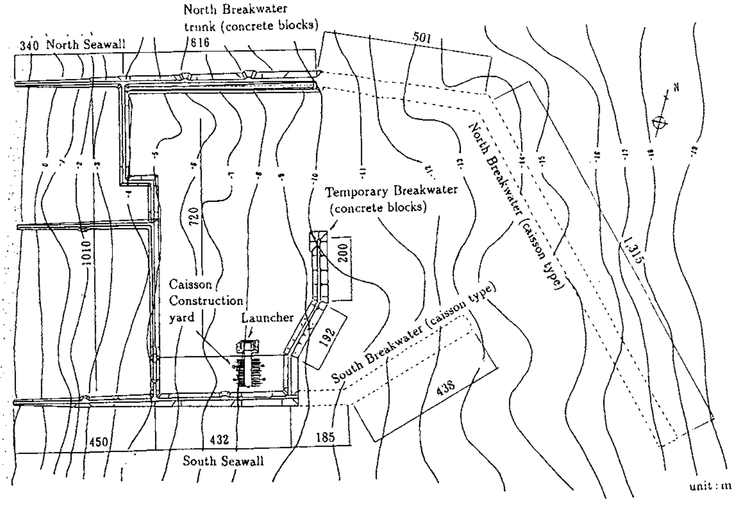

Figure 2. Lay-out of Haramachi power station harbour.

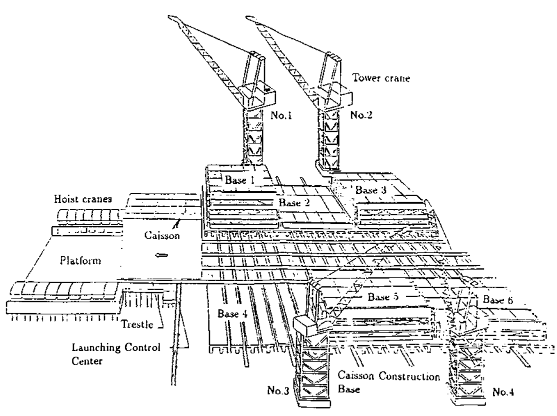

Figure 3. Construction yard of caissons and launching facility.

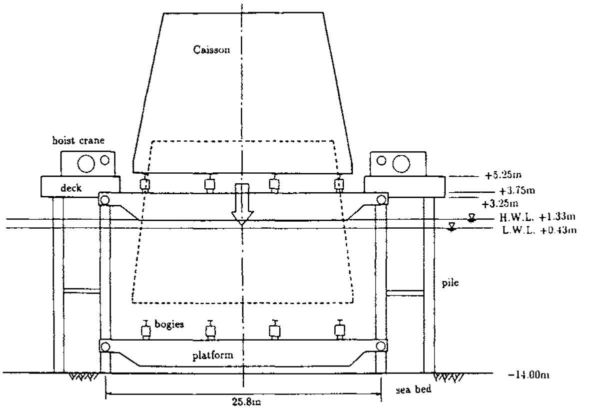

Figure 4. Launcher.

One wave has a significant wave height of 0.6 m and a significant period of 8 sec, while the significant wave height of the other is 0.4 m and its period is 10 sec. In Figure 7 the amplitudes of the surge motion for the two waves are plotted against the caisson's draft. The maximum amplitude in each case is found at the draft where the incident wave period coincides with the natural period. It is also observed that the maximum response to the 10-sec period wave is larger in spite of its smaller incident significant wave height, implying potential danger in long waves. Because the surge motion exceeded 1.0 m and the clearance between the caisson and the piles is 1.0 m, it is clear that the caisson will collide with piles as it is lowered. This experimental result requires a new fender system to absorb the impact force due to the collision between the piles supporting the deck and the caisson.

FENDERING APPARATUS

A new fendering apparatus was developed in order to reduce the caisson's motion due to waves and ensure the efficiency and safety of the launching operation. Figure 8 illustrates the new fendering system. Vertical steel bars are attached to the piles that support the deck, and fender blocks made of steel and rubber are placed on the platform touching the caisson. The clearance between the steel bars and the fender blocks on the platform is 10cm. At any draft of the caisson, the clearance is always kept at 10cm. By limiting the motion of the caisson by this small clearance, the collision force with the piles was reduced and was absorbed by the bending of the piles. Thus, the launching operation with this new fender system becomes safer as the displacement of the piles is kept within their allowable range.

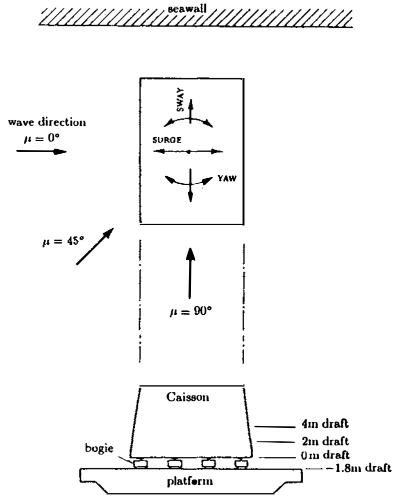

Figure 5. Definition of the model.

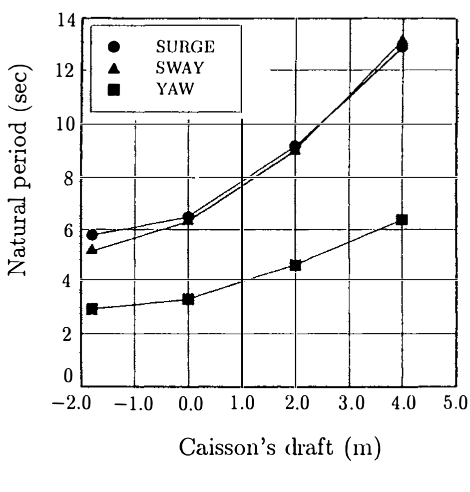

Figure 6. Caisson's natural periods related to drafts.

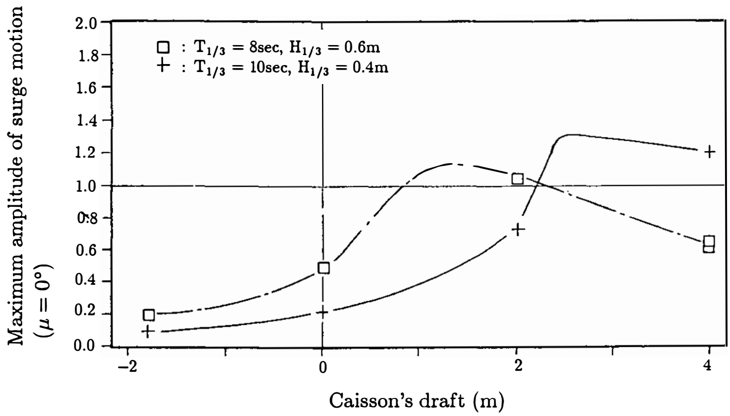

Figure 7. Surging amplitude of caisson's motion at different drafts.

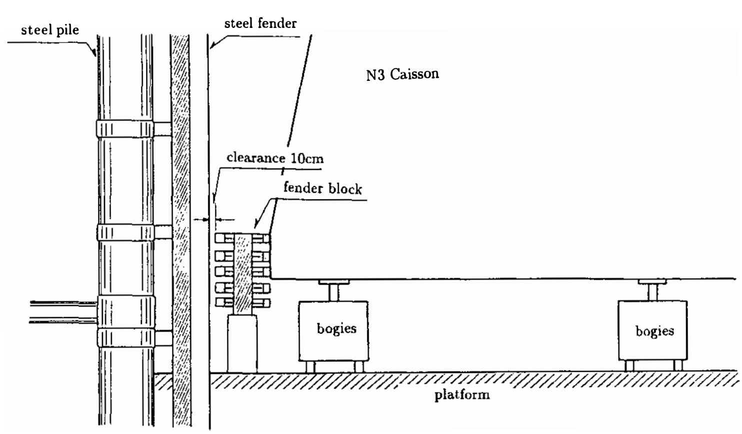

Figure 8. Fendering system.

ANALYTICAL MODEL

An analytical model was introduced to predict the caisson's motion and displacement of the deck that was set in motion by being hit by the caisson. Since the motion in the direction parallel to the sea wall, which may result in the collision with piles, is more critical in the launching operation, only two dimensional motion in the vertical plane parallel to the sea wall is assumed in the model as shown in Figure 9. In order to determine the spring coefficient k of the pile structure, the frame analysis was conducted based on the model as shown in Figure 10. Under the assumption that the amplitude of the caisson's motion is small enough compared with the wire's length l, the caisson's horizontal and vertical motions are described by the equations of motion as follows.

Horizontal motion

$$(M+M_a)l\frac{d^2\theta}{dt^2}+Cl\frac{d\theta}{dt}=-S\theta+F\cos\omega t \quad :-\theta_0<\theta<\theta_0 \qquad (1)$$

$$(M+M_a)l\frac{d^2\theta}{dt^2}+Cl\frac{d\theta}{dt}=-S\theta-kl(\theta+\theta_0)+F\cos\omega t \quad :\theta<-\theta_0 \qquad (2)$$

$$(M+M_a)l\frac{d^2\theta}{dt^2}+Cl\frac{d\theta}{dt}=-S\theta-kl(\theta+\theta_0)+F\cos\omega t \quad :\theta>\theta_0 \qquad (3)$$

Vertical motion

$$0=S-Mg+\rho Vg \qquad (4)$$

where θ is wire angle from the vertical, t is time, M is mass of a caisson and the platform, M_a is added mass, C is wave making damping coefficient, l is wire length, S is tension of wire, k is spring coefficient of pile structure, θ_0 is clearance between both fenders, ρ is water density, V is volume of caisson under still water level, g is gravitational acceleration, F is amplitude of wave-exciting force, ω is angular frequency of incident wave.

In this model, the hydraulic equations are first solved by the eigenfunction expansion method derived by Ijima, Chou and Yoshida (1976) to obtain the hydrodynamic coefficients M_a, C and F. Since Equations (1)-(4) are non-linear, the equations were solved for θ numerically by Runge-Kutta-Gill's method.

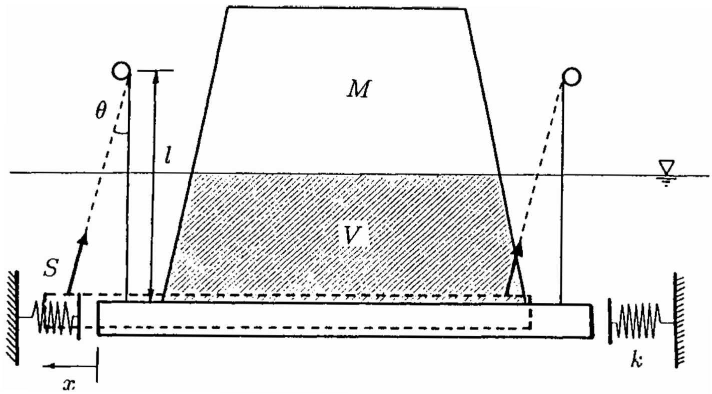

Figure 9. Analytical model.

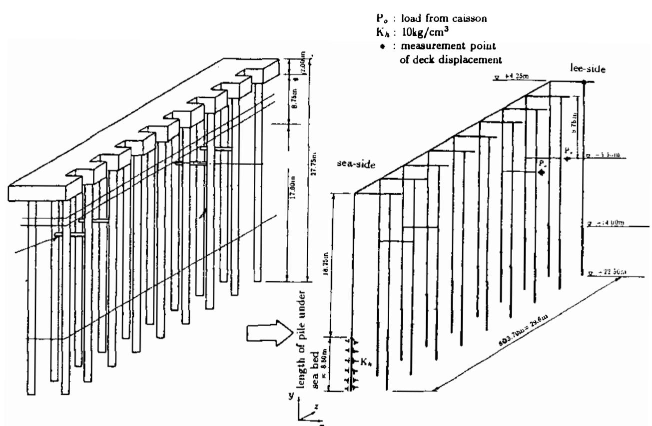

Figure 10. Frame model of the pile structure.

SITE MEASUREMENT

To examine the validity of the analytical model and to bring it in use, the site measurement was conducted on two occasions when a 3500 ton N3 caisson and a 2400 ton S1 caisson were launched. The sizes of two caissons are shown in Figures 11 and 12, respectively. Deployment of the measuring instruments is shown in Figure 13. Wave profiles are measured by two wave gauges installed at the offshore end of the two decks. Translation of the caisson was recorded continuously by two video cameras. The video tapes were then processed by a video analyzer, developed by Imai and Ikeya (1988), that digitally tracks the markers put on the caisson to obtain numerical translatable data, surge (parallel to the sea wall) and sway (perpendicular to it). The horizontal displacements of the decks were also obtained by the other cameras VTR3 and VTR4 in the same manner. All data were continuous in time and, in turn, in the draft, but the behavior of the caisson and decks were summarized at the several different drafts of the caissons. Wave conditions under which N3 and S1 caissons were lowered are shown in Table 1.

Table 1. Wave conditions.

	Significant wave height $H_{1/3}$(cm)	Significant wave period $T_{1/3}$(sec)
N3	24.9	8.2
S1	26.2	10.7

Figures 14 and 15 show the measured and computed double amplitude of the surge motion at certain drafts. In both cases, the analytical results practically agree with the measured data, though the estimates are larger almost all times. In the case of the N3 caisson, the agreement becomes better when its draft becomes larger. This indicates that the influence of the bogies and platform on the motion of the caisson becomes smaller at the large drafts. Because the bogies, the platform and some spaces between them were not modeled in the analysis except for their weight, the turbulence associated with the complicated geometry might have some significant effect on the behavior of the suspended caisson with small draft.

Figures 16 and 17 show the deck displacements caused by the collision between the piles and caisson N3 or S1, respectively. The analytical result for N3 caisson is in better agreement with the measured one. Since N3 caisson is much larger and heavier than S1 caisson, it is clear that the influence of the bogies and platform upon the caisson's motion could be smaller.

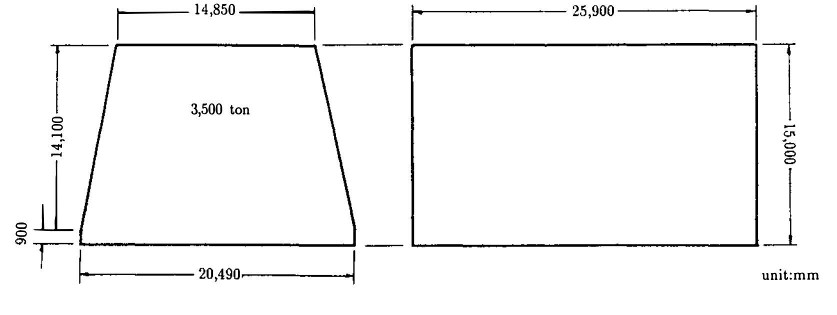

Figure 11. Dimension of N3 caisson.

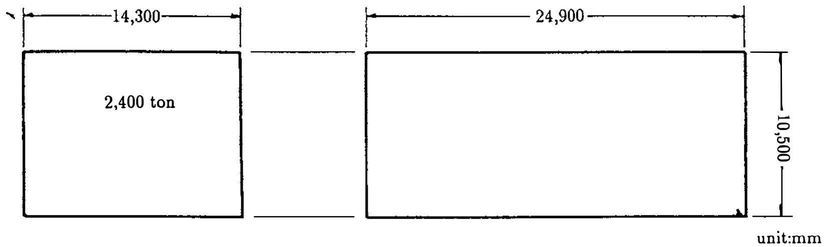

Figure 12. Dimension of S1 caisson.

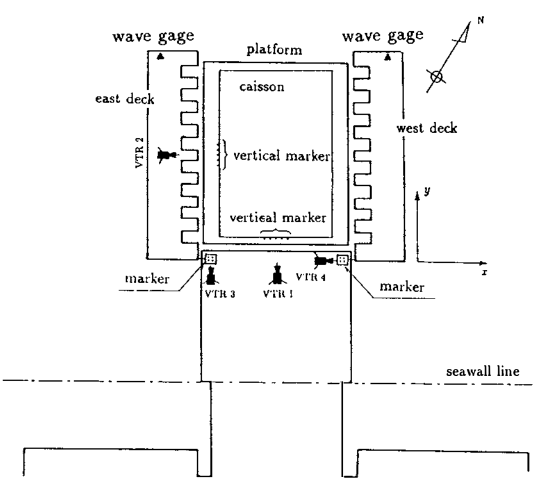

Figure 13. Deployment of measuring instruments.

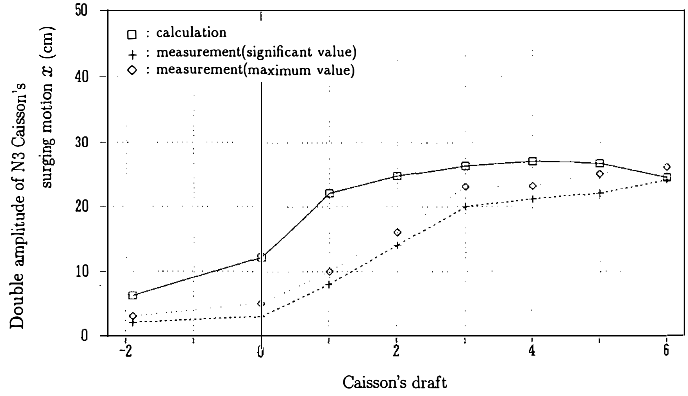

Figure 14. Comparison between computed and measured surge motions for N3 caisson.

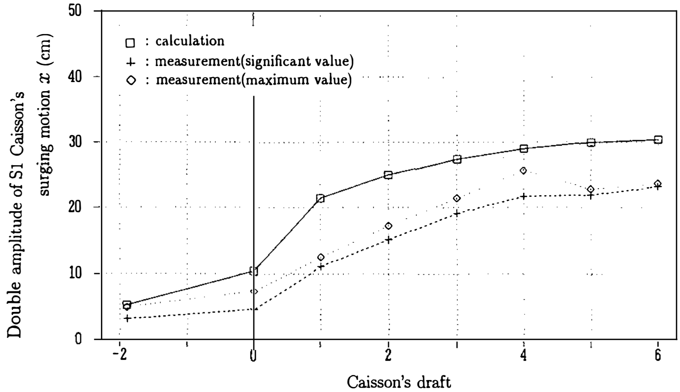

Figure 15. Comparison between computed and measured surge motions for S1 caisson.

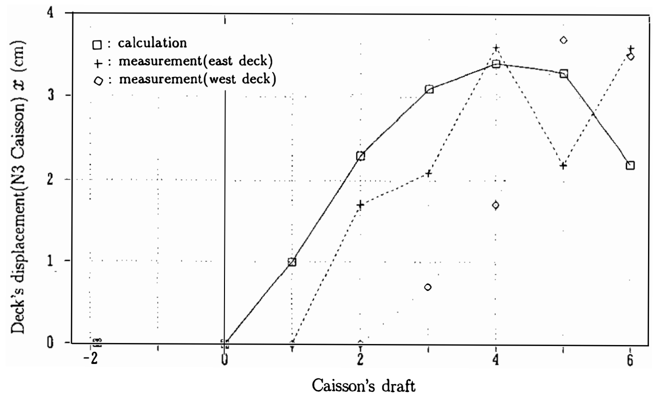

Figure 16. The deck displacement for N3 caisson.

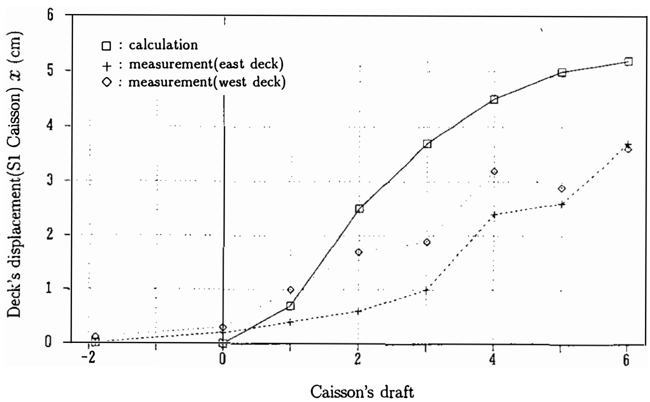

Figure 17. The deck displacement for S1 caisson.

CONCLUSION

A platform suspended by hoist cranes has been used to launch large caissons for breakwaters on the northern Pacific coast of Japan. In order to establish the managing system for the safe and efficient launching operation, extensive studies were made experimentally, numerically and by field measurement. The findings through those studies are as follows.

(1) The launching system employed in this project, which behaves like a pendulum, tends to swing more by long-period waves, and the suspended caisson went beyond the allowable clearance of the facility at certain drafts.

(2) It was confirmed by field measurement that the conventional analytical model, proposed here, considering the collision between the caisson and the fender was able to practically explain the actual behavior of the caisson due to waves.

(3) In order to reduce the caisson's motion, a new fender system was proposed. This new fender system, expected by the analytical model to work as designed and be useful for safe operation, has been performing well.

(4) The managing system for the safe and efficient launching operation was established with the aid of the analytical model, and it has been successfully in use.

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THE MANAGEMENT OF SAFETY IN MARINE TRANSPORTATION

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ABSTRACT

This paper considers the risks associated with marine transportation and measures that exist to control these risks taking account of the diverse and international nature of the industry. Consideration is given to the various regulatory bodies including the IMO, flag and port states and classification societies.

The use of reliability and risk assessments to demonstrate the positive effect such studies can make to marine safety is considered. Safety management systems are already accepted in other industries as an important factor in improving safety. How they can effect the marine industry and the application of the International Safety Management Code is discussed.

The risks associated with the marine industry are quantified based on data collected by Lloyd's Register since 1976. Direct comparison with other hazardous industries both onshore and offshore is not a simple exercise because of numerous factors specific to the marine industry. However, as an example, the safety record of liquefied natural gas carriers is briefly considered. The controls and procedures that have contributed to the low rate of casualties are identified.

INTRODUCTION

This paper considers the control of technical risks in the shipping industry, especially risks to people, property and the environment. Before considering the risks and their control it is important to understand the nature of the industry. It is truly international in that the purpose of shipping is to facilitate trade between nations involving the carriage of people and a wide range of goods. At the same time it is a very nationalistic industry as ships are built, operated and regulated by virtually every seafaring nation in the world.

Trade opportunities dictate the type and design of a ship whether it is for carrying hazardous chemical cargoes, crude oil, food products, iron ore or passengers. Increasingly the designs are becoming more specialised as market niches are exploited. It is rare for ships to be built in a series of more than four or five; in the present climate it is much more common for single or perhaps two ships of the same design to be ordered and built. With the exception of some of the patented specialised cargo containment systems each ship design is unique and typically is likely to be ordered, built and in service within less than two years, responding to a specific commercial opportunity. There is therefore little scope for prototype development.

In recent years competition within the industry has been fierce and this has resulted in severe economic pressures on shipowners. This has led to structural changes in the industry and has forced responsible owners and operators to consider radical solutions. Some of course have met this pressure head on through investment in new ships to provide a technologically superior service.

It is against this background that this paper considers how technical risk issues in the shipping industry are addressed and what developments are taking place to reduce risk. The paper considers the nature of marine risks, the current bodies involved in regulating and managing risk and a brief review of the casualty record to compare risk levels with other industries. Observations are also made on the place of risk and reliability assessment in more detail with reference to the marine transportation of LNG.

THE CONTROL OF RISK

The prime risks facing the marine industry can be grouped into five categories, that is, loss of life, loss of or damage to the cargo, loss of or damage to the ship and its equipment, damage to the environment and damage to business reputation.

These risks arise from a variety of causes which may be connected with the vessel itself, from the nature of the cargo, from the weather, from collision with another vessel or from human error. Whatever the cause the seaworthiness of the vessel and the competence of the crew are inextricably linked to the outcome. Each of these risks entails significant economic loss for one or more of the many parties involved in ship ownership, management and insurance.

It is clear that all parties in the industry have an interest in the proper management and control of risk. Management of risk is largely the preserve of the owner and operator who are seeking an optimum balance between the cost of risk reduction measures with the benefits they bring and the profitability of the operation. In reaching this balance it is necessary to acknowledge the measures to control risk that the industry has delegated to the regulatory authorities. There are two aspects of risk control considered here: statutory requirements, being the application of national and international law, and Classification offered by Societies such as Lloyd's Register.

The International Maritime Organisation

International legislation regulating the marine industry is prepared and agreed at the International Maritime Organisation (IMO). The IMO permanent secretariat prepares and coordinates the conventions and meetings at which delegations representing members debate the legislative issues.

Membership of the IMO is open to any member state of the UN and also to other states under prescribed circumstances. The organisation now has a total membership of one hundred and forty four countries, all of whom have the same voting power, the size of the merchant fleet of a country having no influence on the value of its vote. With such a large constituency, it is not surprising that rapid decision making is virtually impossible. This has led to the organisation being criticised for being too unwieldy and unable to respond to events. Various changes are being introduced by the current administration to alter this but it is unlikely that the organisation will ever be able to change legislation quickly enough to satisfy all its critics.

International conventions passed by IMO now form the backbone of international marine safety legislation. These conventions contain detailed requirements for:

- Fire protection, detection and extinction
- Carriage of dangerous goods
- Intact and damaged stability
- Lifeboats, life-rafts, life-jackets and other life saving appliances
- Navigational aids
- Light and sound signals
- Radio equipment
- Pollution prevention arrangements and equipment
- Computation of Load-line marks and conditions of assignment
- Tonnage computation

Development of these conventions, their amendments and countless resolutions has taken place in response to marine accidents. This reactive approach is almost unavoidable for such a body but in tackling new issues, such as the "Human Element in Shipping" the IMO is taking a more pro-active approach.

Each member state undertakes to establish national regulations based on the Conventions to which it is a party, to provide survey and administrative services to control its own shipping, to respond to requests made by other member states and to ensure that ships using its ports are properly certificated and maintained. Whilst this should provide for a uniform regulatory framework the varying degrees to which the codes, resolutions and conventions are adhered to and the different interpretations applied by member states is now recognised as a significant weakness.

Flag states

All ships are required to be registered and thereby come under the legal jurisdiction of a national administration. Each administration has its own conditions of membership reflecting local legislation, two relevant areas being employment and taxation. Furthermore each administration has its own interpretation and implementation of the IMO conventions. The variation in operating costs between regimes can make a significant difference to a ship's competitiveness. "Flagging out" ships from their home registries, particularly in the developed countries, to registries where there are lower costs is one of the effects of the economic pressures facing shipowners. Some would argue that this has had an adverse effect on safety.

Compliance with the IMO conventions is a statutory requirement and without statutory certification ships cannot operate internationally. Many member states do not have the capability to undertake the technical assessment of their ships, therefore for this and other reasons they have decided to delegate this function. In common with other major Classification Societies Lloyd's Register has been authorised by over 125 national administrations to implement some or all of these functions on their behalf. Such delegation is allowed under the IMO Rules but the administrations retain their responsibilities and obligations under the Conventions. The training and assessment of crew competence and the administration of certification of seafarers is usually retained by the national administration.

National administrations therefore have a key role to play in reducing risk through ensuring proper and uniform implementation of IMO Conventions, proper standards of training and certification for personnel and delegation, where necessary, only to those bodies competent enough and with sufficient resources to undertake surveys on their behalf. Regrettably there is still some way to go in achieving these aims universally.

Port state control

Not surprisingly the implementation of IMO Conventions varies considerably from Flag State to Flag State. Also for various reasons some governments have not ratified all of the IMO conventions. This has created a concern that there are a large number of ships at sea without paper certification. The response to this led to the introduction of Port State Control. The Memorandum of Understanding on Port State Control was signed in Paris in 1982 by 14 maritime authorities. The signatories agreed to inspect at least 25% of foreign flag ships visiting their ports in any one year with the sanction of delay until deficiencies were put right. This has had a significant effect on the standards of maintenance of ships visiting ports of the signatories of the Memorandum of Understanding and has resulted in pressure on various governments to ratify and implement the provisions of the conventions. This is a good example of where responsible national administrations have taken active steps to reduce risks to their waters, coastlines and port environments from sub-standard vessels.

Classification

Ship Classification comprises the setting, updating and world wide application of standards for hull structure and essential shipboard engineering systems, prior to and during construction and throughout the life of the ship. Classification came into being more than two hundred years ago as a voluntary activity and is carried out today on the basis of sophisticated, comprehensive and detailed classification rule requirements. The Classification Societies' expertise in the areas of hull and shipboard engineering systems is acknowledged by IMO and therefore few of these aspects are addressed in IMO conventions. The process of Classification is still, in theory, voluntary, but in reality is intimately bound up with statutory requirements.

Lloyd's Register's Rules for the Classification of Ships are a mixture of goal setting and prescriptive requirements and have evolved over many years. They are continuously updated in the light of research and development, new materials and technologies and regular feedback from service experience received through survey reports. LR's database contains reported defects for the entire classed fleet over the last twenty years providing a unique source of information on why and how components fail. The Rules contain detailed requirements for materials, ship structures, main and auxiliary machinery, control engineering systems, electrical installations, refrigerated cargo installations and fire protection, detection and extinction arrangements. They also contain requirements for survey during construction and periodic survey in service to ensure the prescribed standards are satisfied.

Designers of the ship's hull or machinery have the option to use prescriptive formulae for the determination of scantlings and allowable stresses or may use more complex methods of analysis to demonstrate equivalence with the requirements. In addition to scantling determination the Rules also prescribe requirements for the provision of safety devices, control alarms and shutdown arrangements to protect life and equipment. For piping and electrical installations the Rules stipulate key requirements for layout, arrangement, duplication and duty. In areas of rapid technology change, such as computer based control systems, the Rules are increasingly of the goal-setting type setting out what has to be achieved rather than how it should be achieved. Unlike individual standards for specific items of equipment considered in isolation the Rules are based on a systems engineering approach thereby ensuring that technical interfaces are properly addressed.

The Rules are in reality the result of a continuing series of generic risk assessments tempered by experience of what is practically achievable. Precisely the same questions are asked, in a systematic way albeit implicitly in this process, as in the assessment of risk. What can go wrong (on the basis of experience and current knowledge), how likely is it to go wrong (have we seen similar failures before?), what are the consequences of failure (does this merit a Rule?) and what can we do to prevent it from failing in the first place .

A criticism that has been levelled at the Rules is that they are not scientifically based, they are too prescriptive and should be rewritten so that ships can be designed from first principles against design standards. These arguments do not stand up well to close scrutiny. The Rules are indeed scientifically based having had the fruits of research and development in structures and equipment continually fed into them and are constantly validated against service experience. It is true that many of the Rules are prescriptive but it has to be realised that the diversity of the shipping industry means that ships are being built in the most sophisticated yards with large design teams and at the same time in small yards which may have limited resources and experience. The knowledge and expertise encapsulated in the Rules is of vital importance for the latter case whilst providing a useful check in the former. Again it is the issue of diversity coupled with the practical realities of an international and highly competitive industry which dictates the approach. Thus Classification, through survey programmes and the Rules, makes a very significant contribution to the reduction of risk by ensuring that ships and their equipment are built and maintained to a recognised and accepted standard.

Owners responsibilities and the International Safety Management Code

Certification of the ship and its equipment is of course only a part of the picture in managing the risk of the operation. The possession of the right certificates awarded by a competent organisation may enable the operator to comply with the law and obtain the necessary insurance cover but it does not relieve him of the ultimate responsibility for safety.

There are a whole range of operational issues for which the owner, operator, manager and ultimately the master is responsible which contribute to good risk management. Increasingly these aspects are being encapsulated as part of Quality Systems for ship management addressing the shore based support and management structures as well as the shipboard operations.

The IMO has recently adopted the Certification Scheme to the International Safety Management Code (ISM Code) which when applied will demonstrate a shipping company's commitment to the safety of its vessel, cargo, passengers and crew and to the protection of the environment. It sets broad levels of performance in such areas as resources and personnel and emergency preparedness and it will be for the company owning or running the ship to develop and implement a Safety Management System and to audit it regularly. The ISM Code will be made mandatory for most vessels from July 1998.

It is widely accepted in the marine industry that the "human element" in the management of risk has been ignored for too long. Analysis of casualty data shows that over eighty per cent can be directly attributed to human failings of one sort or another; a statistic that is common to many industries. It is this factor which the implementation of the ISM Code will address providing an opportunity to reduce risks.

The Certification Scheme to the International Safety Management Code

The Certification Scheme to the ISM Code is a means by which a shipping company can demonstrate its commitment to the safety of its vessels, cargo, passengers and crew and to the protection of the environment.

The scheme provides for the assessment of a company's safety management systems on board vessels and in shore based offices. The ISM Code requires each ship in a company's fleet to be certified along with the shore based management systems. This certification does not in any way replace international or national statutory requirements and does not endorse the technical adequacy of the vessels managed by the company. However, ISM Code certification will confirm that:

- an appropriate management system has been defined by the company for dealing with safety and pollution prevention on board,
- the system is understood and implemented by those responsible for the various functions,
- as far as periodic assessments can determine the key actions indicated in the system are being carried out,
- records are available to demonstrate the effective implementation of the system.

As noted earlier the ISM Code Certification Scheme does not in any way replace or substitute statutory or class surveys. It is an assessment of the management systems of the company and the vessels it owns. An ISM Code certificate is valid for three years provided the vessel remains under the same ownership/management, flag and class throughout the period of the certificate's validity.

Application of the ISM Code will be mandatory from 1 July 1998, however, many owners will seek certification well ahead of that date. In Australia, the Australian Ship Managers Association is hoping to achieve voluntary certification of all Australian flagged vessels by 1 July 1995.

THE CASUALTY RECORD

It is necessary to examine the casualty record to see how effective the regulatory regime has been at controlling risk. Lloyd's Register publish a Casualty Return each year and from this Table 1 shows the number of ships lost as a percentage of the world fleet over the period 1980 - 1991. This shows a clear reduction over the period, the increase in 1991 being due to the number ofbulk carriers lost.

Lloyd's Register's databases containing details of all serious casualties to ships over 100 GRT have been interrogated to estimate the Fatal Accident Rate for different types of ship over the period 1978 - 1992. The database only records fatalities or missing persons resulting from ship casualties, eg. fire, explosion, collision etc., and does not include deaths for other reasons, eg. man overboard, disease etc. The estimates are shown in Table 2 for a selection of ship types. In arriving at the FAR assumptions have had to be made about the number of crew and this has been taken as 25 for the first four categories and 15 for fishing vessels.

Table 1. Number of ships lost as a percentage of the world fleet

YEAR	NO OF SHIPS LOST	PERCENT OF TOTAL FLEET	TOTAL NOS. IN WORLD FLEET
1980	387	0.52	73,832
1981	359	0.49	73,864
1982	402	0.53	75,151
1983	340	0.45	76,106
1984	327	0.43	76,068
1985	307	0.40	76,395
1986	265	0.35	75,266
1987	219	0.29	75,240
1988	231	0.31	75,680
1989	211	0.28	76,100
1990	188	0.24	78,336
1991	258	0.32	80,030

Table 2. Estimate of Fatal Accident Rate due to casualties for typical ship categories

SHIP TYPE	WORLD FLEET SIZE (1992)	SERIOUS SHIP CASUALTIES (1978-1992)	CREW FATALITIES (1978-1992)	SHIP HOURS (x 10^8) (1978-1992)	ASSUMED CREW SIZE	FATAL ACCIDENT RATE
BULKERS	4552	98	1235	6.0	25	8.2
TANKERS	8484	195	1267	11.1	25	4.6
GENERAL CARGO	16601	542	3957	21.8	25	7.3
LIQUEFIED GAS	921	13	71	1.2	25	2.4
FISHING	24,000	269	1949	31.5	15	4.1

These estimates need to be treated with caution for the reasons mentioned above. In his submission to the House of Lords inquiry into Safety Aspects of Ship Design and Technology [House of Lords, 1991, 1992], Dr J Cowley presented data for the UK fleet from 1978 to 1988 from which it can be estimated that deaths due to accidents on board are between one and two times those from vessel casualties, whilst deaths due to disease, suicide etc. are between two and three times the vessel casualty rate. This suggests that the true FAR figures are, approximately, at least double those shown above assuming of course that the ratios from the UK fleet hold good for the world fleet. The FAR for the offshore industry in the North Sea, without Piper Alpha is commonly taken as 8 for group risk and as 30 for the most exposed persons. Analysis of the casualty data over the fifteen year period clearly shows a reduction in the number of deaths for the world fleet although it has not been possible to measure this against the total number of seamen at risk.

RISK AND RELIABILITY ASSESSMENT

In the marine industry risk assessment techniques have typically been used to consider operational issues connected with ships at the concept design stage. The predictive nature of risk assessment allows consideration of issues which are not readily addressed by other approaches. One of the most common applications is consideration of the transport of hazardous cargoes by sea, usually with particular emphasis on the consequences of cargo or bunker spillage on the population and environment in the vicinity of port installations. It has been used frequently in LNG importation schemes enabling integration of shipping and shore based considerations.

The use of risk assessment has also been used in submissions to the IMO. On the question of double hulls for tankers a risk based approach was used to argue successfully for the equivalency of different designs. A further example was the comparison of the risks associated with the transportation LNG and other hazardous and noxious substances which supported a recent Indonesian Government submission to the IMO. Brief details of the study are discussed in the next section.

Risk and reliability assessments are also employed in life extension studies and the transfer of hazardous cargoes at sea. There are also a number of studies associated with shipping in environmentally sensitive areas eg. the Great Barrier Reef.

Following the Herald of Free Enterprise tragedy a number of studies were carried out into the application of risk assessment to ship operations. In particular this included looking at human factors in ship operations, and these were some of the first studies to consider the risks arising from actions on board. It is likely to be this area in which most new developments will take place in support of the development and implementation of Safety Management Systems, in part through the ISM Code.

The new IMO High Speed Craft Code requires reliability analyses to be carried out on critical propulsion, directional control, power and auxiliary system in order to demonstrate that the likelihood of failures resulting in hazardous operating states, eg. causing loss of steering or potential instability, can be reduced to acceptable levels.

Whilst this paper is restricted to marine transportation, it is worth noting that the offshore marine industry has requirements for a number of safety, risk and reliability assessments of marine systems. For more than a decade these have included failure analyses of dynamic positioning systems on diving support, drilling and production vessels, ballast systems and fire-fighting systems on offshore drilling and production units. In earlier days these assessments were hardware oriented however, more recent requirements for offshore safety cases are increasing the application of safety assessment techniques and dealing with them in a holistic manner, to integrate the operational aspects. It is noted that the safety management systems offshore, whilst underpinned by quality systems focus more directly on hazard identification, and risk assessment and control. However, the offshore industry has its own hazards and works within its own regulatory frameworks which are increasingly "goal-setting" or objective where safety case regimes apply.

RISK ASSESSMENT OF THE MARINE TRANSPORTATION OF LNG

In preparation for an IMO debate on the carriage of hazardous and noxious substances, Pertamina asked Lloyd's Register to undertake a comprehensive study on the risks associated with LNG. The study covered:

- a review of marine incidents involving gas carriers and other HNS vessels,
- a review of experimental work on LNG,
- the use of risk assessment in marine activities,
- a comparison of the risk associated with LNG and other HNS cargoes and how these compared with other industrial risks.

The study of marine incidents highlighted the benefit gained through a high standard of crew training and operating procedures and emergency response procedures for both the crew and onshore operators. There are of course other operational factors which contribute to the excellent casualty record of LNG carriers including long term trade contracts on dedicated routes. However, crew training and rigorously implemented procedures are very important. The port control procedures applicable to LNG carriers is another example of the application of safety management systems.

Design features which have contributed to the low level of incidents and limited the consequences when casualties have occurred include:

- double hull protection,
- containment systems specifically designed for the transportation of LNG at low temperatures,
- containment at near atmospheric pressure,
- less complex design of operational equipment.

The review of the experimental work conducted over the last 25 years was to provide a basis for understanding the hazards associated with LNG and the consequences of both ignited and non-ignited releases. This work was used as supporting evidence in the risk assessment that followed.

The transfer and shipping of LNG can be the subject of a risk assessment like any other process. The difficulty lies with the small data population given the excellent record of LNG carriers. Like many industries, human errors are a major cause of incidents in the marine industry. This is also true in the transportation of LNG despite the high level of crew training. However, it is apparent from the risk assessment that operating procedures and the response of operators to hazardous incidents, significantly contribute to the control and mitigation of the consequences of these incidents.

The levels of risk determined for transporting LNG and other HNS cargoes were assessed and compared with other industrial risks and with societal risk generally accepted by the public. The study included the impact on people, the environment and property. Although, as with any risk assessment there is a level of uncertainty in the results the level of risk was demonstrated to be tolerable particularly where hazardous sites are located away from centres of population.

The risk assessment for LNG carriers identified the hazards and the controls and procedures which contribute to the excellent safety record of these ships. The application of these techniques to other vessels would not in itself improve safety, but it would provide the information required to identify cost-effective measure which contribute to the reduction of risk to the crew, the environment, the ship and port facilities.

CONCLUSIONS

The technical management of risk in the marine industry relies on a pragmatic mixture of prescriptive and performance based regulation derived from many years of practical experience, research and theoretical study. To date it has been successful in controlling risk, in what is a very hazardous and diverse industry, although as the casualty record shows there is room for further improvement. The detailed examination of the safety record of marine activities and the quantification of these risks through a structured assessment will also help in determining cost-effective measures to improve safety at sea.

The industry is moving towards a more systematic approach to risk management and evidence for this is seen at IMO and in the more progressive national administrations and Classification Societies. The development of Safety Case regimes in offshore exploration and production is a related area regarding the marine systems and their assessment and the progress there is noted.

The greatest contribution to risk reduction is likely to come from improvements in operational practices and proper management of safety. Current initiatives to introduce formal safety management requirements through IMO will lead in this area. It seems likely that safety cases will be required for some specialised ships in the future although there is no clear consensus yet on how a regime would be developed . With most of the hazards well understood such a regime would focus heavily on safety management issues which are already being addressed through the Quality Systems approach of the ISM Code.

Initiatives such as the Engineering Council's Code and Guidelines [Engineering Council, 1993] will also assist engineers working throughout the industry take a wider view of their responsibilities in managing risk. Worldwide dissemination of the documents is to be encouraged so that the safety of all mariners is raised to the highest practicable levels.

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ENHANCEMENT OF AUSTRALIAN FISH STOCKS: ISSUES CONFRONTING RESEARCHERS AND MANAGERS

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ABSTRACT

Australia has a huge area of ocean under its control but relatively limited fisheries resources. Enhancement therefore appears highly desirable and likely to succeed, at least at first glance. Despite this potential there have been few successful enhancements of marine fish stocks and several introductions of species are regarded by some as ecological disasters. The issues facing Australia's fisheries researchers and managers include: should enhancement be restricted to species which are recruitment limited; can we predict what displacement or substitution of other species will occur; will the inevitable ecological changes be acceptable; will there be detectable changes to the gene pool and, if so, is this acceptable; can the inadvertent introduction of diseases or parasites be completely ruled out; can the introduced individuals, or their progeny, be constrained; can success (cost effectiveness), or failure, or disaster, be accurately assessed; who will own the product of enhancement and who will benefit; who will take the blame if the results are inconclusive or negative?

INTRODUCTION

Australia has the world's third largest declared fishing zone and yet production from this zone is ranked only fifty-fifth in the world (Kailola *et al.,* 1993). Domestic production of a little more than 200,000 tonnes annually (ABARE, 1993) represents approximately only 0.2% of world fisheries (FAO, 1993). In terms of production per unit area, Australia is at the bottom of the international scale. Fortunately for Australia, an unusually high proportion of our seafood production is high priced crustaceans and molluscs such as lobsters, prawns, oysters and abalone.

It is now accepted that the low yields from Australia's waters are not the result of either unimaginative fishing practices or any inherent desire not to exploit, but are the true manifestation of low productivity of Australia's immense ocean areas (Rochford, 1980). In fact many of Australia's important fish and crustaceans are already over-exploited. A casual observer could be forgiven for immediately assuming tremendous potential for enhancing Australia's fisheries by somehow increasing the underlying productivity or otherwise making better use of the immense area available.

AUSTRALIA'S HISTORY IN FISH STOCK ENHANCEMENT

Natural historians with the First Fleet in 1788 described Australia's coastal fisheries resources as meagre (Tench, 1791). An 1880 Royal Commission concluded that they had already declined significantly (Anon, 1880). In 1900 attempts began to introduce English fish species to enhance our coastal fisheries (Anon, 1901). Efforts to breed and stock these species proved unsuccessful, perhaps fortunately.

Salmonids were introduced to Tasmania in 1864 and by 1888 brown trout (*Salmo trutta*) had been released in NSW waterways (Faragher, 1986). Most of Australia's cold, freshwater habitats remain "enhanced" with trout.

Enhancement of freshwater fisheries with local species has gained momentum in recent decades. Since the 1960's research has enabled the breeding of an increasing number of our native freshwater fish, for example, murray cod (*Maccullochella peeli*), trout cod (*Maccullochella macquariensis*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*). Millions of individuals of selected species have been stocked to enhance fisheries or help remove threats to the survival of the species. These stockings have been largely concentrated in artificial impoundments to and from which natural recruitment is minimal or non-existent. Many significant fisheries have been created and the existence of several threatened species given much greater security.

The introduction of certain species, however, has been seen to be detrimental to the native flora and fauna. The European Carp (*Cyprinus carpio*) has invaded most of the Murray-Darling basin since its introduction last century and now dominates the fauna in many areas (Harris, 1994). Although few unequivocal research results are available, it is believed that carp displace native fauna and undermine waterways. As a result of their feeding behaviour, water turbidity is increased and this is believed to increase the nutrient concentration which promotes the growth of blue-green algae (Gehrke and Harris, 1994). The destruction of aquatic plants may be due to these changed conditions or to the physical uprooting of plants caused by the feeding habits of the carp (Harris, 1994).

There have been very few deliberate introductions of marine fish or invertebrates, or major enhancements of wild populations of existing species. The Pacific oyster, *Crassostrea gigas*, was deliberately introduced in the 1940's with mixed success (Thomson, 1952). In Tasmania the species now forms the basis of a significant aquaculture industry while in many estuaries in New South Wales it is regarded as a noxious competitor for the local Sydney rock oyster. Scallops, *Pecten fumatus*, have been reseeded in parts of Tasmania but success is questioned.

ISSUES TO BE ADDRESSED

While Australia's record of successfully enhancing freshwater fisheries is impressive, our record in marine areas is neither long nor spectacular. Some would argue that even our successes are inappropriate as we should not try to improve on nature. Restoration of damaged habitats, decreased pollution and reduced fishing pressure are seen by many as the only appropriate enhancements. Others argue maximum economic yield, even short-term in many cases, is the appropriate goal for aquatic resource management (eg. DPIE, 1989).

Commercial and recreational interest in reaping increased returns from our oceans will ensure incessant attempts to improve on nature; the world's ongoing dependence on agriculture is a compelling analogy. Accepting that attempts to enhance fish stocks are not only inevitable, but probably desirable, it is appropriate to consider some of the major questions that must be addressed:

Should enhancement be restricted to species which are recruitment limited?

The assumption is often made that when a species declines, for whatever reason, to the point that recruitment is diminished, then only good can result from attempting to help the species recover. Pressure from community groups to have depleted resources restored will often tip the balance in favour of attempts to supplement natural recruitment. Unfortunately it cannot be taken for granted that human efforts to even restore fish populations will be entirely benign. Nonetheless the banner of restoration will normally provide adequate justification for attempting enhancement. If we are to play God then restoration appears less sinful than tampering with nature merely to produce some risky economic gain.

Enhancements to recruitment, such as may flow from improvements to vital habitats, have, at least superficially, fewer risks than those based on artificial direct supplementation of recruits. They therefore have great appeal even though in very few cases will it be possible to predict the outcome accurately.

For situations other than restoration of depleted stocks it will be extremely difficult to prove that population levels are recruitment limited. Natural fluctuations in populations coupled with uncertainty over issues numbers 2 and 7 below, will further complicate assessment of the feasibility of enhancement.

Can we predict what displacement or substitution of other species will occur?

In most cases the answer is a resounding "no", even without addressing the vexing issue of the accuracy of predictions. If we do "enhance" a fish stock by artificial introductions of juveniles we cannot be certain what species mix or size composition of food organisms will be consumed as these juveniles grow. We must assume that if the enhancement is to be successful, at least some individuals of other organisms that make up the ecosystem will be consumed or displaced. The quantity consumed will be dependent upon the numbers of introduced organisms, their survival rates, feeding preferences and food conversion ratios. The species consumed will be dependent upon availability and can be expected to vary enormously depending upon the vagaries of a multitude of natural processes which influence recruitment, distribution and abundance of all impacted organisms. For complex ecosystems, such as estuaries, it is difficult to accept that we will ever know enough to enable an accurate description of what displacement or substitution actually occurs. Accurate prediction may be fantasy.

Will the inevitable ecological changes be acceptable?

The ecological changes resulting from enhancement are complex to predict and, because of the highly interactive nature of many aquatic ecosystems, determining cause and effect will be expensive and difficult (di Castri, 1990; Holcik, 1991). In this context it is useful to differentiate between two sorts of enhancement: the introduction of new species and the augmentation of populations of existing species.

The introduction of new species or individuals of the same species from different reproductive populations has the potential to cause large changes in ecosystems. Often these introductions cause the decline or disappearance of endemic species, hybridization and the introduction of diseases. Examples of such deleterious effects in terrestrial systems abound (Elton, 1958; Mooney and Drake, 1986; di Castri, 1990). Although the ecology of invasion in aquatic systems is less well documented (Carlton, 1992), several case studies exist, eg. trout (*Salmo* spp.) in Australasia (Crowl *et al.*, 1992), Nile Perch (*Lates niloticus*) in Lake Victoria (Okemwa and Ogari, 1994), and the movement of introduced and native species among drainages in south-eastern Australia (Tilzey, 1980; Fletcher, 1986; Harris and Battaglene, 1990; Arthington, 1991).

The enhancement of fisheries by augmenting populations with more individuals of the same species is likely to be less problematic than introducing new species. Whether altering the relative abundance of species in an ecosystem produces significant change is, however, a large issue. The development of a major (> 100,000 tonnes/year) fishery for chum salmon in Japan is quoted as a major successful enhancement (Suda, 1990). But do all Japanese fishers, and those in neighbouring countries and open ocean areas, agree that the approximately 1 million tonnes of marine organisms (assuming a 10:1 conversion ratio) that these salmon must be consuming have not been missed or have not altered the ecosystem in some deleterious way? A separate issue is whether the impact of population augmentation is measurable.

Will there be detectable changes to the gene pool and, if so, is this acceptable?

Changes to the gene pool of the receiving ecosystem inevitably follow human manipulation, either directly by the introduction of new genetic material, or indirectly by changing the relative representation of species and altering the selective regime operating in the system. Predicting the population consequences of such changes and providing unequivocal evidence of their impact will be difficult in all but the most striking examples.

There is increasing evidence that stocking rivers with hatchery reared fish may reduce or otherwise alter genetic diversity (Allendorf and Phelps, 1980; Allendorf and Ryman, 1987; Billington and Hebert, 1991; Hindar *et al.*, 1991). Perhaps the most well documented example of this problem has been the impact of enhancement as a tool in managing salmon fisheries in North America. The strong homing behaviour of these fishes has produced a number of genetically distinct populations that have been lost or contaminated as a result of widespread introductions (see Waples, 1991 for review). Recognition of this problem has led to programs that seek to ensure genetic diversity in source populations (eg. the ONMR program; Ferguson *et al.*, 1991).

The gene pool may also be altered after the introduction of exotics by hybridization with indigenous species (Allendorf and Leary, 1988). Again, the gathering evidence from salmonid fisheries suggests that hybridization may cause long-term and unpredictable genetic changes (see Waples, 1991 for review). In an interesting variation of this problem, Arthington (1991) describes the interbreeding of two introduced strains of European carp in the Murray-Darling system and the creation of a more vigorous and invasive hybrid that is now found over a very much larger area.

Policies to minimize alteration of the genetic complement of native populations are clearly required. Regrettably, however, it is likely that the unpredictability and great potential for lagged effects of introductions will make post hoc descriptions of irreversible changes more common than prescriptive guidelines.

Can the inadvertent introduction of diseases or parasites be completely ruled out?

Obviously not completely, indeed the history of introductions would suggest that secondary introduction of diseases and parasites is disturbingly common (Carlton, 1992; Welcomme, 1986; Stewart, 1990). Understanding of diseases and their transmission in aquatic organisms is relatively fragmentary. Successful control of disease requires an understanding of the life-history of the disease organisms, including vectors of transmission. Whether introduced diseases can be controlled at acceptable levels is yet another conundrum.

Several codes of practice to reduce the transfer of disease around the world have been proposed (eg. Sindermann, 1986; Turner, 1988). The ICES Code of Practice requires both an in-depth knowledge of potential diseases and the production of F_1 individuals from introduced broodstock held in isolation (Sindermann, 1986). Although any code of practice controlling such introductions will be difficult to administer, a policy of minimizing risks to some rather arbitrary and low level will most likely prevail. This appears appropriate and is in keeping with Australia's current quarantine policy (eg. Langdon, 1990).

Can the introduced individuals, or their progeny, be constrained?

This question highlights the differences in principle between enhancement of isolated impoundments and open ecosystems such as estuaries or oceans. Obviously the more constrained the possible dispersal of individuals the easier it is to describe at least the direct known risks. Only in impoundments will constrainment be possible and even then there are other serious risks.

Can success (cost effectiveness), or failure, or disaster, be accurately assessed?

Success, at least as defined by recapture of introduced individuals, may be relatively easily confirmed but assessing the cost effectiveness of enhancement will be more complex. In this context clear understanding of the objective of enhancement is required. If the desired goal is to rehabilitate populations of fish decimated by over-fishing or habitat loss, then economic return is not the only measure of success.

If the motivation behind enhancement is to improve economic return from a fishery, then the currency by which success is measured is more clear. We could find relatively few examples of effectiveness of such enhancements. The coastal fisheries of Japan are an exception. Populations of many species have been enhanced since at least 1963 (Suda, 1990; Kitada *et al.*, 1992). As Suda (1990) reports, there have been spectacular increases in production of scallops (*Pecten* spp.) and chum salmon since the early 1970's, and smaller increases in the production of red sea bream (*Pagrus auratus*), flounder (*Paralichthys olivaceus*) and kuruma prawns (*Penaeus japonicus*). Kojima (in press) has quantified returns from an enhanced fishery for abalone (*Haliotis d. discus*) in Tokushima prefecture in Japan. In that fishery, between 11% and 51% of outplanted juveniles were recaptured in the fishery and these individuals account for up to 34% of total landings (Kojima in press).

Enhancement of regional production by the introduction of new species adds further complexities because, in addition to the relatively simple exercise of quantifying catches, the ecological impacts of introducing new species must be assessed (see also 3. above). This latter assessment is rarely done and always difficult.

Failure may be defined in terms of lack of economic return, the failure of populations to recover, or unforseen negative impacts on other species and ecosystem function. Interestingly, some introductions, initially seen as disasters may prove to be economically successful in the long term. For example, Pacific oysters, for many years regarded as introduced vermin in eastern Australia, now support a major industry in Tasmania. Similarly, the development of a large fishery for Nile Perch in Lake Victoria may be viewed as an economic success but it has had severe impacts on endemic species, including those that once supported fisheries (Okemwa and Ogari, 1994).

Who will own the product of enhancement and who will benefit?

If enhancement is carried out by government in the interests of "public good" then traditional access to common property resources may apply. If industry or local authority's contributions are involved, then the issues of access could become immensely complicated, particularly if the species is highly mobile. How to enforce restrictions on access can get even more complicated, particularly if non-government ownership is acknowledged.

Who will take the blame if the results are inconclusive or negative?

It will be surprising if blame is readily accepted by any individual or even agency. With some failures blame may not even be appropriate; the outcome may have been contrary to that anticipated from the best possible advice. Nonetheless, when public money is assessed to have been wasted, or worse, resulted in a negative impact, pressure will grow to assign responsibility. Governments, as the ultimate fisheries managers, will find it difficult to avoid criticism, even if the offending action is carried out by private interests. After all, shouldn't the Government have prevented such action, or at least not licensed it? Governments have reason to be wary - there are potentially great gains but there are also considerable risks.

CONCLUSION

Unfortunately, the lack of productivity of the waters surrounding Australia is due to primary nutrient deficiency and significant increases in total productivity would require major changes to nutrient loads. Grand scale enhancements through oceanographic manipulations, such as artificial upwellings, are unlikely, at least in the immediate future. Enhancement of productivity through wiser use of nutrients, which often occur in localised excesses resulting from agricultural run-off or sewage disposal, has more immediate potential. Unfortunately most of Australia's efforts to research and manage nutrients in our waters are still concentrated, almost exclusively, on how to minimise the negative effects of excess concentrations. The management of primary nutrients is still normally regarded as a pollution problem and not as an enhancement issue. In a country with Australia's combination of expansive ocean areas and low primary productivity potentials must exist to better utilise our localised "excess" nutrients. The possibility of providing world leadership in this area is exciting.

More classical enhancement, through propagation and release of juveniles of selected species, have already proven to be of great benefit to Australia's freshwater fisheries but our successes in coastal areas are limited. In non-constrained, open ecosystems such as most coastal areas, the consequences of enhancement will be complex and, coupled with the extreme difficulties of measuring outcomes, make enhancement both difficult and risky. However, the needs to restore depleted fisheries, improve existing ones and create new opportunities will, quite correctly, ensure enhancement increases in priority for both researchers and managers. We remain strong advocates for appropriate enhancements even though there will undoubtedly be some controversy over most of them.

Finally society must ensure that the potential to restore and enhance fisheries through recruitment supplementation and other measures, is not used as an excuse for not properly researching and managing existing fisheries. The belief that excesses in current harvest strategies or environmental damage can be readily rectified by future enhancements is already far too common.

ACKNOWLEDGMENTS

Our thanks go to Russell Reichelt for the invitation to present this paper at the PACON Conference and to Sherry Mead and Liz Hayes for considerable help in preparing the manuscript.

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DEEP SEABED MINERAL EXPLORATION OF KOREA

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ABSTRACT

Korea has little or no domestic deposits of non-ferrous metals, such as nickel, cobalt, copper, and manganese that are essential for the development of national economics. In tackling those fundamental problems, the Government of Korea enacted the Overseas Resources Development Law in early 1960s to promote investment activities in overseas mineral resources development projects. The Korea Ocean Research and Development Institute (KORDI), sponsored by the Ministry of Science and Technology, has been conducting explorations for deep-seabed mineral resources since 1983. Target areas are the central and eastern parts in the Clarion-Clipperton fracture zones of eastern Pacific. The total area surveyed by KORDI during the past covers more than 1,500,000 km^2. At the end of 1993, Korea finally designated 300,000 km^2 of commercially prospective mining area for manganese nodule in the Clarion-Clipperton fracture zones. Based on collected data, the Government of Korea submitted the application in January 1994 for registration as a pioneer investor and for the allocation of a pioneer area to the United Nations. This application was finally approved from the General Committee of the 12th Resumed Session of the Preparatory Commission in August 1994. As a result, Korea became the 7th pioneer investor under the United Nations Convention on the Law of the Sea. Korea is planning to carry out detailed survey and environmental studies in the registered area from 1994 to 2001.

INTRODUCTION

As land-based mineral resources are getting exhausted and the world's demand for strategic rare metals such as Ni, Cu, Mn, Co are ever-increasing, the world has come to focus on the seabed resources, especially on the poly metallic manganese nodules that are expected to be commercially exploited around early next century. Interest in mining of deep seabed manganese nodule has rather been warned because of the low level of its economic viability compared to that of land-based mining and uncertainty of international political environments. However, these obstacles will be removed sooner or later by the rapid development of ocean technology and the possible mutual concessions about the "Draft Regulations on Prospecting, Exploration and Exploitation of Poly metallic Nodules in the Area" (so called "Mining Code") of the United Nations Preparatory Commission for active participation of technologically advanced countries in deep seabed mining.

Because Korea's land based mineral resources are limited, the dependence on mineral supplies from overseas has intensified the vulnerability of Korean economy to sporadic external shocks. In tackling these fundamental problems, the Korean government enacted the Overseas Resources Development Law in early 1960s and has promoted investment activities in overseas mineral resources development projects. It is natural that Korea has evaluated a deep seabed mining venture as a possible option for stable long-term procurement of strategic metals to continue its economic growth and it has accelerated a national seabed exploration effort as one of important marine policies since the beginning of 1980s. For example, Korea depends on overseas sources for almost 100% of the four strategic rare metals (Ni, Cu, Mn, Co) which can be extracted from manganese nodules. If Korea could harvest 3 million tons of manganese nodules per year from the deep seabed area, by around 2015 it could theoretically reduce its dependence on foreign sources to zero percent for cobalt, 12 percent for manganese, 77 percent for nickel, and 97 percent for copper (Hong, 1993; Hong and Kang, 1993).

Prospecting activities (1983-1991)

The Korea Ocean Research and Development Institute (KORDI), sponsored by the Ministry of Science and Technology (MOST), has been conducting exploration activities for deep seabed mineral resources since the beginning of 1980s. However, after initial prospecting in 1983 using the R/V "Kana Keoki" of the University of Hawaii, the Korean government deferred any immediate action mainly due to legal-political uncertainties. Uncertainties included the mine site conflicts among the potential pioneer claimants and the ambiguity of the terms of pioneer activities.

The Korean exploration program for deep seabed mineral resources was resumed in 1989. KORDI and United States Geological Survey (USGS) made a bilateral agreement to carry out joint exploration focusing on the reconnaissance of cobalt-rich crusts as well as the exploration of ferromanganese nodules from 1989 to 1991 (MOST, 1990, 1991). This KORDI-USGS joint program, which was funded by MOST, performed a total of seven cruises for deep seabed mineral resources exploration using R/V "Farnella (1,431 tons)". Three of the cruises were designed for the purpose of surveying seamount evolution and cobalt-rich crusts. The survey area was the western Marshall Islands and the Micronesia Islands which are characterised by volcanic complexes (Figure 1). The other four cruises were dedicated to the exploration for poly metallic manganese nodules, covering approximately 250,000 km^2 in the western part of the Clarion-Clipperton fracture zone (C-C zone), with the purpose of surveying the geological, geophysical, and oceanological environments in deep ocean (Figure 2).

The Korean government's intention for this program was to prospect and understand two different types of deep seabed mineral resources and to enhance their marine scientific and technological capability. Of the two types of potential mineral resources, the government gave large-scale national priority to research and development for the manganese nodule program.

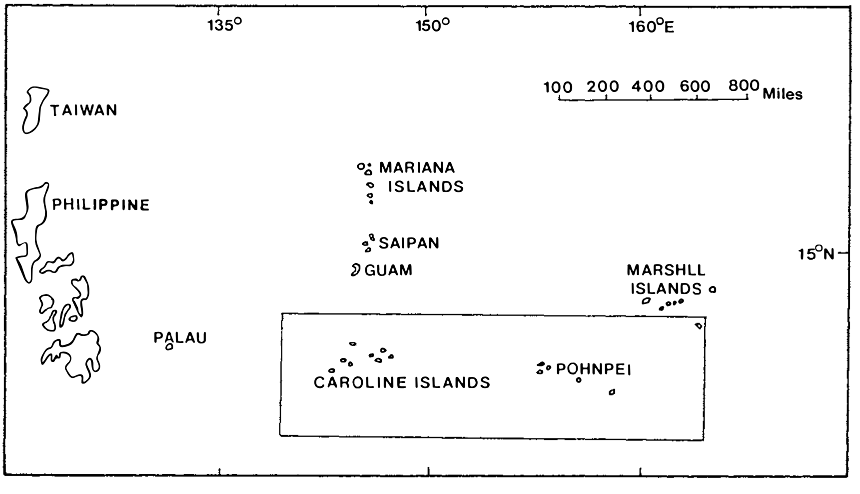

Figure 1. Location map of KODOS Exploration Site for Manganese Crust in the western Marshall Islands and Micronesia Islands.

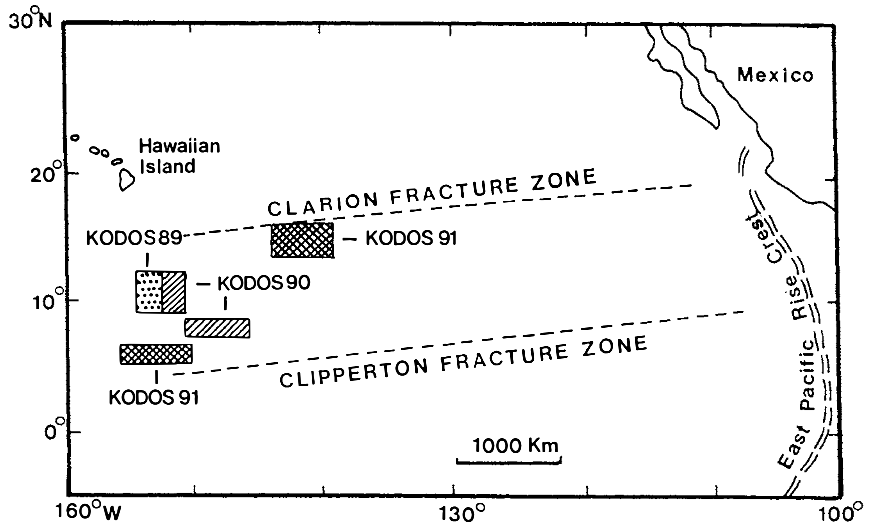

Figure 2. Location map of KODOS Exploration Site (1989-1991) for Manganese Nodules in the north east Pacific.

Regional exploration (1992-1993)

The Korean exploration program for deep seabed manganese nodules was initiated by MOST and later expanded and strengthened through the decision of the Economy-related Ministerial Committee (August 1991 and December 1993) to a full-scale national program under the guidance of the Ministry of Trade, Industry and Energy (MOTIE). MOTIE has acted as a catalyst for supervision of the program, coordination of the policy for deep seabed resources exploration, and promotion of survey and exploration in general. Government-supported organisations such as the Korea Institute of Geology, Mining and Materials (KIGAM) and the Korea Mining Promotion Corporation (KMPC) joined KORDI to cooperate in the survey program for poly metallic nodules and in the development of technology to exploit the deep seabed nodule resources.

With the acquisition of the R/V "Onnuri (1,422 tons)" which was funded through a Japanese OECF loan and completed in January 1992 by Mjellem & Karlsen Verft AS, Norway, KORDI strengthened its capability to conduct deep seabed resources surveys and related environmental studies more efficiently. The R/V Onnuri is endowed with state-of-the-art deep-seabed survey equipment, including a multi-beam echo sounder, a seismic research system, a deep-tow camera system, a sub-bottom profiler, and a hydrographic echo sounder. More than 1,000,000 km^2 area has been surveyed using the R/V Onnuri, and part of the area was also surveyed using the Russian research vessel "Yuzhmorgeologiya (5,512 tons)" (MOTIE, 1992, 1993).

In the survey cruise, selected areas were firstly surveyed using geophysical equipment to understand the geological environments and geophysical characteristics. After finishing this geophysical line survey, manganese nodules, associated sediments, and water samples were collected from sampling stations at approximately 25 to 35 km intervals.

Through a total of 365 working days at sea, manganese nodules from almost 2,000 sampling sites (650 stations) and associated sediments from 270 sampling stations were collected using free-fall grabs and a box corer attached to a cable. Approximately 4,000 chemical and mineralogical analyses on those samples were performed. More than 1,000 photographs of the sea bottom were taken with cameras attached to the free-fall grabs (MOTIE, 1992, 1993).

The topography of the sea bottom was mapped by the multi-beam echo sounder. A high resolution long range side scan sonar attached to the Seabeam 2000 sensors was successfully operated, and good quality side scan images were obtained simultaneously. Single channel seismic surveys, 3.5 kHz sub-bottom profiles, and magnetic and gravity surveys were performed to study the relationships between the occurrence of the nodules and the structures of the uppermost sediments and the volcanic basement.

Temperature and salinity measurements from the surface to the bottom of the survey area were obtained at 40 stations using CTD to study the physical conditions of deep sea. Satellite recordings were acquired and studied to determine the probability of occurrence of hurricanes and tropical storms. Undisturbed box core samples of sediments were collected for soil mechanics measurements and for biological observations as a basis for assessing possible environment impacts of future deep-seabed mining operations.

Geological features, such as geomorphology, sedimentary environments, deep-sea bedforms, deep-seabed structure, and gravity and magnetic anomalies, were interpreted on the basis of the acquired cruise data. Physical properties, grain size, paleomagnetism, and mineralogy were studied to obtain data on the characteristics of sediments. Furthermore, geochemistry of pore water and sediments was also studies. Sedimentary parameters such as sedimentation rates and ages of the sediments were studied utilising the paleontological and paleomagnetic data.

Physical properties of the manganese nodules such as exterior morphology, and the mineralogical and geochemical studies were investigated. Concentrations of manganese nodules on the sea bottom were calculated from a comparative analysis of the samples and of seabottom photographs, because the output of sampling system varied depending on the nodule size.

Correlations between bottom morphology, sedimentary environments, and resource potential were based on the occurrence, concentration, continuity and physio-chemical characteristics of nodules.

Registration as a pioneer investor (1994)

In the past six years the Korean government has successfully carried out its pioneer activities of sea bed mineral evaluation, and has documented the nature, shape, concentration and grade of manganese nodules and of the environmental, technical and other appropriate factors.

At the end of 1993 Korea finally designated 300,000 km^2 of commercially prospective mining area for manganese nodule in the Clarion-Clipperton area from the results of past six years exploration. The Korea government submitted the application in January 1994 for registration as a pioneer investor and for the allocation of a pioneer area to the Preparatory Commission.

For the application, the most promising area in terms of nodule abundance as well as metal grades was identified from the total surveyed area. Areas with fewest possible number of obstacles such as seamounts and minimum areas of steep regions higher than 6^o seabed slope were identified for inclusion in the application area (MOTIE, 1994). In addition, geological features such as volcanic and sedimentary structures were considered.

The application area was divided into 11 sectors, eight of which fell in the southern region and the remaining three sectors in the northern region (Figure 3).

Manganese nodules in the application area show various sizes, shapes, and surface textures. Nodule abundance is very low in areas where calcareous sediments are dominant, whereas it varies over a wide range in areas where siliceous sediments are dominant. It was also observed that most of the nodules in the northern region are exposed on top of the sediments, but many nodules in the southern region are covered partially or completely by a thin layer of sediment.

Average nodule abundance varies from 5 to 8 kg/m^2 in each sector of the application area. At this prospective stage of exploration, the calculated nodule tonnage varies from the 100 million tons to 350 million tons in sectors of application area. Mean size of the nodules from the application area ranges from 2 to 6 cm. Distribution and mineralogy of nodules are strongly affected by the topographical and geological conditions. The abundance of nodule in the southern region is generally higher than that of the northern region, but the variability in abundance is also higher in the southern region. In general, the metal grade is much lower in the northern region (MOTIE, 1994).

The Group of Technical Experts under the Preparatory Commission evaluated the Korean application and reported the review statement to the Preparatory Commission, who recommended that 150,000 km^2 be allocated to the Republic of Korea from a total application area of 300,000 km^2 (LOS/PCN/BUR/R.40, 1994). The Korean application for registration as a pioneer investor was finally approved from the General Committee of the 12th Resumed Session of the Preparatory Commission on 2 August 1994 (LOS/PCN/L.115, 1994). As a result, Korea became the 7th pioneer investor under the United Nations Convention on the Law of the Sea. Of the total area, Korea will freely choose 75,000 km^2 as its mining site after relinquishing half of the total allocated area over the next eight years.

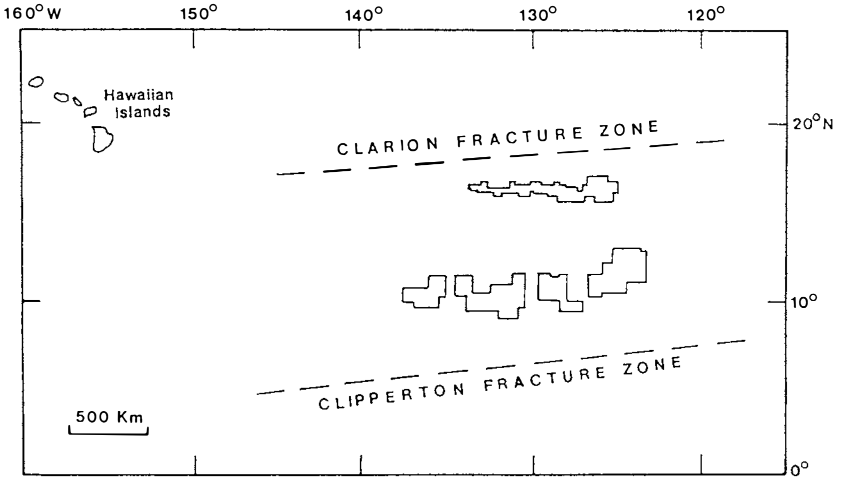

Figure 3. Overview map of the application area.

Future exploration plan

Although the registered area was identified in the first stage exploration, more detailed exploration activities are now required to identify the commercial mining value, absolute commercial potential, and to delineate commercial mining sites. KORDI will carry out this detailed survey during the next eight years with the support of MOTIE.

Together with these detailed assessments of commercial potential of nodules, environmental studies of the allocated area will be carried out to estimate the effect of mining activity on both surface and benthic communities. As a part of this environmental research, a KORDI scientist participated in BIE (Benthic Impact Experiment) Program research cruise in August 1994.

Moreover, we will also maintain our interests in research and exploration of the ferromanganese crusts and hydrothermal deposits in deep-sea environments.

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COCOS (KEELING)ISLANDS: MANAGING THE HARVESTING OF MARINE ORGANISMS

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ABSTRACT

Harvesting of marine organisms on coral atolls traditionally provides a vital source of food, is an important part of the cultural heritage and occupies a large proportion of time for islanders. On many atolls, there are increasing pressures on stocks caused by increasing human populations, tourist developments, more efficient fishing techniques and attempts to develop export economies based on local resources. The Cocos (Keeling) Islands comprise two small, coral atolls under Australian sovereignty. Their geographical isolation may limit the replenishment of exploited stocks by larvae dispersed from other populations. Information on harvesting was obtained from questionnaires and fish and invertebrates were surveyed quantitatively. The questionnaires revealed a wide range of exploited organisms, but two species of lethrinid fishes, *Lethrinus semicinctus* and *L. xanthochilus*, and a strombid gastropod, *Lambis lambis*, were highly sought-after. Harvesting was done by relatively non-destructive methods, including line-fishing, gathering by hand, some netting and spearfishing. This paper focuses on two types of harvesting, 1) fish on shallow coral reefs which are not considered to be threatened by over-exploitation and 2) *L. lambis*, whose exploitable stocks may currently be at threat.

INTRODUCTION

The harvesting of marine organisms for food and recreation plays a vital role in the lives of many people inhabiting tropical islands (Catterall and Poiner, 1987; Russ, 1991; Williams, 1994) and the Cocos (Keeling) Islands are no exception (Gibson-Hill, 1949; Bunce, 1988). The management of marine biota at the Cocos (Keeling) Islands may, however, be more critical than on some other islands due to its geographical isolation from other tropical landmasses. Most harvested coral reef biota disperse via the plankton (eg. Scheltema, 1986; Leis, 1991) and many species have relatively short dispersive stages (eg. Victor, 1986; Davis, 1994) compared with the distances they may need to travel to reach the Cocos (Keeling) Islands. Thus, replenishment of stocks on the Cocos (Keeling) Islands from other areas is likely to be unreliable and consistent replenishment of stocks dependent on reproductive adults on the islands themselves.

Previous studies of the biota and harvesting activities of the Cocos (Keeling) Islands are limited. Gibson-Hill (1949) described harvesting activities, including gathering of sessile biota by hand, fishing with lines, netting, trapping and spearing. Recently, the Australian Nature Conservation Agency became concerned about the nature and sustainability of current practices at the Cocos (Keeling) Islands.

The present study addressed three questions: 1) What species of fish and marine invertebrates are harvested at the Cocos (Keeling) Islands? 2) What is the abundance of harvested species of fish or marine invertebrates at Cocos (Keeling) islands? 3) How should the harvesting of marine organisms at Cocos (Keeling) Islands be managed?

METHODS

Location, environmental conditions and human habitation

The Cocos (Keeling) Islands are located in the Indian Ocean (Figure 1). The nearest land masses are Christmas Island and Java, 900 km and 1000 km to the northeast, respectively. The Cocos (Keeling) Islands consist of two main islands, South Cocos Atoll, which is ringed by a series of small islands (Figure 1) and North Keeling Island, which is smaller and some 25 km to the north (not shown on figure). Work reported here was done at South Cocos Atoll. Strong winds blow from the southeast for much of the year, creating rough seas outside the atoll. The outer margin of the atoll has a narrow coral terrace which slopes away to deep oceanic waters. Much of the lagoon is very shallow, particularly in the southern part of the lagoon. Lagoonal flats contain several habitats, including seagrass and algal beds, sand and rubble with isolated coral heads and areas of bare, coralline sand. In addition to the flats, there are numerous holes of 10's m depth, known as the Blue Holes (Figure 1).

South Cocos Atoll has been inhabited by humans since about 1820 (Bunce, 1988). Currently there are settlements at Home Island and West Island (Figure 1). The Home Islanders are Australians of Indonesian and Malay descent who are, by and large, permanent residents. The West Islanders are mostly Australians from the mainland who have come to the atoll to work, usually for several years. The overall population of the atoll is relatively stable (600 - 700), with a small decline in recent years due to emigration. At the time of the study, tourist accommodation at Cocos (Keeling) was limited to a small lodge on West Island.

Design of the study

The Cocos (Keeling) Islands were visited in May/June and November 1992. Information was gathered from three sources: the distribution of questionnaires to island residents; interviews with fishermen and tourist operators and; quantitative surveys of habitats where marine biota are harvested.

A questionnaire requesting information on harvesting marine organisms was distributed among Home and West Islanders in May, 1992. Questions were asked under two main categories: 1) harvesting methods, time spent harvesting, target species and preferred harvesting locations and; 2) catch of fish and marine invertebrates by number and weight.

The West Island Lodge provided data on the weekly delivery of fish (kg) for consumption by tourists over the period August 1991-November 1992. The fish were caught by Home Islanders and sold to the Lodge.

Two types of quantitative survey were done: 1) fish on shallow coral reefs (<10 m deep) and; 2) a commonly-harvested gastropod (*Lambis lambis*: Family Strombidae) on shallow lagoonal flats (see Lincoln Smith *et al.*, 1993a for details on several other surveys done). Fish on shallow coral reef were surveyed in November 1992 at two sites randomly selected in each of four regions (Figure 1). Selection of regions was limited by weather conditions, although these were the regions of the atoll most accessible for fishing. The selection of sites was not based on geographical distance, but on similarity of habitat features, particularly exposure to winds and ocean swells. At each site, fish were surveyed on 7 randomly laid transects, each 50 m long by 5 m wide and each survey was over a fixed 15 min time period (Lincoln Smith *et al.*, 1993). The species of fish surveyed were generally large demersal or pelagic fishes, selected on the basis of prior discussion with island residents, who nominated target species. These fishes were often nominated by groups (eg. Lethrinidae, nominated as emperors), hence most emphasis during the survey was at the taxonomic level of family.

Data were examined by a hierarchical analysis of variance, which compared regions and sites within regions. Prior to analysis, homogeneity of variances was checked using Cochran's test and data were transformed where necessary. Means of the significant factor(s) were compared using Student Newman Keuls (SNK) tests (Winer *et al.*, 1991).

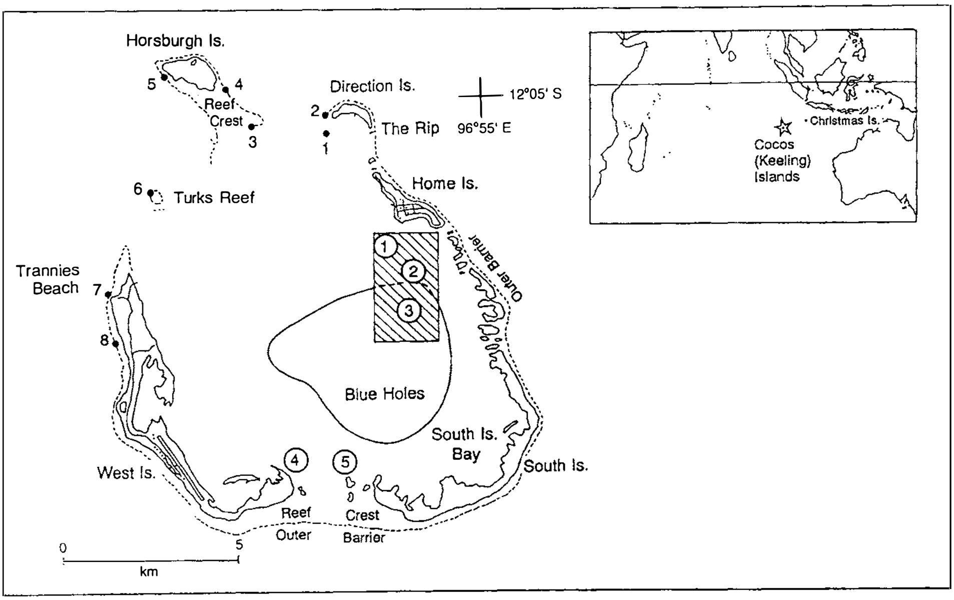

Figure 1. Cocos (Keeling) Islands. Spots with numbers indicate survey sites for shallow reef fishes. Circled numbers indicate locations for sampling *Lambis lambis*. Note: 3 sites were sampled at each locations. Hatched rectangle represents approximate position of main *L. lambis* harvesting zone.

Lambis lambis were surveyed in November 1992 at three sites randomly selected in each of five locations in the lagoon (Figure 1). Selection of locations was based on discussions with Home Islanders: Locations 1-3 were in the main collecting zone for *L. lambis*; Locations 4 & 5 were remote from the main collecting zone but were believed by the Home Islanders to contain large numbers of (unharvested) *L. lambis*. At each site, *L. lambis* were counted along 10 randomly laid transects, each 20 m long by 2 m wide (see Lincoln Smith *et al.*, 1993a). A hierarchical analysis of variance examined if the abundance of *L. lambis* varied significantly among locations and/or sites within locations. Cochran's Test and SNK tests were used as described above.

RESULTS

Harvesting activities

Questionnaires were completed by each family on Home Island, yielding about 100 responses. None of the questionnaires distributed on West Island was returned. Thus, although the results described here relate only to the Home Islanders, our personal observations suggested that the West Island residents fish comparatively little compared to Home Islanders. Eighty-eight percent of the families on Home Island harvest marine organisms weekly and about 10% harvested ≥ 2 times each week. Only 1% of families stated they did not harvest marine organisms. There was a strong preference for fishing within the lagoon, probably due to the rough conditions on the open ocean. Ninety percent of families fished in the Blue

Holes and 53% fished on lagoonal flats in the eastern lagoon. Only 5% of families ventured outside the lagoon. The most popular fishing method was the use of handlines for fishing on the seafloor (used by 94% of families), with a lesser amount of netting (seine, mesh and cast nets).

Home Islanders caught a wide variety of fishes, including lagoonal fishes (eg. Gerriidae, Mugilidae, Albulidae, Lethrinidae) and reef fishes (eg. Serranidae, Labridae, Carangidae). The estimated combined weight of fish taken annually by the Home Islanders was estimated to be from 50 000 to > 73 000 kg. Most of the catch was made up of two species, *Lethrinus semicinctus* and *Lethrinus xanthochilus* (Family Lethrinidae), which are line fished in the lagoon and to a lesser extent on coral reefs. A wide variety of invertebrates is also taken, including gastropods, octopus, crabs (which are often used for bait) and crayfish (Palinuridae). Estimates of the annual catch of invertebrates range from about 2600 to 3700 individuals. The most commonly harvested species was the spider shell, *Lambis lambis*, which dominated the numbers of invertebrates harvested. Known locally as gong gong, *L. lambis* are collected at low tide by hand while wading over lagoon. They are typically gathered for celebrations, when several hundred may be taken in a single trip by one family. During our field studies, we saw one family group with 650 *L. lambis* collected in an afternoon.

Seventy-one deliveries of fish were made to the West Island Lodge. The total weight of fish delivered was 925 kg, with an average of 13 kg delivered per week (S.E. = 1.4 kg). The weekly delivery of fish varied from none to about 47 kg. The fish supplied to the lodge were filleted and skinned, thus the total biomass of fish harvested for the Lodge is greatly underestimated by the weight of fillets. Typically, the lodge bought larger fish, such as coral trout and cod (Serranidae) and large emperors (Lethrinidae) because they provide large fillets with few bones. There was little overlap in the fish taken for the lodge with those caught and eaten by Home Islanders.

Quantitative surveys of marine biota

Totals of 5,400 fish and 33 taxa were recorded on the 8 coral reefs surveyed. The most abundant groups were the Acanthuridae and Scaridae which, although highly sought-after on many coral islands, were not particularly popular at Cocos (Keeling). The number of taxa per site varied from 9 at Site 4 to 23 at Site 6 (Figure 1) and the total number of fish counted per site varied from 238 (Site 4) to 1 044 (Site 7). Abundant families of fish included Holocentridae, Serranidae, Lethrinidae, Lutjanidae and Labridae. Some groups, particularly the Lethrinidae, were probably under estimated in the survey because they tended to avoid divers. There were sufficient data to analyse 16 taxa. Of these, six showed no significant effects and 10 showed significant differences from one site to another, but no variation among regions. Two examples of the latter are total abundance of harvested fish (Figure 2a) which varied significantly between sites in every region and the Scaridae, which varied significantly between sites in three regions (Figure 2b). It is interesting to note that Sites 1, 3, 6 and 7 ranked consistently highly in terms of abundance of several types of fish.

The abundance of *L. lambis* varied at both spatial scales considered: among locations which were several km apart and among sites within locations, approximately 100 m apart (Figure 3). The largest numbers of *L. lambis* were recorded in the area where most collecting was done. Numbers were significantly smaller at Locations 4 and 5, where *L. lambis* were supposedly plentiful.

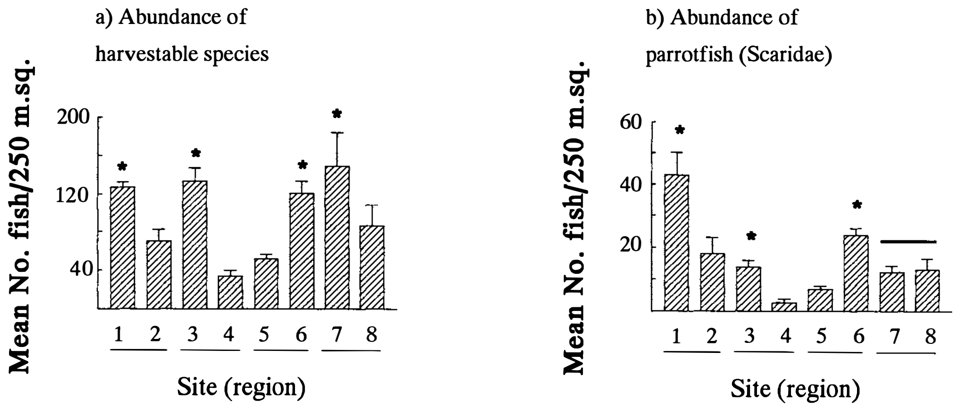

Figure 2. Mean abundance (+ 1 S.E.; n=7) of fish on shallow coral reefs. * = significant differences between sites within a region (P < 0.05); thick line indicates no significant (P > 0.05).

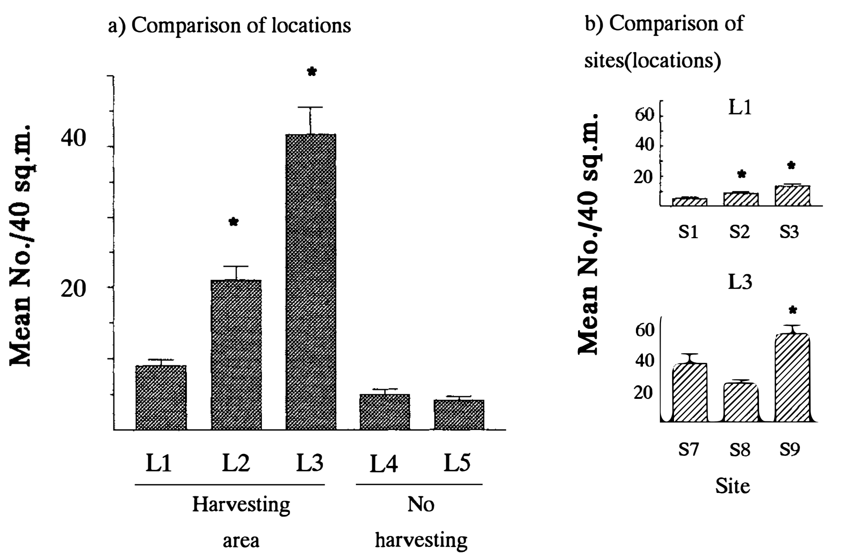

Figure 3. Mean abundance (+ 1 S.E.) of *Lambis lambis* a) among locations L1-L5 (n=30); and b) between sites within 2 locations (n=10) selected as examples. Means with asterisks are significantly different (P > 0.05) to those without asterisks.

DISCUSSION

Considerations for management of fish on shallow coral reefs

The information obtained during this study indicated that fish on shallow coral reefs at Cocos (Keeling) are presently unlikely to be over-exploited, for three reasons. First, the fishing methods used do not destroy habitat. Some methods of fishing can destroy coral habitat, for example the use of traps (Koslow *et al.*, 1988) or explosives and certain netting techniques (Russ and Alcala, 1989). Second, large areas of shallow coral reef outside the lagoon are inaccessible under most weather conditions, providing a potential refuge for many of the species sought on more accessible reefs. Third, the data for fishes compared favourably with similar studies done elsewhere in the Indo-Pacific, including areas closed to fishing (eg. Samoilys, 1988; Russ and Alcala, 1989; Lincoln Smith *et al.*, 1993b).

There are, however, several potential threats to fishes on shallow coral reefs. There is a likelihood of increased tourism to the islands (Armstrong, 1992) leading to environmental effects from development (Maragos, 1993). There may also be direct effects due to tourists fishing on the reefs and of increased demand for those types of fish that yield large fillets with no bones (ie. many larger reef fish). Finally, there may be a development of fishing for export of marine organisms to provide local income. There is currently no commercial export of fish (other than a small trade in aquarium fish), but various proposals were raised during our interviews with residents of the islands.

Managers addressing the potential threats to fish stocks on shallow coral reefs should consider three issues. First, the Cocos (Keeling) Islands are geographically isolated from other coral reefs. Many coral reef fish have larval durations of < 3 weeks (Leis, 1991) suggesting that the transport of propagules to Cocos (Keeling) from > 900 km (ie. the nearest land mass) would be haphazard and intermittent. Recently, Schultz and Cowen (1994) determined that transport of larval fishes to the reefs of Bermuda from other reefs in that area would be too infrequent to sustain Bermudan populations of reef fish. They concluded that populations were replenished mainly from larvae spawned locally and retained in and around Bermuda. In the Indian Ocean, Peter (1968) found that the densities of eggs and larvae of fish in oceanic waters around Cocos (Keeling) were relatively small. If populations of harvestable reef fish are replenished mainly by locally spawned propagules, management of adult stocks becomes crucial to the sustainability of populations. Second, the quantitative survey of coral reef fishes indicated that significant spatial variability occurred at the smaller scale. This has consequences for management of stocks and ultimately ongoing monitoring in that managers should seek to identify and conserve those reefs with large numbers of fish.

Third, two types of monitoring should be considered for future early-warning of problems; estimates of catch and comparisons of fished and unfished areas. In the present study, estimates of harvesting were derived from questionnaires. These estimates need to be validated by direct observations of the catch and by measurement of catch-per-unit-effort. The surveys of reef fish were done once, hence there is no measure of temporal variability. Before stocks of fish can be managed, the temporal patterns of abundance of fish must be known. The other type of monitoring that should be considered is the closure to fishing of some reefs in areas which are currently accessible to regular fishing. Estimates of abundances on "closed" reefs would provide a context against which variability on fished reefs should be compared.

Considerations for management of *Lambis lambis*

There are several reasons for needing more information on harvesting of *Lambis lambis*, which may be at risk from over-exploitation. First, large numbers of *L. lambis* are harvested and it appears that the main collecting zone also has the largest densities of *L. lambis*. Based on the approximate area of the main collecting zone and the measures of density from our survey, the Home Islanders may harvest annually 2.6-3.9% of the *L. lambis* living in the main collecting zone. A further issue of concern about collection of *L.*

lambis on Cocos (Keeling) is that it is not known how long they have been harvested. Some respondents to the questionnaire stated that harvesting of this species is relatively recent - of the order of several decades - and Gibson-Hill (1949) in a very thorough description of harvesting practices in the 1940's, did not mention collection of *L. lambis*. It is therefore important that further information be obtained on the nature of harvesting, including catch and effort.

Second, refuges from collecting may be limited, as seen from the relatively small numbers occurring in the southern part of the lagoon. We were unable to sample other regions of the lagoon and there is clearly a need to do this to determine if there are large populations present outside the main harvesting area.

Third, stocks may be replenished mostly from inside the lagoon at Cocos (Keeling), with little input from populations on other land masses. We have no information on planktonic duration of *L. lambis*, but the confamilial *Strombus gigas* only survive 24 days in the plankton (Davis, 1994). Scheltema (1986) estimated that, for the Pacific, the chance of a larva from a shoal-water benthic invertebrate encountering an island is 1 in 3 300. He found that gastropod veligers were among the most common planktonic larvae of benthic invertebrates in surface waters of the central Pacific (they occurred at 78% of 210 stations) but that Strombidae occurred at only 5% of stations. He concluded that the relatively small amount of endemism and attenuated Indo-Pacific faunas found on central Pacific islands suggest there is sufficient capacity for dispersal to islands and that dispersal and gene flow between islands is frequent enough to account for the persistence of most shoal-water, sediment-dwelling Indo-Pacific species. Berry (1989) noted little endemism at Cocos (Keeling). Thus, dispersal to the islands may be sufficiently frequent to maintain gene flow but not frequent enough to replenish stocks depleted by over-exploitation. Clearly, information on the supply of larvae from outside the Cocos (Keeling) Islands would assist in determining how important the stocks at the island are in providing local recruits, but in terms of timely management, it would be prudent to assume that recruits are derived from local stocks.

There are several potential threats to the harvestable stocks of *L. lambis*. First, they are not presently eaten by tourists but the initiation of supply to a growing tourist industry may significantly increase exploitation. Second, the means of collection, by hand while wading, could be made much more efficient by using snorkelling equipment. Third, changes to habitats as a result of development could affect populations of *L. lambis*. Finally, export may cause increases in exploitation. At present there is an unknown quantity of *L. lambis* taken to the Australian mainland by visiting Home Islanders to give to or trade with relatives. Given the emigration to the mainland, there may be an increasing desire for visiting Home Islanders to take *L. lambis* with them to relatives and friends on the mainland.

Managers addressing potential threats to stocks of *L. lambis* are faced with similar issues to those of shallow reef fish, such as replenishment of stocks from other areas. In addition, however, a major issue that needs to be addressed is the finding that the main collecting zone for *L. lambis* may also be the major area for the population and that there may be no local refugia from harvesting. Also, there is a lack of biological information needed for management, including pelagic larval duration, timing and intensity of recruitment, size at maturity, location of nursery habitat, etc. Validation of catch rates and measurement of temporal variability in catches would also help to refine estimates of harvesting. Finally, initiation of monitoring of areas where harvesting occurs and where it becomes restricted would provide information on the effects of harvesting the adult population.

ACKNOWLEDGMENTS

This study was commissioned by the Australian Nature Conservation Agency. Their assistance, particularly that of J. Tranter, Island Conservator, is gratefully acknowledged. The Administration at Cocos (Keeling) provided logistical assistance. The Home Islanders, particularly Hadlan Macrea, provided information on the main collecting areas for *L. lambis*. A. Smith, P. Hawes, L. Howitt and J. Stark assisted in the surveys; these and M.G. Chapman and G. White assisted in analysis and interpretation of data.

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THE TERABYTE PROBLEM IN ENVIRONMENTAL DATABASES

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ABSTRACT

The size and complexity of environmental issues is paralleled by the size and complexity of the databases used to comprehend them. Many environmental issues now demand the management and processing of huge volumes of data. Indeed, terabytes of data (10^{12} bytes or one million megabytes) are now required to understand some problems effectively. Remotely sensed data in general, and satellite imagery and seismic data in particular, generate datasets of such sizes.

We argue in this paper that a "terabyte problem" exists in that we are witnessing a shift from megabytes to terabytes of data without really pausing for gigabytes. This imposes qualitative as well as quantitative shifts in the way we harness information technology for sustainable development and in the storage management techniques we apply to these terabyte stores. In developing this argument, we will draw on our practical experience in building an operational terabyte store for Australia's national offshore seismic dataset.

The terabyte problem imposes demands on the way we compute, the way we communicate, the way we use storage management techniques to maintain and manage the store, and the way we deliver information to end users. Each of these issues needs to be addressed for the next generation of environmental databases to be used effectively for sustainable development.

INTRODUCTION

Over the last five years or so there has been a preoccupation in the Information Technology (IT) industry, both vendors and buyers, with faster and faster CPUs. The vendors have promised, and generally delivered, systems which double the CPU performance every 18 months or so (Amdahl's law). This has been gratefully accepted by the buyers - you and us - while we await yet another CPU upgrade. However, we must not forget that today's computing systems depend on three components to fulfil their promise. Not only do we need faster CPUs, but we must not neglect our networks or our storage requirements. Any computing solution must be **square** in the three aspects of CPU performance, storage and interconnection (Chorafas, 1994). Otherwise, we will find ourselves with very fast CPUs that are bottlenecked by slow or inadequate storage systems and that cannot communicate effectively with each other because of our communications technology.

In this paper we will dwell on the storage issue, which imposes demands on the way we compute, the way we communicate and the way we deliver information to end users. Along the way we will find time to consider the impacts of both CPU and communications.

DEFINITIONS

First, some definitions so that we can all agree on what we are considering. On the CPU side two major terms are (still) used to describe or measure the performance of our machines. The first, much maligned number, is the MIP (million instructions per second) made famous by the DEC VAX 11/780, which was the original 1 MIP machine. The other term used for CPU performance is MFLOP (million floating point instructions per second), a measurement intended to give more meaning to scientific computing. The relationship between the two measures, and any real measure of CPU performance, is tenuous at best. However, as Messina (1991) comments, "An example of the extent to which the flop rate has become an accepted way of measuring performance is that the recent High Performance Computing initiative in the United States is also known as the teraflop initiative."

As a rough rule though, we can assume that for every 10 MIPs we get 1 MFLOP of performance.

Next we consider networking speeds. There is only one measurement here: the number of bits (binary digits) of information transmitted across the communication link per second. They may be in the hundreds, thousands, millions or even hundreds of millions.

Finally, to storage. The basic measure is the number of bytes held on the device. We measure the storage in thousands (kilobytes), millions (megabytes), thousands of megabytes (gigabytes) and now in millions of megabytes (terabytes).

CURRENT PERFORMANCE

The current position in the performance areas for both CPU and networks begs a quick visit. On the CPU side we have a vast range of performances available to us. At the lower end we have the ubiquitous PC which has performance approaching the 5 to 10 MFLOPs. Next comes the workstation at around 15-25 MFLOPs, then the server at around 75-100 MFLOPs. Above this we have Symmetric Multi-Processor systems at between 100 and 500 MFLOPs and, at the top end, the Supercomputers at any between 1000 and 10,000 MFLOPs (1 to 10 Gigaflops). Figure 1 depicts the vast range of processing or CPU performance available today. To handle the large range of problems we encounter we need access to the complete range of CPU performance.

As we have already said, it is not enough just to increase the performance of our CPUs. We also need to consider the networks that interconnect our computers and our storage systems. Most computers these days are connected to or constitute part of a "network". This may be just local or have connections to other networks and even the far reaching Internet. The majority of these local connections use the Ethernet connectivity standard. This provides for connection speeds at up to 10 million bits per second. However, this is not sufficient for moving large amounts of data between computers or computers and storage devices. For example, even if we used the full 10 million bits per second - almost impossible to achieve - then it would take over 3.5 minutes to move a standard Landsat scene of around 250 Mb between two computers. When we consider that a terabyte is 4000 times larger, then we can easily see that Ethernet speeds are not sufficient to handle the movement of such datasets.

Figure 2 describes some of the other networking methods available to us and their respective speeds. From the figure we can see that much faster networking or rather interconnection methods are available to us. However, as usual such speeds do not come cheap. Two methods that are becoming affordable are the Fibre Distributed Data Interface (FDDI) and the Asynchronous Transfer Mode methods. These two methods provide from 10 to 60 times the "bandwidth" of ethernet - from 100 Mbps to 622 Mbps - but are still not cost effective for other than high-intensity workstations and/or server interconnections.

The High Performance Parallel Interface (HIPPI) is not really a networking method at all. It is a point-to-point interconnection technology normally used to connect two devices, such as a high-speed computer and a storage device. The technology can communicate at either 800 or 1600 Mbps over a cable no more than 25 metres long.

An introduction to these and other networking technologies can be found in the book *Gigabit Networking* by Partridge (1994).

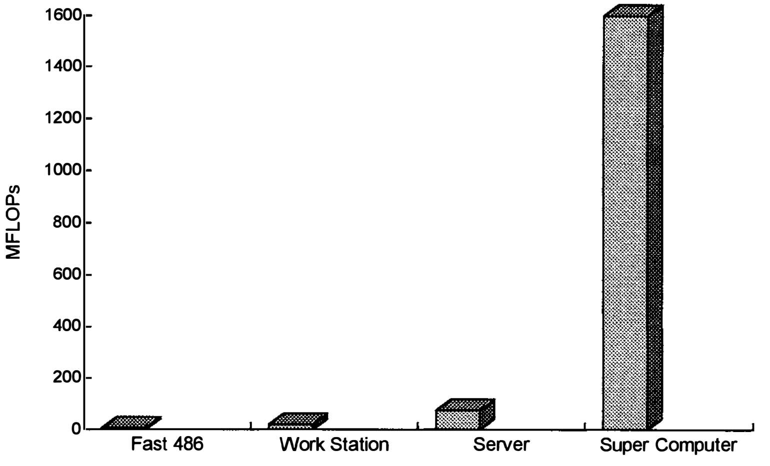

Figure 1. CPU Performances

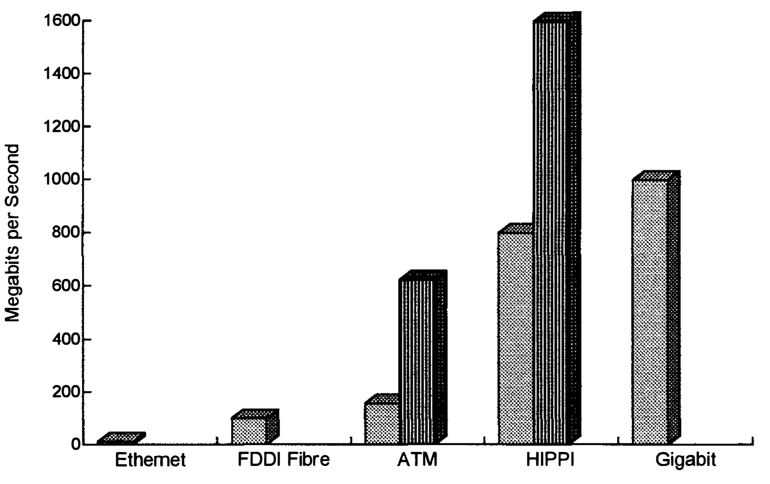

Figure 2. Networking Performances

DATA STORAGE NEEDS

Today most computer users need 250 Mb to 1 Gb of storage just to manage their day-to-day operations. This includes space to store their working files, office automation software (spread sheets and word processors), the operating system and network software.

Larger analysis tasks are undertaken on the network servers and compute engines which must provide tens to hundreds of gigabytes of fast, reliable and recoverable (backed-up) storage for the network and users. Many datasets we now collect, hold, use or analyse run to many hundreds of megabytes each. For example, a simple coastline of Australia at 1:100,000 can easily take up 150 to 200 megabytes. We may only ever use this dataset to overlay on some final output to produce a "map". This dataset still needs to be stored and managed so that it is readily available when needed.

However, many files systems can best be described as Write Once, Read Never or **WORN** systems (Hanss.T in Khanna. R, 1994). That is, we create files but never remove them since they will be or may be needed some day. In fact, it has been shown that 80% of all networked files are generally not accessed for periods exceeding 30 days. As well, a user's "working set" of active files remains relatively stable in size over time.

Given this situation it does not make sense to keep all files on expensive disk drives. What is needed is a more innovative storage management approach, rather than just more storage.

Imagine a completely different way of managing storage and data distributed on your network. A method that automatically and centrally manages disk or storage space, but makes it appear that the existing disks have expanded to be infinite in capacity. Such storage management systems are called Hierarchical Storage Management (HSM) systems for reasons that will become obvious.

These systems provide management of files, extending the file system capacity by the ability to migrate files from fast, expensive devices to slower, more economical devices. They are based on a layered or hierarchy of storage devices which contrast device and media cost to performance. Table 1 indicates the contrast between media costs and retrieval times for devices which can be used to construct a HSM system.

To provide effective management of storage, especially for large, terabyte-plus, data storage needs, a hierarchical storage management scheme must satisfy five important requirements:

- The scheme must be **automatic**. Manual intervention must be eliminated or at least minimised. Files must be migrated to or from storage levels based on age, size and inactivity with no intervention.
- The scheme must be **transparent**. Users should not know or need to know that files have been or will be migrated. Files should remain logically in place from the user's perspective.
- The scheme must be **reliable**. Migrated data must be protected against failure of a layer in the system. Data must remain available for years.
- The scheme must be **scalable**. As storage requirements expand the system should support expansion of storage capacity without major change. This is especially important for large data storage requirements.
- The scheme must be **distributed**. Storage levels or layers must be able to be managed by different servers on the network. Multiple small to medium stores provide better performance, less network load and higher reliability and redundancy (Webb, 1994).

The majority of software implementations for HSM, adhere to the IEEE Mass Storage Reference Model. This model defines how mass storage systems should be implemented within an open systems framework. By providing a set of concepts and terminology the reference model leads the way in the development of standard mass storage systems or architectures. A detailed description of the model is available in the document *Mass Storage System Reference Model*, edited by S. Coleman and S. Miller, and published by the IEEE Technical Committee on Mass Storage Systems and Technology.

A detailed description of the operations involved in a HSM system, including migration, can be found in technical documents provided by suppliers of such systems. Their *modus operandi* differ in precise detail, but not in concept. The document from Epoch Systems, in the reference list, provides an easily read introduction to the more technical aspects of HSM.

Hierarchical Storage Management provides a flexible approach to storage management for network and systems administrators. HSM utilises both tape and optical subsystems as primary storage devices.

Table 1. Media Cost versus Retrieval Time

Storage Layer or Level	Media Cost per Mb	Retrieval Time hh:mm:ss
Server	$5.00	0:00:00
Hard or Cache Disk	$1.30	0:00:01
Optical Jukebox System	$0.30	0:00:20
Tape Jukebox System	$0.10	0:01:30
Offline Tape Storage	$0.03	1:00:00

THE PROBLEM

Each year the search for petroleum in Australian off shore waters generates terabytes of digital seismic data at a cost of millions of dollars to the petroleum industry. The data are both regional and detailed and used by explorationists to define the structure of the earth and identify prospective areas to drill for hydrocarbons. In Australia basic exploration data after a period of time become public domain property and are available for further analysis long after the initial processing of the information. The use of existing data minimises unnecessary new seismic data acquisition.

Commonwealth legislation governing petroleum exploration and development in Australia requires digital data to be deposited with the Australian Archives in Villawood, NSW. The Bureau of Resource Sciences carries the overall responsibility for managing the data and ensuring that it is available to the petroleum exploration industry and others.

Of growing concern to both the BRS and Archives has been the escalating cost of storing and handling such vast amounts of data. Currently the Archives has some 600,000 tapes occupying 12.5 km of shelf storage. This is being exacerbated by the emergence of new 3D seismic technology which generates on the order of 4 times the amount of data as conventional seismic. Furthermore, in recent years, deterioration of the magnetic tapes has become a critical problem. The phenomena of "stiction", whereby the oxide coating of the tape peels off and sticks to adjacent strips of tape is posing a serious threat to a valuable national information resource. To salvage the data, special techniques have been developed to temporarily revert the deterioration process and allow data to be copied to new high density media.

The BRS is currently engaged in a major project to preserve data at risk and improve its accessibility as a publicly available resource. As part of this initiative, it was decided that a terabyte storage system be established to provide efficient storage and retrieval of data transcribed to high density media.

The storage required to hold all the data is between 6 to 10 terabytes. Initially, the aim was to store around 1 terabyte of data in an easily accessible form to allow the companies and researchers rapid access to the data. Other constraints on the solution included:

- the need to provide data copies to clients in an industry standard form.
- the solution had to provide a simple but reliable method of moving the large dataset(s) around the storage vaults and computing systems.
- it had to allow the segmentation of the dataset(s) between slow, inexpensive media such as tape, for data of little current interest, and faster more expensive media such as magneto-optical and hard disks for data that was of high current interest to varying groups.
- the solution needed to be scalable, reliable, innovative and relatively inexpensive.

THE SOLUTION

The solution chosen to provide this innovative storage management was of course a hierarchical storage management system (HSM). The HSM was based on five levels of storage:

- At the top level, working storage is provided on the server or analysis systems while data of interest is being analysed.
- After a period of inactivity data is moved or migrated to a cache or "fat" disk. This allows storage of up to 4 Gb of data and is the first level of file migration.
- With further inactivity data is then migrated to a magneto-optical jukebox which holds 56 Gb at any one time. The media in this device is removable so that theoretically the storage capacity of the device is unlimited.
- Relatively inactive data is then migrated to a tape jukebox which holds up to 116 tape cartridges. Each cartridge can hold upwards of 10 Gb using compression. The total storage available exceeds 1.2 Tb given a relatively achievable compression ratio of 2:1. Again, the media in this device is removable, so that the theoretical storage is unlimited.
- At the lowest level is offline storage of tape and/or magneto-optical media. This is used for archival and data backup purposes.

The migration path between the different storage layers can be ordered. That is server -> cache disk -> optical -> tape -> offline, or nominated disks and/or file systems can be migrated to particular levels, skipping others. For example, some files may be migrated from the server to cache disk and then held, or never migrated at all. Other files may be migrated straight from cache disk to tape, and then offline, without ever being stored on optical media. The migration strategies available are almost endless.

The advantages of adopting this hierarchy of storage management includes:

- The solution is both **scalable** and **distributed**. Each storage device is located on a separate server and more storage can be added by adding extra cache disk, optical or tape storage or by moving inactive files to offline storage.

- The solution is based on existing, mature technologies including magneto-optical and 8 mm helical scan tape. The software used is also based on the IEEE Mass Storage System Reference Model.
- The solution is **relatively inexpensive**.
- The solution requires a **low level of intervention** and management.

However, a solution to any large storage problem always generates other or new problems. The major problems generated by this solution are:

- backup and disaster recovery requirements are increased. Management of offline storage and backup-sets within the storage system is of paramount importance in ensuring the reliability of the storage solution.
- the formats used for writing the files or data to the layers of the storage system must be non-proprietary or at least well understood. This allows for reading of the data on other devices, increasing the **redundancy** of the system.
- problems with network bandwidth can emerge. We now have fast CPUs for the analysis and "unlimited" storage available, but we now need faster networks and interconnections between our storage and computer systems to allow movement of large datasets for analysis.

FUTURE DIRECTIONS

The use of optical and tape technology to provide hierarchical storage solutions is set to continue. There are at least four developing technologies which will ensure that this trend will continue:

- Helical scan tape technology will continue to develop into a storage technology that will deliver high capacity storage solutions. Table 2 outlines the current and future increases in capacity and performance of this technology. This table is based on data from the major supplier of this technology, Exabyte Technologies.

The technology used at the lower levels of most HSM systems is helical scan technology. The future increases in both speed and capacity for this technology provides for a relatively stable and inexpensive upgrade path for the existing tape jukebox layers of HSM systems.

- Optical tape storage, the tape equivalent of magneto-optical disks will become available. Currently this technology has just left the development stage. Each tape holds approximately 1 terabyte with an average access time of 15 seconds. However, the technology is sequential not random.
- Digital linear tape is an available, maturing technology which provides 20+ Gb of storage per tape. Currently no jukeboxes or robotic changers are available.
- The availability of low cost, large capacity (> 10 Gb) disks, and physical disk "spanning" software could lead to large, relatively inexpensive disk storage vaults. These will provide fast storage systems but will still remain more expensive that other technologies.

Table 2. Development of Helical Scan tape Technology

Year	Transfer Speed Mb per Second	Capacity Gb Stored
1987	0.25	2.5
1990	0.5	5
1994	3	20
1997	4	40
1999	6	80

One other technology that will be used to provide larger storage solutions will be CD-ROM (Dvorak, 1994). This will almost certainly be used for distribution of collateral or value-added products after analysis of our terabyte datasets. The emergence of CD-ROM jukeboxes, holding more than a dozen disks, allows the storage of gigabytes of such products.

CONCLUSIONS

We are collecting and storing ever larger volumes of data and information. Access to and availability of this information is still a problem. These access problems generate a need for innovative storage management techniques, such as hierarchical storage management, more than just a need for more storage.

Hierarchical storage management provides an automatic, reliable expansion of our storage to unlimited amounts. HSM positions optical and tape based media as primary storage devices. In using these solutions we accept the trade-off implicit in using slower, less expensive media as against the fast, expensive disk systems and the need for better backup and recover strategies and management.

We need increased storage capacity and CPU performance. But this is not enough. Increasing these two "axes" of system performance, causes a bottleneck to arise in the third axis, networking and interconnection. We must also consider increasing our interconnection performance as well, if we are to fully utilise the expansion that we have experienced in CPU and storage performance.

In short, we now have Gigaflops of CPU performance and terabytes of managed storage available. We still need Gigabits of networking.

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THE SYDNEY HARBOUR EXPERIENCE

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ABSTRACT

Sydney Harbour is a waterway of renowned beauty with its shores populated by several million city dwellers. Its quiet waters have historically been of vital importance as a major shipping port. Since 1901, the Harbour has been managed by a Government authority, firstly the Sydney Harbour Trust and then the Maritime Services Board of NSW whose prime responsibly has been to accommodate and facilitate commercial port activity. As demands on the waterway have intensified, need has grown for a range of controls:

- over development, both on shore and over water
- over on-water traffic, and
- over runoff into the Harbour

The qualities of Sydney Harbour are treasured by the community of the Sydney Region. This paper addresses not only the protective measures adopted with respect to this natural resource but also the wider measures demanded by the community to enhance the environmental amenity of the Harbour, its islands, its foreshores and many sites of historic value.

HISTORY

British settlement at Sydney Cove commenced in 1788 with the founding governor, a naval officer, declaring Sydney Harbour to be "the finest natural harbour in the world".

Sydney began as a penal colony dependent on supplies shipped in from Britain. However, within 20 years, merchants were operating and trade had been established with a number of overseas ports.

Shipping was the lifeline of the infant colony and Sydney Harbour was the focal point of economic activity. As commerce grew, Sydney became a city, with its port and its business district located side by side.

Throughout the 19th century, the port of Sydney was allowed to operate and grow under the free enterprise principle. As the 20th century dawned, the perimeter of the city's business district was lined with privately owned wharves and warehouses. Competition to handle cargo was fierce, profit margins were accordingly low, hence the standard of maintenance of waterfront structures was poor.

The Sydney waterfront had become what, in today's terminology, one might call an environmental trouble spot.

Trouble erupted in the year 1900 with an outbreak of bubonic plague, the cause of which was linked with rat infestations throughout Sydney's ill planned, ill maintained wharf areas.

Serious loss of life forced the New South Wales Government in 1901 to take control of the wharves away from the private sector and commence a comprehensive redevelopment program. This was based on cleaning up the waterfront environment, replacing sub-standard wharves with new well-engineered structures to a proper plan and integrating the port more effectively into Sydney's business centre. To undertake the many construction tasks required, the Government established a body known as the Sydney Harbour Trust. Significantly, the Trust was granted title to the entire bed of Sydney Harbour, of which the area taken up with wharves represented about 5%. This provided the Trust with wide powers in relation to any development or activity below the high tide line.

In 1936, the Sydney Harbour Trust was succeeded by the Maritime Services Board of NSW, which has retained to the present day the powers granted to the Trust as long ago as 1901.

During the 90 years since management of Sydney Harbour was identified as an essential responsibility of Government, there has been, as the foregoing account indicates:

- an authority with the power to influence all development and activity within the Harbour. The community has therefore had a distinct focal point for any concerns relating to use or abuse of the Harbour.
- a consistent means of integrating and co-ordinating the needs of shipping with other users of the Harbour.

SYDNEY HARBOUR: A MULTI-USE WATERWAY

Early history depicts Sydney Harbour as a transport artery for the colonial population as well as a haven for visiting ships. Today, these uses remain important. Recent developments have seen new passenger ferry routes established which service the length and breadth of the Harbour and its tributaries.

The Harbour is fed by several rivers which, as population in the Sydney Region began to spread, became carriers of effluent. Modem sewerage systems have reduced the effluent load discharges into Sydney Harbour and its headwaters. However, stormwater is still necessarily directed into the river system and, given the extent of urban development which has occurred in the catchment over 200 years, runoff during storms is considerably higher today than when the landscape was in its natural condition. The catchment is not a significant source of urban water supply. Accordingly, runoff is not trapped and treated and therefore most reaches the Harbour carrying into it any pollutants and solids picked up during overland flow.

Industrial development within the catchment has been extensive. In early times, a particular category of industry was attracted to the waterfront due to need for a source of cooling water. Until the 1970's, several major power generation plants were drawing water from the Harbour and its tributaries and returning into the stream a high temperature discharge which adversely affected fish and marine plant life. Other waterfront industrial activities have focussed on use of the waterway for the transport of raw materials and products. Ship and boat building, though not as prevalent today as in the past, are among a further category of industrial uses commonly associated with maritime communities.

Small scale fishing is conducted within Sydney Harbour by a fleet of professional operators. Such commercial activity is paralleled by considerable amateur recreational fishing from boats and from the shoreline.

Towards its downstream extremity, the Harbour has several natural, sandy beaches which are popular swimming locations. However, by far the most intensive use of the Harbour is recreational boating - sailing, rowing and power boating.

The Harbour is a major centre of attraction during the Australian summer when its waters become the scene of boat racing as well as a place of general recreational traffic.

The multiplicity of uses to which Sydney Harbour is put places the water body under pressure and necessitates concerted management action to:

- keep the waterway accessible
- protect the water quality
- preserve the natural amenity where possible and to guide development where such is appropriate
- regulate waterborne traffic.

The natural depth of Sydney Harbour has meant that very little dredging has been required to accommodate shipping. Because there is no requirement for regular maintenance dredging there is seldom any serious disturbance of the bed. Although evidence of industrial pollution has been found in sediments along the Parramatta River which feeds into the Harbour, the quality of the Harbour bed has not been a subject of recent attention.

Finding a balance between the interests of people who seek active use of the Harbour and the interests of people who gain passive enjoyment from the beauty of the Harbour scenery has been a major challenge for Government.

In 1990, the Government adopted a special Regional Environmental Plan (REP) to provide a framework for decision making regarding use and development of Sydney Harbour. Further reference is made to the REP later in this paper.

CITY/PORT RELATIONS

Sydney began as a port but as the city grew, it progressively overshadowed the port in terms of interest shown by the community in all that other activities of a city have to offer.

Additionally, the other uses to which Sydney Harbour is put have, for over 40 years now, been challenging the right of port usage (including port-related industry) to hold supremacy.

Significant changes began in 1947. In that year, the first draft of a land-use plan for the Sydney region was released by the Government. The most significant effect of this event from the ports' point of view was the planners vision to force the oil industry to relocate to Botany Bay, approximately 10 km south of Sydney Harbour and, at that time, a recreational waterway with negligible shipping activity.

Consequently, two new refineries were built on the shores of Botany Bay in 1948 and 1954.

The port activity created by such developments led, in the 1960's, to a Government proposal to transfer more of Sydney Harbour's shipping and cargo handling operations to Botany Bay. By the mid 1970's work was underway in Botany Bay to establish a major container port complex. In the ensuing 15 years, the availability of modern port facilities at Botany Bay has resulted in the withdrawal from service of many Sydney Harbour wharves built in the early 1900's. Several precincts with wharves from the pre-containerisation era are now being prepared for a change to other uses. These include the Walsh Bay wharves, the Woolloomooloo Finger Wharf and the Pyrmont wharves. Already, one key area of former wharves, Darling Harbour, has been redeveloped as a tourism and shopping attraction close to Sydney's central business district. The other areas, particularly Pyrmont Peninsula will be redeveloped over the next 10 years as a major inner city residential and commercial precinct including the Sydney Casino.

These examples illustrate how, in the last 15 years, the role of Sydney Harbour has been changing. Thus, although there is still more than 15 million tonnes per annum of cargo using the port facilities in Sydney Harbour, the community perception in the 1990's is that Sydney Harbour is primarily a place valued for its scenic beauty. Management emphasis is now on protection of the natural amenity of the Harbour. Tourism and recreation have become regarded by the community as just as important uses of the Harbour as port activity. To keep in step with the changes, the Maritime Services Board, as a port authority, has had to adjust its approach to management of Sydney Harbour.

THE MSB: A BROADENING RESPONSIBILITY

Having taken over from the Sydney Harbour Trust control of the bed of Sydney Harbour, the Maritime Services Board (MSB) began in 1936 as an estate manager whose assets included islands, beaches, undeveloped foreshore and natural marine habitats in addition to the facilities required for shipping and cargo handling purposes. Navigation powers were granted to give the MSB control, also, over traffic activity on the Harbour waters.

In recent years, the MSB has relinquished control of the Harbour islands, most of which are now the responsibility of the State National Parks and Wildlife Service.

This step accompanied the establishment of a Sydney Harbour National Park designed to protect the natural environment at locations within the Harbour and along its margins where significant development has not occurred despite 200 years of urban activity in the region.

The MSB has also divested (or is in the process of divesting) former wharf areas affected by a change of use.

Notwithstanding the loss of such areas, the MSB has found its responsibilities growing. The navigation powers available to the MSB have taken on new importance as the waters of Sydney Harbour have increasingly assumed popularity for tourism and recreational purposes.

Today, sightseeing cruises and commuter ferry services account for more vessel traffic on Sydney Harbour than commercial shipping ever created. Additionally, thousands of yachts regularly take to the Harbour to compete in organised races. The primary task of the MSB's Waterways Authority, a subsidiary of the Maritime services Board, is to ensure that the various uses of the Harbour can interact with safety.

Because of the intensity of usage, the Waterways Authority - as a secondary responsibility - also concerns itself with protection of the marine environment. In this regard it exercises two important functions:

- it operates a harbour cleaning service to collect flotsam, and
- it requires operators of vessels using the harbour to observe strict procedures in relation to discharge of sewage and galley wastes.

HARBOUR CLEANING

Since its inception, the MSB has carried responsibility, previously held by the Harbour Trust, for clearing floating debris from the navigation lanes in Sydney Harbour. The cost of this activity has been funded through port charges. Until recently, a fleet of small punts provided a service from which approximately 500 tonnes of rubbish would be collected annually.

Though originally established to respond when debris likely to damage ships' propellers or rudders was sighted, the cleaning service evolved over 50 years into a routine operation, performed daily and available to collect any rubbish on the water whether hazardous to shipping or otherwise.

In the late 1980's, the value of this service to the wider community was formally recognised by the MSB and a decision was taken to invest in new equipment which would enhance performance and allow the operation to gain legitimacy as an environmental protection measure as distinct from a navigation-related service.

The harbour cleaning fleet now consists of:

- the "Gadarra", a 15 metre twin hull vessel. The vessel can intercept and mechanically collect rubbish floating in the Harbour before it reaches the foreshore. Rubbish is collected and directed by a rotor located at the bow into 2 x 7 cubic metre wire containers suspended between the hulls.

- the "Bangalee", a 12 metre self propelled landing barge with an hydraulically operated bow ramp and deck crane. The vessel is capable of reaching most beaches and deploys the "Beachcat". The crane is used to remove heavy objects such as refrigerators, discarded tyres, treetrunks and car bodies from the Harbour.
- the "Beachcat" is a rubber tracked vehicle capable of cleaning and sifting sand to a depth of 200 mm.
- the "Dingo" beach rake and loader. These versatile tracked vehicles (2) have been designed to quickly remove surface rubbish deposited on sandy beaches.
- "Fast Response Launches". Four work boats of 7.8 metres length provide rapid response to rubbish problems throughout the Harbour.

Introduction of the "Gadarra", the "Bangalee", the "Beachcat" and the "Dingo" has seen collected rubbish volume increase from around 500 tonnes per annum to around 1300 tonnes per annum. This reflects a broadened attack on the problem, not a broader or growing problem. The cleaning service has been integrated with measures by other agencies of Government to trap debris at major stormwater outfalls. Floating booms have been installed where the debris loads are highest.

The cost of the cleaning service is funded through a Community Service Obligation (CSO) payment made by the NSW Government. Classification of this activity as a Community Service resulted from the Government's recognition that rubbish accumulating in Sydney Harbour originates chiefly on-shore, generally as litter entering the stormwater system.

Other clean up initiatives include the "Clean Up the Harbour Day". At the initiative of Mr Ian Keirnan, OAM, a renowned Australian yachtsman, a Committee was established in 1988 - Australia's Bicentennial Year - to arrange a special clean up of Sydney Harbour.

The efforts of 40,000 volunteers on 8 January 1989 were directed at removal of rubbish which had settled to the bed of the Harbour over many years. To that time, routine work by the MSB's cleaning service had been confined to objects still afloat.

Success with the "Clean Up the Harbour Day" led to a "Clean up Australia" campaign.

SEWAGE PUMPOUT

Whereas the collection of unsightly floating debris can be undertaken after the material enters the Harbour, it is too late to deal with sewage and galley wastes once these have been discharged.

To prevent the entry of wastes which in the past may have been pumped or poured overboard from small vessels using the Harbour, the MSB Waterways Authority has recently introduced "no discharge" regulations, backed up by the establishment of shore-based reception facilities plus penalties for failure to comply.

Recent changes to regulations make it an offence for vessels to discharge toilet wastes into the waters of Sydney Harbour and tributaries from 1 July 1992.

In summary, from July 1 1992 new boats with toilets need to be fitted with a holding tank, storage toilet or on-board treatment facilities. Older boats may retain their pump-through toilets but may not discharge toilet waste into Sydney Harbour.

The MSB Waterways Authority is currently funding the operation and maintenance of public sewage pumpout facilities and the services are provided at no cost to users. Four pumpout facilities can be found at strategic locations around the Harbour, while a mobile barge mounted facility is also available.

SYDNEY HARBOUR REGIONAL ENVIRONMENTAL PLAN

The Sydney Regional Environmental Plan (REP) No. 23, introduced in 1990, states that "The Harbour and its foreshores have become the most intensively used area in Australia. This, combined with its outstanding natural characteristics, also means that the harbour has become possibly Australia's most valuable cultural resource. . . . . . . Intensive use of the area has steadily increased and expanded, so that today it is subject to an immense number of competing pressures . . . . . By the early 1980's it had become - in a practical sense - very difficult to plan and control the use of the harbour and its foreshores in a manner that was responsive to contemporary community values."

The REP provides a single overall framework for decision making and planning for the harbour. Prior to the introduction of the REP, development along the edge of the Harbour was controlled by 10 different sets of local government planning controls.

The Plan "aims to guide major waterway use and to separate potentially conflicting uses through a waterway zoning plan. It also aims to facilitate in appropriate locations, the achievement of additional foreshore open space and public access, and the protection of the areas natural assets and environmental heritage." The Plan encompasses not only the Harbour waters but also four islands. It excludes areas presently occupied by commercial wharves but introduces controls over any expansion of wharf development.

A set of "Design and Management Guidelines" is provided as part of the plan to assist local and state government, developers, builders and landowners to make the most of the harbour by using design that complements the unique landscape of its waterways and foreshores. They apply to development on both publicly and privately owned land. The guidelines are also for local councils and other public bodies responsible for open space and recreational planning. They can use them for making management plans and planning for waterfront parkland, pedestrian paths and waterway uses.

By giving clear advice on acceptable harbourside development, the guidelines will assist in preserving the scenic quality of the harbour for people to enjoy and streamline the process of making and assessing development applications for developments on the harbour.

This innovative regional planning concept has been extended to include an REP for the Parramatta River and for specific major development sites such as the historic Walsh Bay Redevelopment Area and the Homebush Bay Area covering the principle site of the year 2000 Olympic Games.

MSB SYDNEY PORTS AUTHORITY: ENVIRONMENTAL MANAGEMENT PLAN

The MSB Sydney Ports Authority is responsible for the efficient operation of the commercial port areas of Sydney Harbour and Botany Bay. As a subsidiary of the MSB, the Authority has five main areas of business responsibility including the provision of navigation services, management of the port land and property, trade promotion, cargo facilitation and management of the environment.

In acknowledging the last mentioned responsibility, the MSB Sydney Ports Authority has developed and introduced an Environmental Management Plan which seeks to protect and preserve Sydney Harbour and Botany Bay by minimising both the risk and impact of all port activities on the port environment and the surrounding community.

The Environmental Management Plan contains a blueprint for the management and monitoring of the total port environment. The blueprint includes:

- A planned and structured environmental policy to ensure that the best possible equipment and expertise is maintained to the highest international standards.
- An appropriate environmental management structure which minimises the possible impact of maritime operations and complies with, or exceeds government and community requirements.

- Realistic performance objectives designed to produce achievable improvements over time.
- Specified staff responsibilities covering all contingencies.
- Regular review procedures covering risk assessments and hazard monitoring.
- Rapid deployment of appropriate resources to ensure an effective response in the event of an incident.
- Ongoing training, including exercises with all emergency services and port users.
- Scheduled performance audits to ensure the community expectations are surpassed.

The largest government owned inventory of oil spill equipment in Australia is maintained by the MSB Sydney Ports Authority. Main items of equipment include 10 kilometres of various types of oil containment boom, 7 mechanical skimmers with a maximum recovery capability of up to 22 tonnes per hour for the largest unit, a fully equipped emergency response tug (Shirley Smith), numerous fast response vessels, mobile communication facilities, helicopter spray equipment, holding tanks and barges, state of the art sorbent blankets and a fully equipped Emergency Response Operations Centre.

Australia is a signatory to the MARPOL Convention and, from State to State, legislation has been introduced to give local effect to the provisions of the international requirements.

Should a major oil spill occur in Sydney Harbour, whether ship sourced or otherwise, provisions of Australia's 'National Plan to Combat Pollution of the Sea by Oil' are brought into play.

The operational requirements of both the MARPOL Convention and the 'National Plan to Combat Pollution of the Sea by Oil' are encompassed in the Environmental Management Plan.

HARBOUR EDGE PROTECTION

In addition to the planning and legislative controls designed to protect the natural qualities of the Harbour, a significant program of physical harbour edge protection has been under way for some time.

With the ever increasing volume of traffic and size of vessels using the Harbour waterways, the effects of wash on the natural and man made edges of the Harbour would be serious if left unchecked. The problem is not solely the responsibility of the Maritime Services Board, nor of any other singular agency. For this reason, a large number of agencies are involved in seeking solutions to the problem. Several ameliorative measures have been introduced to keep the effects of harbour edge degradation under control. These include:

- Repair and maintenance of existing seawalls. The Maritime Services Board ensures that landowners adjoining the Harbour are responsible for maintaining seawalls. Seawalls are generally constructed of the natural sandstone material so evident in the area.
- Gabion embankment protection has been employed along sensitive sections of the Parramatta River to mitigate wave action effects from vessels using this relatively narrow waterway.
- State Transit Sydney Ferries, the agency responsible for operation of the passenger ferry fleet on Sydney Harbour and Parramatta River, have recognised the need for and benefits of low wash vessels. The introduction of the JetCats in 1990 and the RiverCats in 1993 has realised vast improvements in the wash effects of passenger ferries throughout the Harbour.
- Mangrove replanting trials have been initiated in various parts of the Harbour and Parramatta River. The Mangroves' natural root growth pattern provides ideal bank stabilisation qualities.

SUMMATION

Sydney's community is proud of its Harbour. Ports, cities and recreational pursuits can co-exist. Sydney Harbour represents a supreme example. There are always people who through ignorance or lack of respect treat the Harbour as an expendable and renewable resource. Fortunately, such people now have the weight of community opinion against them. In most cases the identification of natural resource degradation results from the community awareness of its environment, and its commitment to prevent any further loss.

The community and the administrators of Sydney Harbour, particularly the MSB are clearly aware of the changes and advancement of the technologies which enables us to protect and enhance such a valuable natural resource. The MSB will continue to take every opportunity to investigate and implement those technologies that will help to maintain the quality of the Harbour.

The reader is invited to contact the Maritime Services Board of NSW for more information on any issue outlined in this paper should such be required.

MODELLING AND DESIGNING OF THE WAVE ENERGY CONVERTER DEVICE "MIGHTY WHALE"

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ABSTRACT

The wave energy converter named Mighty Whale is a floating oscillating water column device to extract the energy and convert it a useful form of energy, electricity, heat or compressed air energy. Wave energy is absorbed by the converter device and the calm sea area is created behind it where aquaculture or many marine sports is available. The floating wave energy converter has an advantage over the fixed break water. The current could pass under the floating structure and the sea water exchange between inside and outside of bay could be made. If it is possible to combine the use of wave energy and utilization of coastal sea, the economic value of wave power would be greatly increased.

Based on our previous studies the open sea test model of Mighty Whale was designed to study the construction specification, structural form, its stability and mooring safety. From these studies it became clear that necessary specification of construction materials, structural strength aspect and safety mooring arrangement.

Two- and three-dimensional tank tests of the open sea test model of Mighty Whale were carried out to understand the performance of the energy absorption. The maximum wave energy absorption is about 60% and the band width of high efficiency is wider than our former type of the floating wave energy device.

STRUCTURE OF MIGHTY WHALE

We have studied the wave energy converter devices about twenty years. We made the open sea tests of a floating devices named KAIMEI which has oscillating water columns (OWC) of the air chamber to absorb wave energy from 1978 to 1986. From these tests we found the performances of it in real sea and made clear the problems to construct and operate it. With the experiences, we have studied the influence of the shape of device and the specifications of air chamber to improve the performance of wave energy conversion, and we developed a device name Mighty Whale.

The scheme of the shapes of Mighty Whale is shown in Figure 1. Mighty Whale is consisted from three parts : air chambers, floating chambers, and a stabilizer slope. Wave energy is converted to air flow by oscillating water columns of the air chambers, and it drive the air turbines. Presently, we believe that the Wells turbine is the most promising for wave energy devices because its mechanism is simple and work in reciprocating air flow.

Generator is connect to air turbine axis directly and we get electric output from it to drive some kind of the machines. Forward and afterward floating chambers behind air chambers have the ability to keep the buoyancy. Mighty Whale is moored by some loose chain lines in the offshore which depth is in 30-60m, and its air chambers face to the significant direction of wave at offshore like a floating breakwater.

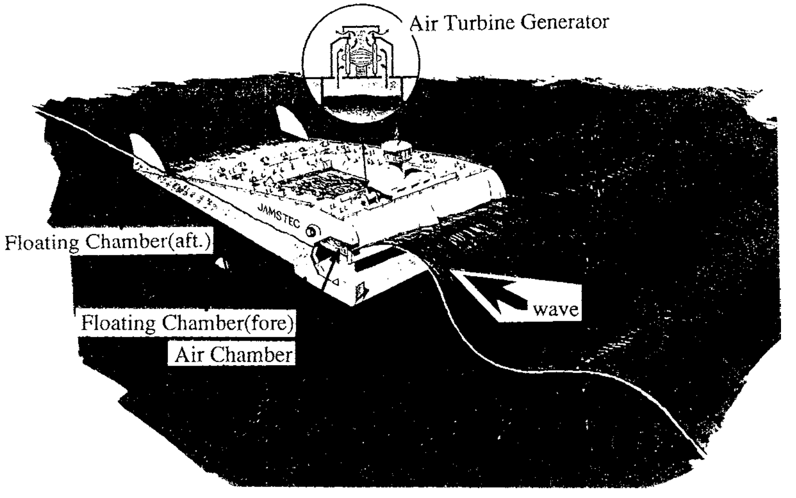

Figure 1. Scheme of Mighty Whale

OPEN SEA TEST MODEL DESIGN

We tried to design the open sea test model of Mighty Whale which is narrower than full scale Mighty Whale in width. The purpose of this design is to clarify the basic construction specification, structural form and intensity, stability and safety mooring and we plan to carry out open sea test in real sea of the pacific coast.

Figure 2 shows the construction plan of Mighty Whale open sea test model which length, width and height are 60m, 30m and 12m respectively and has three air chambers. The 60m long was decided to make the wave energy absorption biggest at the significant wave period of operation condition. Table 1 shows the design condition.

Table 1. Design Condition

Wind speed	26.0	m/sec
Current	0.6	m/sec
Wave height (max.)	11.0	m
Wave period	15.1	sec
Water depth	40.0	m
High water level	1.859	m
Low water level	0.029	m

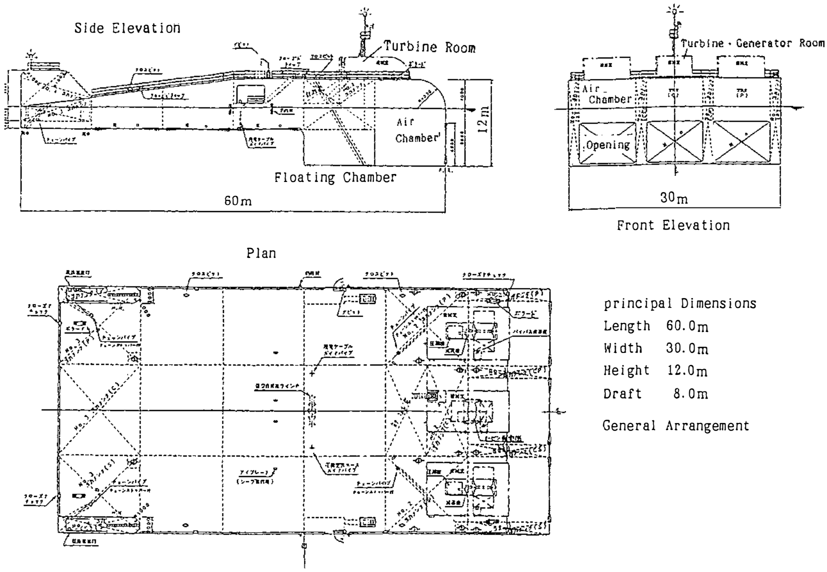

Figure 2. Mighty Whale open sea test model

We studied the general specification, the global and local structure of hull, the structural strength, the hydrostatics, the stability in normal condition and damaged condition, the mooring arrangement, and the external force when the structure is towed to test side from shipyard. Here we show some results of these studies.

We arranged the major machinery on the hull such as turbines, generators, mooring equipment and etc. to study and calculate the total light weight and the distribution of it. This result was used for studies of the stability calculation and the hull structural strength calculation.

We studied the longitudinal strength calculation in still water, hogging and sagging wave conditions. Figure 3 shows one of the result of bending moment and shearing force calculation in sagging wave condition. You can find that Mighty Whale has very big bending moment at midship. It comes from the arrangement of the forward and afterward floating chambers to stabilize the Mighty Whale in wave and make the wave energy absorption bigger.

We also studied the structural strength calculation using finite element method in the conditions when wave comes from front, wave comes from side and oblique direction. Figure 4 is one of finite element model. Figure 5 shows the calculated result of torsion moment in diagonal wave and Figure 6 shows the lateral bending moment when sagging wave comes from side.

To satisfy the requirements obtained from these hull strength calculation, we decided that main structures are constructed by 12.5 mm thick steel plaits.

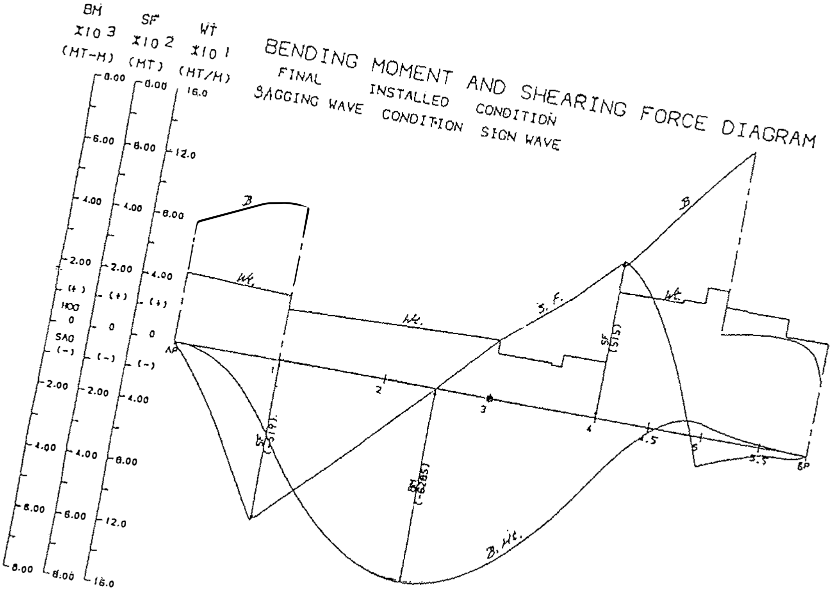

Figure 3. Bending Moment and Shearing Force in sagging wave condition

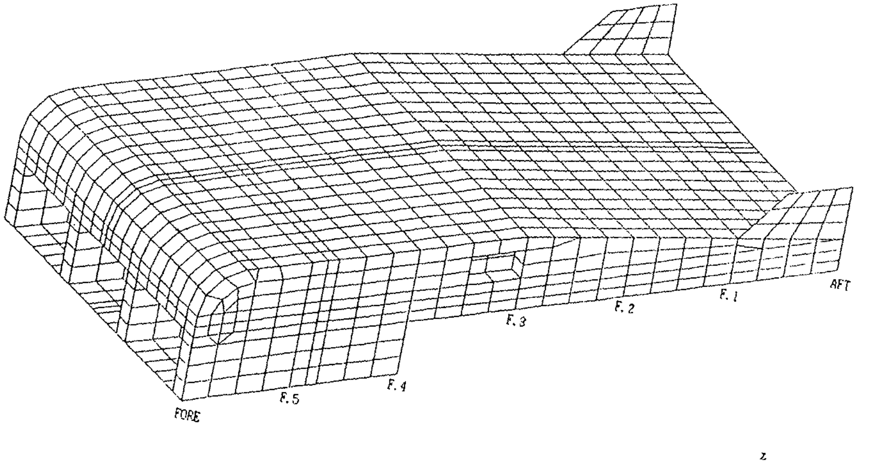

Figure 4. Finite element model

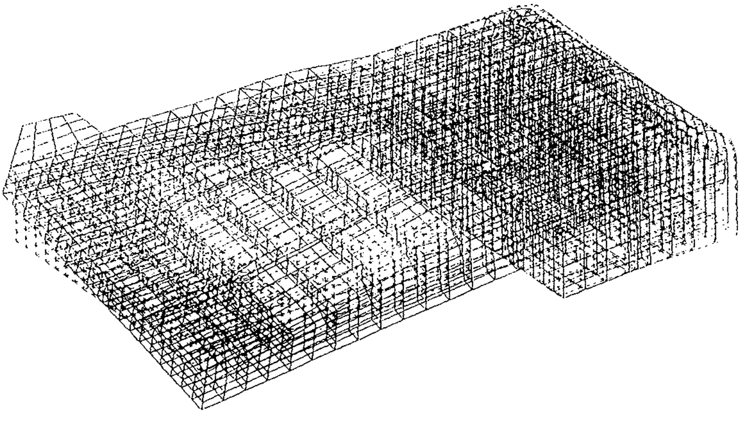

Figure 5. Calculated result of torsion moment in diagonal wave

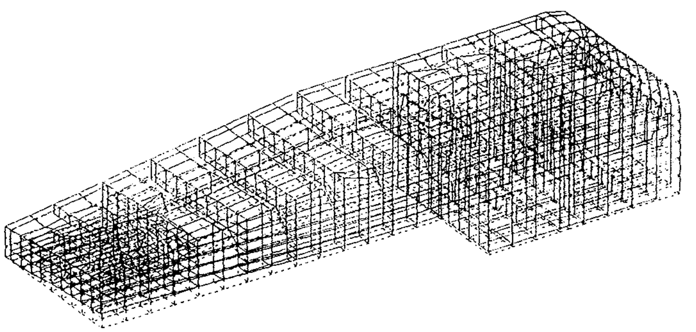

Figure 6. Lateral bending moment in sagging wave

From these design studies of the open sea test model of Mighty Whale, the necessary specifications of construction, structural strength aspect, safety stability and safety mooring are made clear.

MODEL EXPERIMENTS

We studied the ability of the open sea test design of Mighty Whale with the tank model tests. Figure 7 shows a tank tests model of Mighty Whale (1/30 scale model) which is 2000 mm in length, 1000 mm in width. The air chamber has a orifice on the top plate of the chamber which correspond to the real turbine and generator load. This ratio of the orifice (orifice area/air chamber area) is about 1/110, because of the most suitable ratio for absorption wave energy by air chamber in our model experiments. The three dimensional model experiments were carried out in the wave tank (70 m long, 30 m wide, 3 m depth) with this model. The incident wave, reflection wave and transit wave were measured by wave gages. The wave absorbed energy was calculated by the value of pressure deference of before and after the orifice.

The two dimensional tests were also carried out with a smaller tank tests model of Mighty Whale (1/62.5 scale model) which is 960 mm in length and 480 mm in width and has same proportion as the bigger model. We made these tests in a narrow tank (20 m long, 0.5 m wide, 0.5 m depth). These model experiments are corresponded to the two dimensional model tests due to the model width and tank width are almost same. The result of two dimensional model tests mean the ability of a model which has infinite width.

Figure 8 shows the wave energy absorption (Ea/Ew, where Ea is air flow energy and Ew is energy of wave of which breadth is same as one of the model) versus wave length (l) divided by length (L) of the device. This figure shows the results of the two dimensional test and three dimensional test in regular waves. The difference between two dimensional test and three dimensional test is little in this result, so we could say that the abilities of the narrow Mighty Whale indicate these of the wider Mighty Whale for practical use.

In both tests the maximum wave power absorption is about 60% and the band width of high efficiency is wider than our former type of the floating wave energy devices (for example, the wave power absorption of KAIMEI is under 20%). These results show Mighty Whale has excellent performance of wave energy absorption.

Figure 9 shows the wave energy absorption in heading, transverse and diagonal regular waves condition. The decrease of the performance when the wave comes from diagonal direction is not so big. It leads the good performance of Mighty Whale set up on coastal sea.

Figure 10 shows the wave energy absorption in irregular waves. The maximum value of it is about 40% and it indicates the actual performance in real sea.

The above results lead the performance of the Mighty Whale on the wave power absorption are excellent. The reason for such outstanding performance are leaded that the pitching coupling motion of the air chamber and oscillating water column.

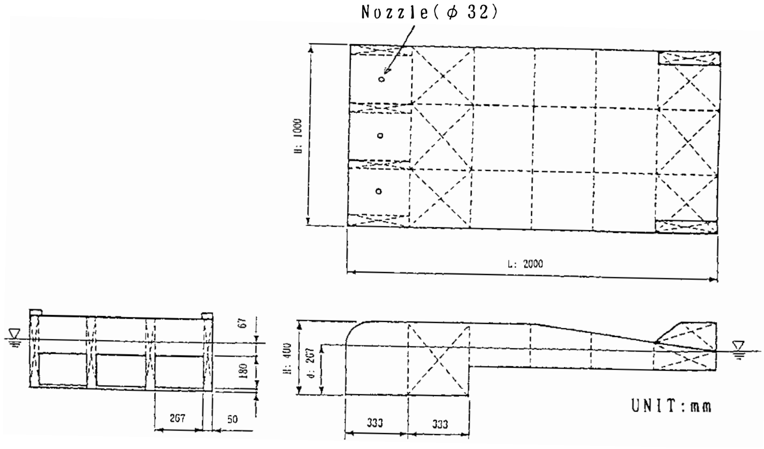

Figure 7. Big Mighty Whale model (1/30 scale model)

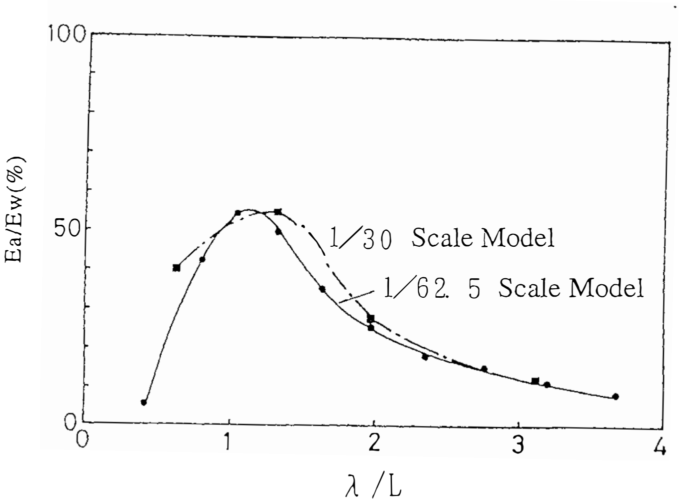

Figure 8. Wave energy absorption in regular waves.

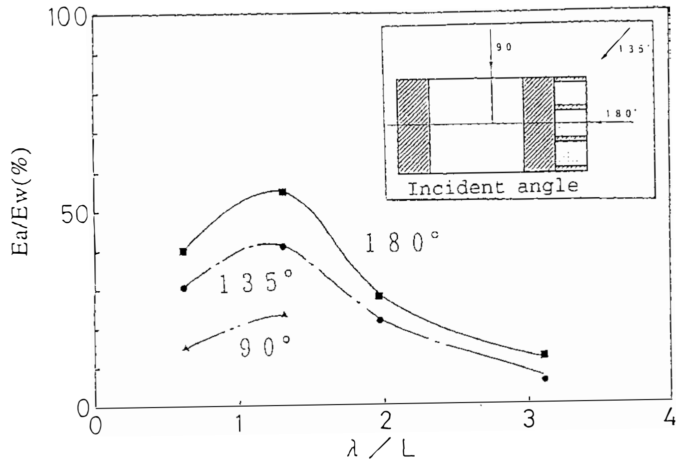

Figure 9. Wave energy absorption with different direction waves.

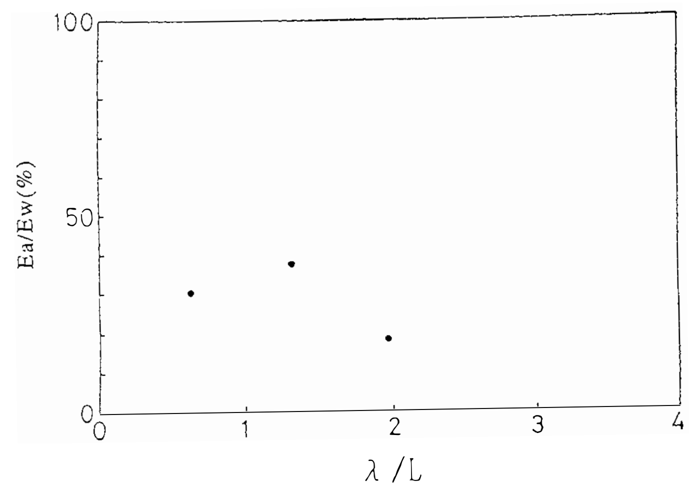

Figure 10. Wave energy absorption in irregular waves.

UTILIZATION OF OFFSHORE AREA

The floating wave energy converter Mighty Whale is designed based on three main concepts, 1)install on offing, 2) multipurpose, and 3)influence of environment.

First item means that Mighty Whale should be moored in the offing. It makes the absorbed energy big because the wave energy is bigger on offing than shallow coastal area. If the depth of water is larger than a certain limit, the cost to construct fix type wave energy devices or breaking water is too big. In such case floating type device is better. And if we put it on offing, we should never wonder about the bad influence to coastal area by it because the influence is very little and we can decide the size of it not to harm coastal environment.

The second item means that to increase the economical value the wave energy devices should have multipurpose functions. Mighty Whale can supply power to some machinery and create useful calm sea area on offing by breaking water. We can use space area on the device for the desalination of sea water and other plants, fishing and aquaculture platform etc.

The third item means that the wave energy devices should have ability of environment cleaning and keep the ecosystem of coastal seas. Especially to purify the environment, it is best way to use these clean energy. Because if we use the dirty energy to clean the local environment, it means to spoil the global environment.

Figure 11 shows the future plan of the utilization of offshore area with large Mighty Whale systems. If we arrange the devices on offing in considering the effect of breaking water to make calm sea and use the power gotten by these to improve environment conditions, we could utilize wave energy in best way.

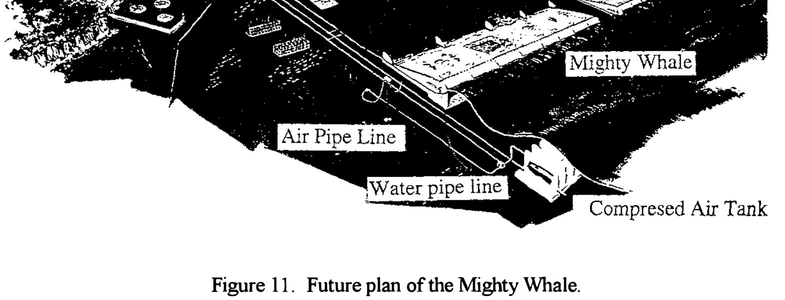

Figure 11. Future plan of the Mighty Whale.

CONCLUSIONS

Following conclusions were obtained.

(1) Mighty Whale basic concept is superior, especially its shape lead various effects such as device stability, high energy absorption efficiency and wide deck space.

(2) Mighty Whale has an excellent performance of wave energy conversion. The maximum efficiency reach about 60% under the condition of regular waves.

(3) With designing open sea test model of Mighty Whale, we could make clear the necessary specification of construction, structural strength aspect, safety stability and safety mooring system.

(4) Total plan of the utilization of offshore area using Mighty Whale was established based on the three study concepts, 1) install on the offing, 2) multipurpose device, 3) good influence to environment.

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FIELD VERIFICATION EXPERIMENT AND UTILIZATION STUDY ON WAVE POWER EXTRACTING CAISSON BREAKWATER

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ABSTRACT

The Japanese Ministry of Transport has been developing a wave power extracting caisson breakwater to absorb wave power and convert it into electric power. The caisson of the breakwater has an air chamber which is a wave power converter of oscillating water column type. A test breakwater was constructed in the summer of 1989 in Sakata Port and the field experiment began in the winter of 1989.

The field experiment was conducted very successfully, although several severe storms attacked the caisson. The characteristics of the wave-activated power generation by the wave power extracting caisson were revealed and the design method of the system was confirmed in this prototype experiments. Several tests to utilize the output electricity were also gave a prospect to a practical use.

INTRODUCTION

Ocean wave energy is clean and inexhaustible. Repeated oil crises and the urgent need for environmental preservation on a global scale have made utilization of ocean wave energy increasingly important.

The Japanese Ministry of Transport has been developing a wave power extracting caisson breakwater which can absorb wave power and convert it into electric power. The breakwater shown in Figure 1 is a composite breakwater with a special caisson for absorption and conversion of wave power. The caisson has a so-called air chamber where wave power is converted into air power. The air power activates a turbine-generator in the machine room on the caisson. The use of the breakwater as a wave power converter will effectively cut down the power generation cost. This breakwater also aims at the improvement of the wave resisting stability and performance as a breakwater by absorbing the wave energy.

The research and development work on the wave power converter is being carried out through collaboration by the First District Port Construction Bureau, the Port and Harbour Research Institute (PHRI) and the Coastal Development Institute of Technology (CDIT) under the guidance of the home office of the Ministry of Transport. PHRI had conducted basic research for five years since 1982 (Takahashi *et al*, 1986; Takahashi, 1988), then the First District Port Construction Bureau began a field verification experiment for the breakwater from 1987 in the form of a joint study with CDIT and twenty private companies. A test breakwater was constructed in the summer of 1989 at Sakata Port in Yamagata Prefecture. The breakwater began the power generation in the winter of 1989 (Goda *et al.*, 1989; Nakada *et al.*, 1992). Photo 1 shows the completed caisson and Photo 2 shows the on-land observation house and a tower illuminated by the converted energy.

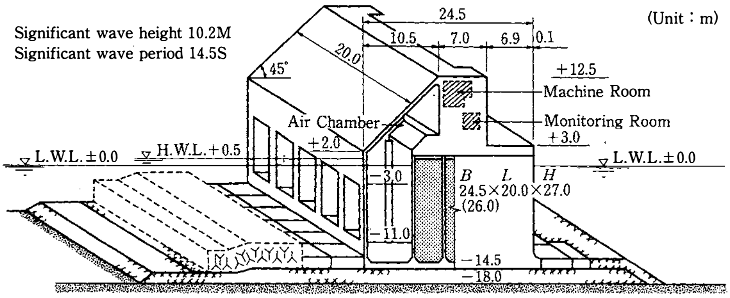
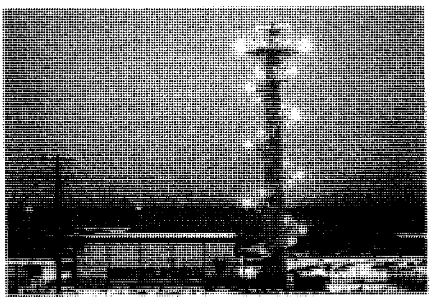
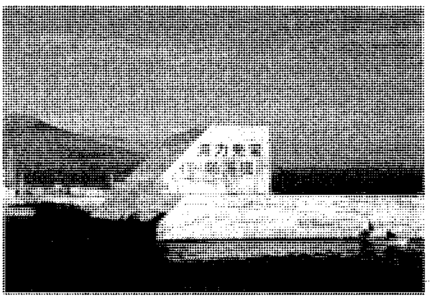


Figure 1. The shape of the caisson breakwater.



Photograph 1. Completed Caisson



Photograph 2. On-land observation house

The field experiments have been conducted aiming at the following items:

1) to confirm the design method of the breakwater caisson including the air chamber against wave forces,
2) to verify the design method of the air chamber, turbine and generator as a wave energy converter,
3) to study methods of constructing the breakwater, and
4) to demonstrate utilization of the power output for various uses.

This paper introduces the system with a wave power extracting caisson in the field experiment, the results of the field experiment, and the utilization of the electric power.

WAVE POWER EXTRACTING CAISSON BREAKWATER

Shape of Caisson

The caisson for electric power generation consists of a hollow box called "air chamber" which is supported by an ordinary caisson. The front wall makes a curtain wall with openings to allow water to enter inside. The power generating equipment is composed of the air chamber, turbine, generator and protection devices. The air chamber, featured by the sloped configuration of the upper portion of the front wall, is the primary converter of the oscillating water column (OWC) type to use the vertical movement of water to compress and expand air, and produces air flow at the top nozzle (Figure 1).

Design of Breakwater

Through model experiments, PHRI has clarified the function of the breakwater for power generation by a wave power extraction caisson and the concept for its design. The Goda wave pressure formula is used as the standard method to calculate the wave pressure on a composite breakwater caisson, and its expansion has been proposed for application to the wave power extracting caisson from model experiment. The caisson is more stable than the conventional caissons. The wave reflection by the caisson in the same experiments varies within the range from 0.45 to 0.50.

Design of Power Generator

Figure 2 gives a concept of the machine room. The air flow converts its energy into the kinetic energy by rotating the turbines and subsequently the generator in Figure 3, which are installed at the center of the machine room at the upper portion of the caisson. Two Wells turbine of 1.337 m in diameter are used to get a one-way rotation from the reciprocal movement of the air. The generator is a 200 V synchronous generator with the rated output of 60 kW and the maximum revolution of 3,000 rpm.

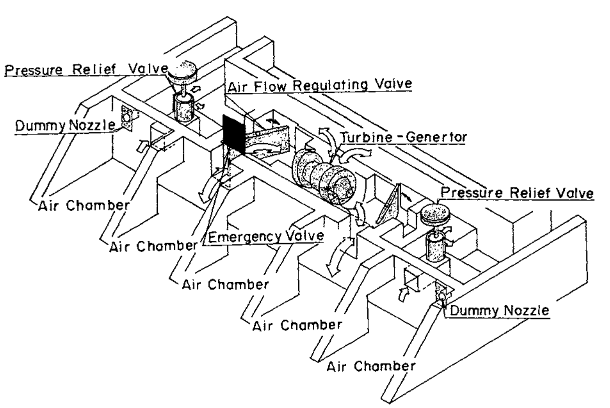


Figure 2. The conception of the machine room.

The protection devices that control the air flow from the air chamber to the turbine consist of three types of valves namely for air flow regulating valves, pressure release valves and emergency valves.

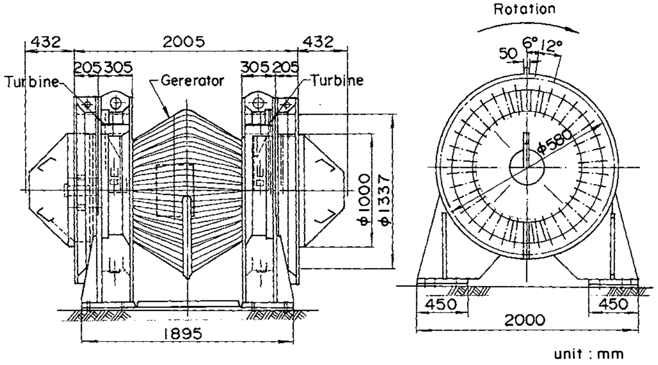


Figure 3. Turbine and generator.

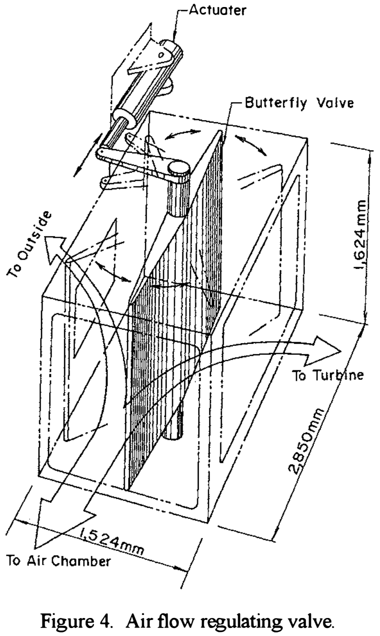


Figure 4. Air flow regulating valve.

The air flow regulation valve of the butterfly valve type in Figure 4 changes its opening in five stages to release part of or total air flow in case the revolution of the generator exceeds the rated value.

The pressure release valve works with the compressive air pressure in the air chamber to adjust the air flow and releases the hammering air flow when one emerges.

The emergency valve, a gravity drop type protection device for the caisson and other equipment, cuts the air flow to stop the turbine and generator and releases it to the atmosphere when waves are so high that the bypass valve or the pressure release valve can not cope with.

FIELD EXPERIMENTS

Location of the Experiment

A caisson of the Second North, breakwater of the Sakata Port is used for the verification experiments as shown in Figure 5. Table 1 gives the design conditions at the site. Data analysis and utilization experiments of electricity obtained by wave power extracting caisson have been done at the On-land Observation House.

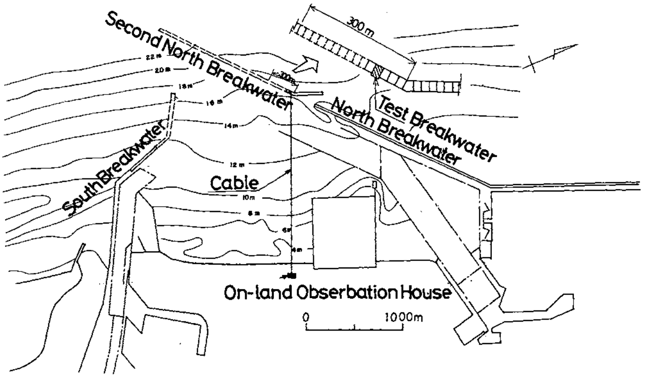


Figure 5. Location of field experiment site (Sakata Port).

Table 1. Design condition.

H.W.L.	+ 0.50 m
L.W.L.	0.00 m
$H_{1/3}$	10.2 m
H_{max}	15.3 m
$T_{1/3}$	14.5 s
θ	25.0°

System of Measurement

In this experiment, the measurement has been done by various sensors installed in the caisson and the generating system. The details are classified broadly into the following three categories.

1) waves: wave height, wave period, wave direction, wave power, etc.
2) stability of structure: wave pressure(uplift, air pressure), reinforcement stress
3) conversion of wave energy: air output, generating power, etc.

Construction of the Breakwater

The wave power extracting caisson has a special shape compared with an ordinary breakwater caisson. Especially, the front wall of the air chamber is sloped and this makes the construction work more difficult. Moreover, a large wave force seems to act to the sloped wall. Therefore, a sufficiently high accuracy is required for building this sloped wall. The lower portion of the caisson was built on a floating dock and the upper portion was made at sea at a calm place in the harbour. The caisson completed up to the sloped portion was then towed out to the sea and installed on the foundation mound. Machine room and so forth for housing the turbine-generator was completed after installing the machines. Figure 6 shows the construction procedure for the caisson.

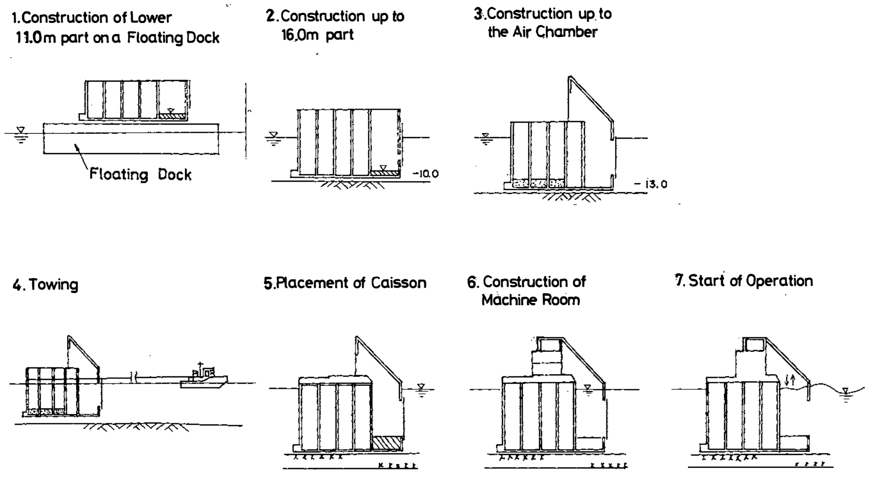


Figure 6. Construction procedure for wave power extracting caisson breakwater.

Wave Power Conversion

Figure 7 gives an example of the records of power generation, ie., the water surface elevation [ƒÅ(m)] and the air pressure [pa(tf/m2)] in the air chamber, opening of the air flow regulating valve [VB], pressure difference in the turbine [pd] and turbine speed[NT(rpm)], and power output for 20 minutes [Wg(kW)], that were recorded at 14:00 on November 8 in 1990, when the significant wave height and period were 3.01 m and 7.9 s, respectively, and the incident wave power was 539 kW per 20 meters of caisson length. The turbine rotation varies from 1250 rpm to 2100 rpm and the electric power varies from 20 kW to 60 kW. As the turbine speed exceeds 2000 rpm the air flow regulating valve opens to reduce the air flow to the turbine as shown in the figure. The average electric power is 36.4 kW, and the conversion efficiencies from wave power to air power, from air power to turbine power and turbine power to electric power are 0.59, 0.37 and 0.91, respectively. However, a large amount of air power is released by the dummy nozzles and valves. Therefore, the utilization rate of air power is very low (0.34). If all the power is used, the electric power is about 100 kW.

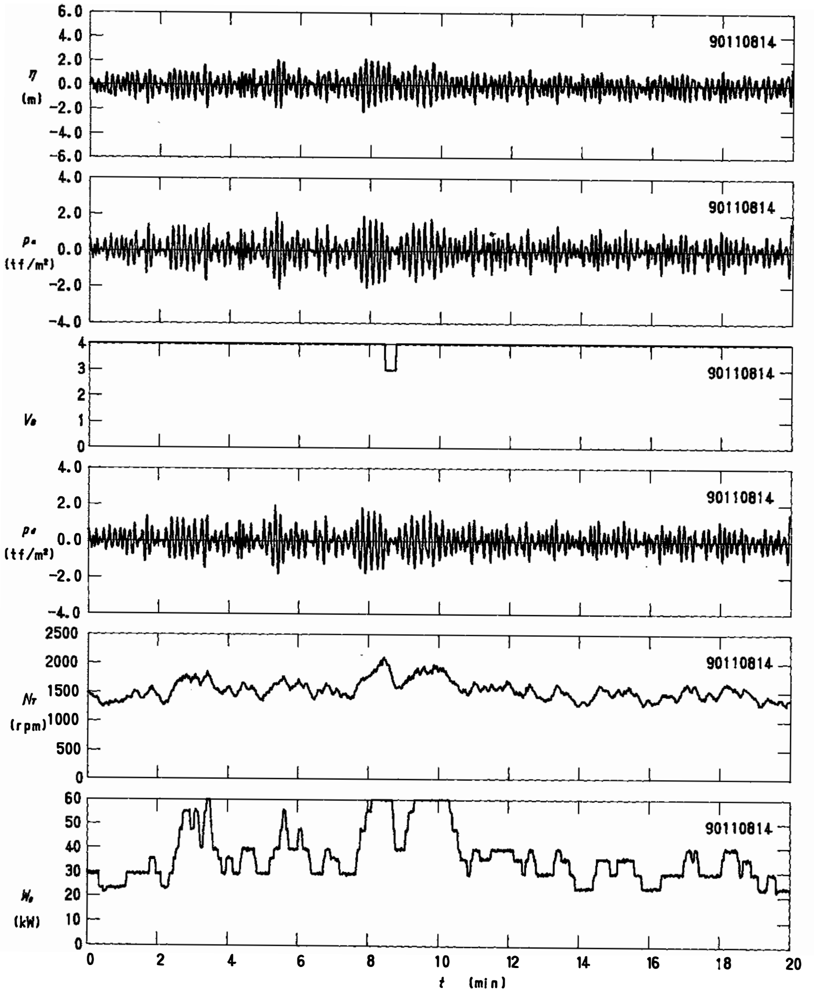


Figure 7. Analogue record of power conversion.

Figure 8, shows the variation of the electric power to the significant wave height. The electric power increases according to the increase of the wave height. However, the electric power becomes very stable at about 55 kW where the wave height exceeds 4m, due to the automatic control of the valves. The system can generate electric power when the significant wave height is 1 m to 5 m as designed. The calculated values for the normal incident waves are shown in the figure by a dotted line. The calculated values, which were used in the design of the present system, agree with the experimental ones for small wave angle. The calculation was based on the thermodynamics and wave-kinematic theory.

The conversion efficiencies in the experiment are shown in Figure 9. The conversion efficiency from wave to air power (EFFa) is from 0.4 to 0.8. The turbine efficiency (EFFt) is from 0.2 to 0.5. The generator efficiency (EFFg) is about 1.0 when the wave height is large. The total efficiency which is given by the product of EFFa, EFFt and EFFg is from 0.1 to 0.3 approximately. However this system includes the control valves and dummy nozzles so that actual efficiency should be multiplied by the air power utilization rate.

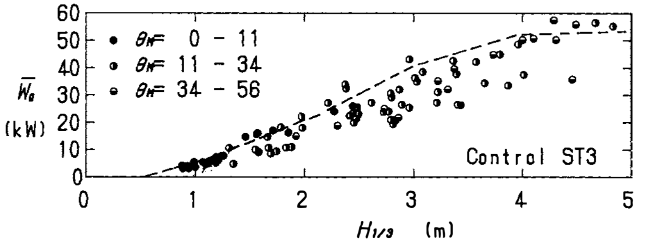


Figure 8. Electric power.

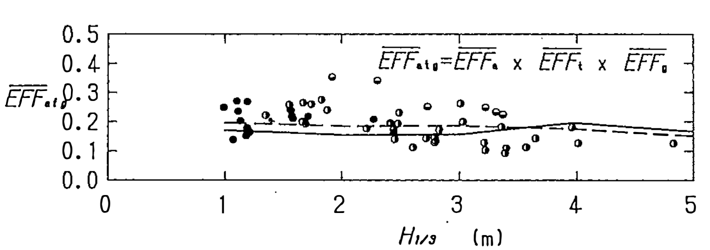


Figure 9. Conversion efficiency.

UTILIZATION OF THE ELECTRIC POWER

Wave Power Conversion by a Full-Size System

The turbine-generator is small in the experiment. A full-size system with a larger turbine generator can produce the electricity more. Figure 10 shows the calculated result of the wave power conversion by a full-size system with an optimal turbine generator for the conditions in Sakata Port. The diameter of the turbine is 2.4 m, which is almost twice that in the experiment. The rated power of the generator is 200 kW. The turbine speed is expected to be 700 rpm and the electric power is 75 kW when the significant wave height is 2.2 m. The electric power becomes 200 kW when the significant wave height is 4 m.

According to the predicted wave power conversion by a full-size system in Sakata Port, using the conversion efficiencies in Figure 10 and the observed wave data from 1990-1991, the annual average electric power in Sakata Port is 27.3 kW and the average value within winter time is 49.3 kW. In Kashima Port the wave power conversion can be made for 67 % of time and the annual average electric power is 40.9 kW.

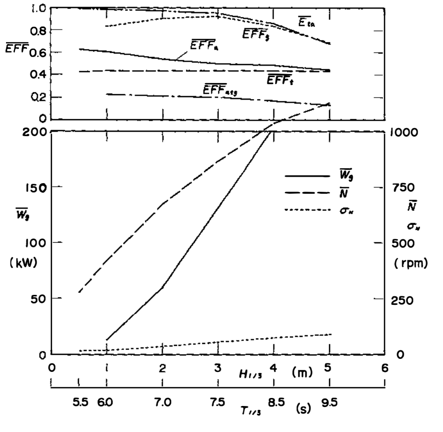


Figure 10. Power generation by full-size system.

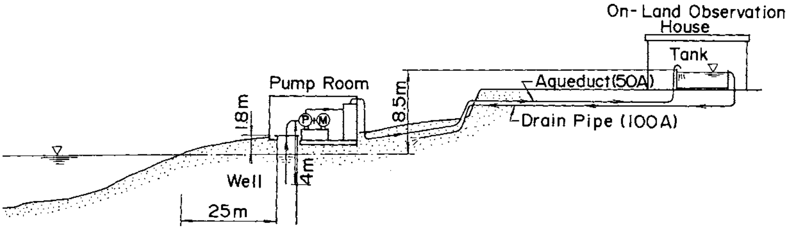


Figure 11. The system of pumping by wave power.

Experiment to Utilize the Electric Power

There have been experiments to utilize the fluctuating electric power generated by wave powers with instruments, installed at On-Land Observation House at the Sakata Port. A pumping device (Figure 11) installed in the sandy beach activates smoothly regardless of the fluctuation of electric power. The pumping system is sufficiently applicable to the SUB-SAND-FILTER METHOD which is one of countermeasure against the coastal erosion by lowering the underground water level in the beach. Furthermore, a road heating system in which electrothermal wires are installed has shown its effectiveness as expected at the time of snowfall during the winter.

While it generally needs accumulators to utilize the variable electric power generated by wave powers as a normal electric power, it is possible to utilize it efficiently without smoothing the electric power. These experiments at Sakata Port shows that wave power can be supplied to these facilities without smoothing electricity. Furthermore, the experiment has been opened to the general public, and more than 6,000 people in and out of the country visited at that time.

4.3 Connection to Commercial Power Line

In Japan, electric power companies are going to change their rule to accept the electricity from natural energy resources such as solar and wind energy, and the rule may be applied also for wave energy in the near future. An electric circuit that can allow the safe connection is now being studied in the second stage of the field experiment. If the circuit can be developed, a commercial power supply from wave power might begin in the winter of 1995.

CONCLUDING REMARKS

The field experiment was conducted very successfully, although several severe storms attacked the caisson. The characteristics of the wave-activated power generation by the wave power extracting caisson were revealed and the design method of the system was confirmed in this prototype experiments. Several tests to utilize the output electricity were also made in the experiments and gave a prospect to a practical use.

The field experiments were carried out under the guidance of the advisory committee chaired by professor Y. Goda. The experiments was conducted by the collaboration with many people. The authors wish to express their sincere gratitude to all the people.

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INVESTIGATION OF THE DURABILITY OF SUBMERGING/SURFACING FISHERY CULTIVATION FACILITY MARINE AYA No.1

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ABSTRACT

To make use of broad underwater space for mariculture, mid-layer floating marine cultivation facility with function of submerging and surfacing, "Marine Aya No.1" was developed and placed at a 16 meters of water in Rias bay in Iwate Prefecture in December 1990. A welded steel structure, the Marine Aya No.1 consists of an artificial seafloor surface 20 meters square that floats 4 meters below the ocean surface, and a machinery hut that projects above surface at the center of the structure. It has been evaluated as abalone cultivation facility since May 1991 and inspected periodically to get the long-term follow-up data on durability.Inspection items were cathodic protective potential measurement, anode volume measurement, mooring chain diameter measurement, appearance inspection, anchor position survey and so on. It was confirmed that durability of the facility was as good as designed. The facility proves to be an excellent for abalone mariculture.

INTRODUCTION

The Marine Aya No.1, (Figure.1) a submersible and surfacing artificial seafloor, was developed as a multipurpose underwater facility for rearing live organisms on Rias seacoasts. It was installed in 16 meters of water in Ryohri-Minato Bay in Iwate Prefecture in December 1990 (Figure .2). A welded steel structure, the Marine Aya No.1 consists of an artificial seafloor surface 20 meters square that floats 4 meters below the ocean surface, and a machinery hut that projects above the surface at the center of the structure. The structure is held in place by a catenary type mooring at four points. Northern abalone hereafter referred to as abalone) is cultivated on this artificial seafloor, which can be raised to the ocean surface for feeding or other cultivation work.Ongoing corroborative experiments have been performed since the facility was installed, and these have confirmed that the facility is effective in increasing the stocks of abalone, an important Iwate Prefecture product (Okamoto *et al.*, 1992. Tomita *et al.*,1992 Suzuki *et al.*,1992).

This paper describes events since the Marine Aya No.1 was moored,test implementation conditions,content and results of the inspections, and the outlook for the future durability of the structure.

DESIGN OF THE MARINE AYA NO.1, AND RECORD OF EXPERIMENTS

A submersible and surfacing artificial sea floor,the Marine Aya No.1 was constructed at a dry dock in Shiogama by Kawasaki Heavy Industries (Figure 1). It was then anchored in 16 meters of water inside a breakwater located in the mouth of Rhohri-Minato Bay at Sanriku-cho in Iwate Prefecture (Figure 2).

Table 1. Principal particulars of Marine Aya No.1

Length x Width x Height (overall)	: 20 m x 20 m x 11.4 m
Draft	: Surfacing abt.2.0 m Submerging abt.6.0 m
Height of superstructure	: Surfacing abt.9.4 m
Draft adjusting capacity	: Loading weight 30 tons
Time required for submerging	: abt.10 min.
Time required for surfacing	: abt.60 min.

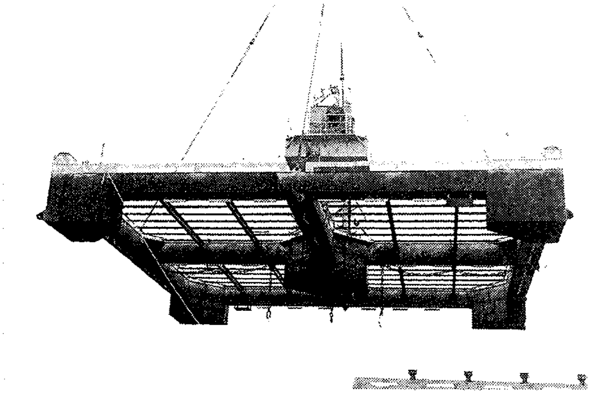

Figure 1. Submersible artificial sea floor Marine Aya No.1. Balance weight is not hung beneath the facility at this moment.

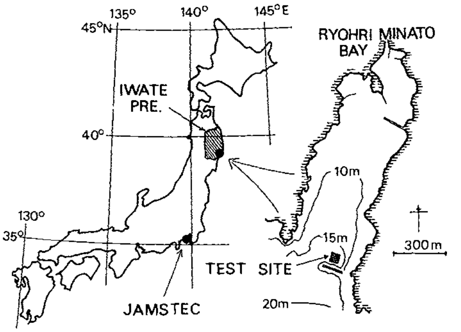

Figure 2. Location of test site.

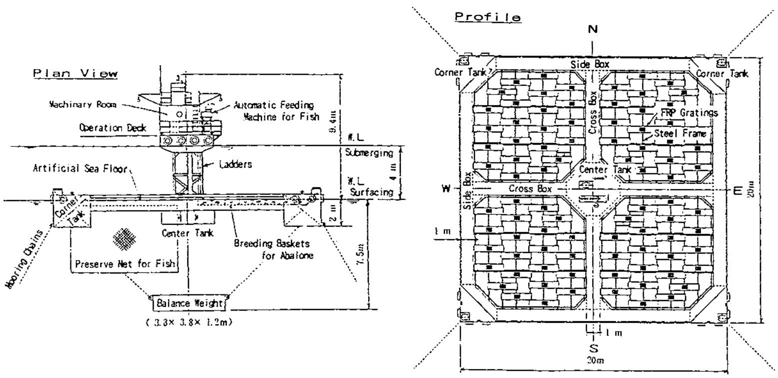

Figure 3. General arrangement of Marine Aya No.1.

It is moored to the sea bottom at four points by anchors and chains. To keep the facility stabile when on the ocean surface, a balance weight has been suspended from its bottom. To submerge and surface the facility,seawater is either taken into or discharged from its center tank. Corner tanks installed at the four corners of the structure have a total capacity of approximately 30 cubic meters and are used to compensate for the weight increases and imbalances caused by attached living organisms and installed machinery. Cathodic protection is provided to those parts of the structure below the waterline. The artificial seafloor surface is of steel frame construction, and a movable FRP grating is installed over 1/3 of its surface for person to walk on this grating while walking across the structure or working upon it. (Figures 4, 5)

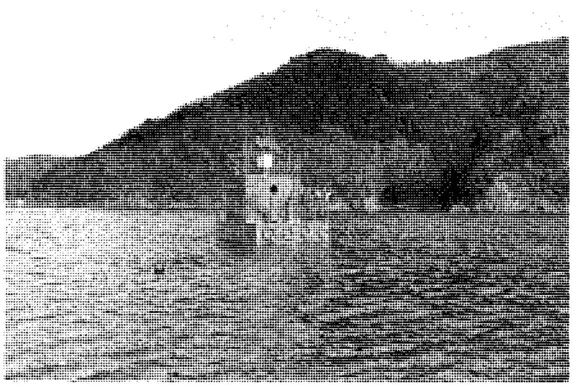

Figure 4. The facility at submerging.

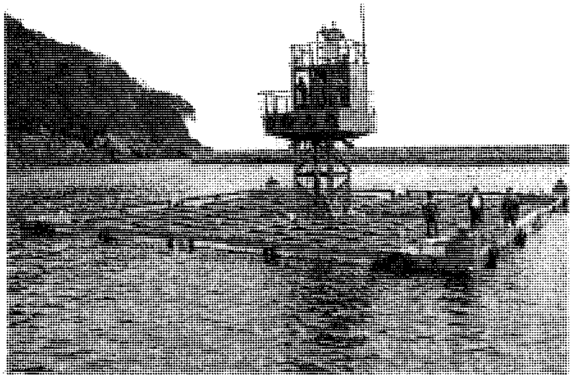

Figure 5. The facility at surfacing

For commercial use of the facilities, JAMSTEC, Iwate Prefecture, and the Ryohri Fishery Cooperative Association have been engaged since April 1992 in cooperative research on three issues: selection of abalone juvenile size and a study of the rearing period that will maximize the economic return of the facility; collection of durability data, and an assessment of the operating characteristics; and economic efficiency of the facility when it is used rear large volumes of abalone.

Ryori Fishery Cooperative a cooperative body, has begun rearing about 45,000 abalone (shell length, 30 to 45 mm).(Figure 6) Some 180 abalone breeding baskets (0.9 x 0.9 x 0.45 Hmeters) have been attached firmly to the surface of the artificial seafloor, and are used to rear about 2 tons of abalone. Feed, in the form of cultivated kelp and seaweed, is provided at intervals of about 20 days. As of the end of September 1993, the abalone being raised are maturing well. As a trial, small quantities are periodically shipped to fish markets, and evaluated as being of equal or higher quality than natural abalone.

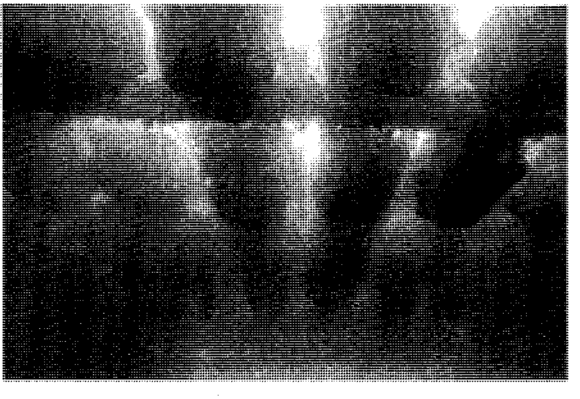

Figure 6. Fixed abalone breeding baskets under the artificia seafloor at 4 m depth.

OPERATION OF THE MARINE AYA NO.1

The Marine Aya No.1 has been in place for two years and nine months, and abalone cultivation has been underway for two years and four months. Outlined below is a summary of assessments of the operation of the facility as a living organism cultivation facility, based on the ocean surface corroborative testing conducted thus far.

Operational performance, maintenance and inspection of the facility

Despite the fact that the Marine Aya No.1 is a large-scale structure with a 20-meter square component that submerges and surfaces, Only a small number of simple operations are involved, such as visual inspections, simple measurements, waterproofing checks, and refueling.(Table 2).

Table 2. Marine Aya No.1 routine check standards

A. Inspection on every workin day
- **a.** General visual inspection
  - Gardrail and ladder
  - Structure (Paint, Damage)
  - Diesel generator
  - Obstruction light

B. Monthly inspection(andmaintenance)
- **a.** Measurement
  - Draft at submerged/afloat condition
  - Time for surfacing/submerging
  - Voltage of generator
- **b.** Cleaning
  - Surface of solar panel
  - Lens of objection light

C. Every three months inspection
- **a.** Close visual inspection
  - Watertight integrity of manhole cover
  - Watertight integrity of objection light

Three devices installed in the machinery hut are required to submerge and surface the facility. The diesel generator (3.8 kVA) is turned on for surfacing and shut off afterwards. When surfacing begins, the underwater pump start-button on the electricmotor shuts off automatically. The time required to complete submerged or surfaced operation has been measured and recorded. Figure 7 shows this data. A total of 260 submersion and resurfacing cycles had been performed as of the end of September 1993.

The mechanisms and equipment used to submerge and resurface the facility have worked perfectly so far, and the water injection and discharge pipes have had to be cleaned to remove living organisms only twice (1991,1993), both times during the annual periodic inspections described below. During the 1993 cleaning, the valves were opened and cleaned at the same time that numerous living organisms adhering to the inside of the pipes were removed.

Table 3. Marine Aya No.1 maintenance record
between Dec.1990 and Sep.1993.

• Diesel generator
Fuel up (1l /surfacing)............................Timely
Lubricating oil change............................3 times
• Obstruction light
Lamp changeOnce
• Ballast adjustment (as test)
Discharge water from a corner tank......... Once
• Ballasting system of center tank (at annual inspection).
Valves disassemble and cleaning.............. Once
Water pipe cleaning................................2 times

Table 3 presents a record of maintenance work performed through the current date. Only extremely simple operations have been involved, accounting for a total of about US$ 300 in direct costs.

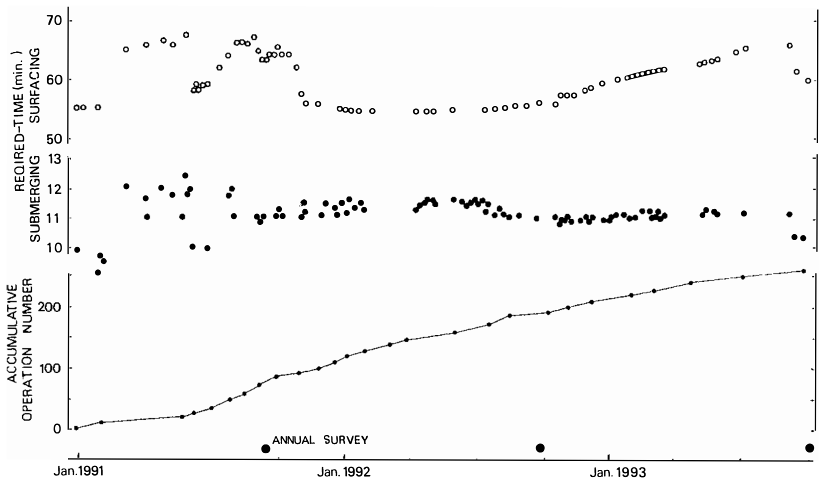

Figure 7. Accumulative operation number and submerging/surfacing time

Performance as an abalone cultivation facility

A compound cultivation trial was carried out in 1991. Abalone were raised on the surface of the underwater seafloor and black rock fish (Sebastes schlegeli) raised underneath them. This trial verified that the underwater space could be divided into two levels. The draft of the facility can be adjusted up to a maximum of 30 tons, allowing it to handle large-scale cultivation and a heavy load of attached living organisms.

Abalone are also effectively protected from changes in water quality by the facility. Large quantities of fresh water and soil are washed into the bay from rivers during a typhoon, for instance, turning the water surface of the entire bay brown and lowering the salinity at the surface. This phenomena only affects the water to a depth of about two meters, however, allowing the abalone, which are being cultivated at a depth of four meters, to remain completely unaffected. When abalone are cultivated at land-based cultivation facilities, control of the sea water (for factors such as water temperature, salinity, dissolved oxygen concentration, and decay of unconsumed feed and excrement) is expensive and involves a great deal of work by the staff. With the artificial seafloor, however, the natural purifying action of the available sea water eliminates the expense of water quality management.

Waves and rainfall generated by Typhoon 11 in 1993 were the most intensive in the area since the facility was installed, but the relevant damage at the facility was the breakage of about 20 of the ropes holding the 180 breeding baskets in place (4 ropes are used per basket). No baskets were lost, however, and no abalone perished or escaped. Two of the FRP gratings were lost when the ropes that held them in place were severed. On a feeding day three days after the typhoon passed by, the breeding basket ropes were replaced. The diving phase of the periodic 1993 inspection commenced the day following the typhoon, and the missing gratings were discovered and recovered from the seafloor.

TRACKING THE DURABILITY OF THE SUBMERGING AND SURFACINGARTIFICIAL SEAFLOOR

An annual inspection is conducted to obtain data concerning deterioration, which will be used as reference material when designing a similar structure.

Preparation of annual inspection standards

To prepare the annual inspection standards for the artificial seafloor, the authors studied the regulations enacted by the Nippon Kaiji Kyoukai (1991) and the Norway Ship Classification Association (1980) on underwater inspections of marine structures, and referred to numerous additional documents on underwater inspections. The annual inspections cover five areas:the cathodic protection system, the mooring devices, the ballast weight, the artificial seafloor structure, and the sea water ballast system. Table 4 presents the visual inspections, measurements, and procedures used for these annual inspections.

Table 4. Marine Aya No.1 annual surveys standards

A. Cathodic protection system
   a. Measurement of potential
   b. Measurement of anode volume

B. Mooring line
   a. Measurement of anchors position
   b. Visual inspection of chain links and eye plates
   c. Measurement of chain diameter

C. Bllance weight
   a. Visual inspection of the ballance weight
   b. Visual inspection of chain links and eye plates
   c. Measurement of chain diameter

D. Structure
   a. Visual inspection of structure outside
   b. Visual inspection of water ballast tank inside

E. Water ballast system
   a. Visual inspection of pump, valves and piping

Annual inspection methods

The first inspection was performed between August 22 and 26, 1991, the second one between August 26 and 30, 1992, and the third between August 28 and September 4, 1993.

The inspections was performed entirely by the authors and other divers from JAMSTEC. The divers working underwater communicated with inspectors above the surface (machinery hut) using wired underwater communication equipment, while one diver operated a television camera to transmit images of the underwater work to those above. Complete video records of the inspections have been retained.

Inspection results

Cathodic protection system

The facility was equipped with a total of forty-two aluminum alloy anodes, which were installed under the machinery hut (3 anodes), the artificial seafloor (38 anodes), and on the ballast weight (1 anode). Each anode weighed 24 kilograms. Figure 8 shows the inspection work to measure cathodic protection potential around a connection between the main facility and a mooring line. Figure 9 shows the distribution of cathodic protection potential, mainly around the mooring lines. A maximum value of -800mV, which is considered to be the corrosion protection control potential, was detected on all sides of the main facility. The mooring lines and the main facility are connected by shackles, swivels, and linking rings. These connections are subjected to severe stress when the facility is buffeted during bad weather and must be strong, the measurements confirmed that satisfactory cathodic protection is provided.

Figure 8. Measure of cathodic protection potential.

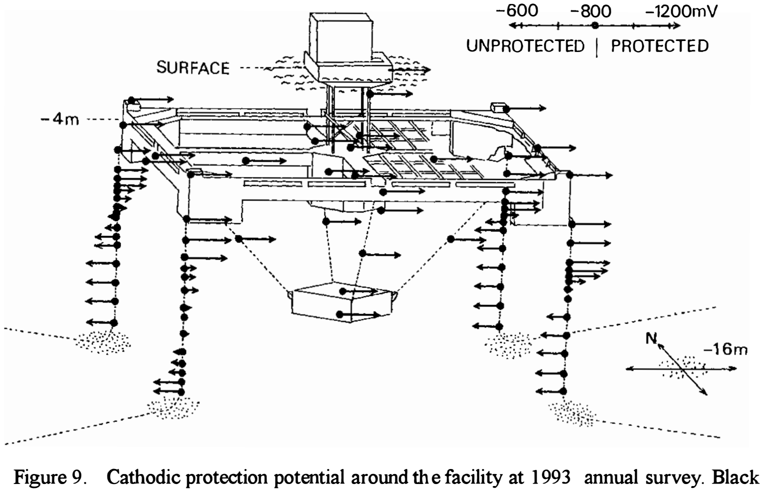

Figure 9. Cathodic protection potential around the facility at 1993 annual survey. Black dot shows measureing point.

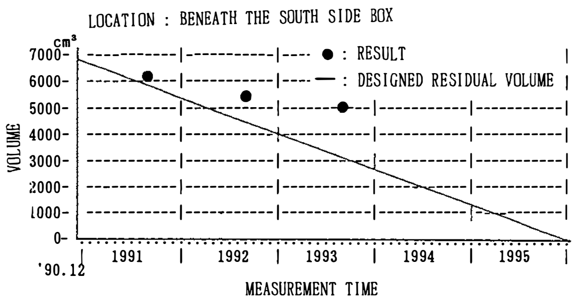

Figure 10. An example of residual volume of aluminum anode.

Four representative anode volumes were selected for the measurements. Figure 10 shows an example of measurement volumes. Based on these results, the system has been judged to be capable of preserving the facility for five years.

Mooring apparatus

Visual inspections (including underwater television and still camera pictures) of the mooring apparatus are carried out to determine the condition of numerous components.

Figure 11 shows condition of the pins on the eye plates and shackles attached to the mooring lines, and illustrates changes in the same part over the three inspections. Although corrosion has been completely prevented within the effective range of the cathodic protection around the artificial seafloor facility itself, some, red rust and advancing corrosion appeared at further distances.

After a typhoon or low-pressure system passed, some storm damage was noted on parts of the mooring line close to the seafloor facility as meandering. This meandering was restored to a straight line condition by subsequent large waves, indicating that the chains absorb the severe external forces inflicted on the facility by large waves.

The state of wear on the mooring chain was determined by measuring the diameter of 20 different locations subjected to heavy loads by inserting two chair links into calipers. The most severe wear was found at the part in contact with the sea bottom during submersion of the facility, the diameter, initially 80.0 mm (nominal diameter, 40 mm x 2), was reduced to 77.4 mm by the time of the third inspection.

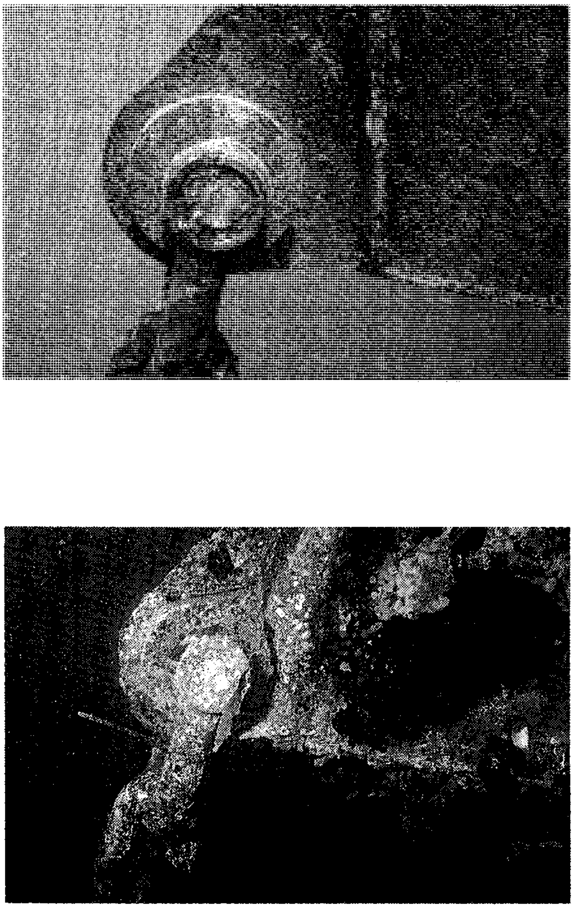

Figure 11. Survey of same eye plate and mooring chain. Upper:Aug,1991, Lower: Aug,1993.

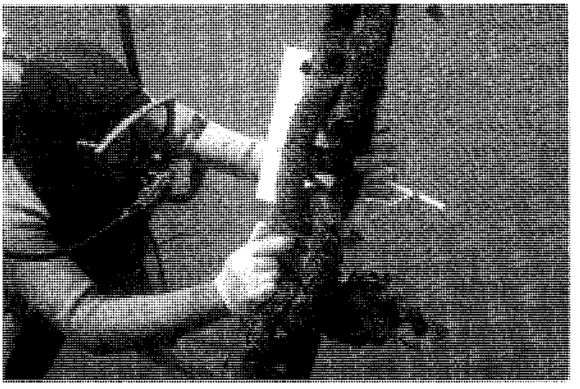

Figure 12. Measurement of chain diameter by calipers.

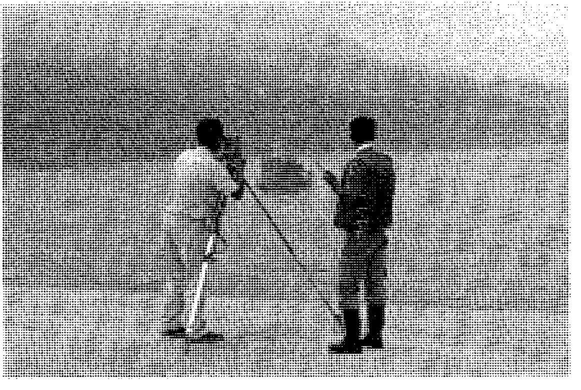

Figure 13. Position measurement of Marine Aya No.1 and anchors.

The balance weight is suspended from the artificial seafloor by four chains. These chains are within the effective range of the cathodic protection system so they have not corroded, and no abnormalities have been discovered.

The artificial seafloor

Large numbers of oysters, mussels, barnacles, sea squirts, porifera, and seaweed are attached below the submersion draft line, and only those that obstruct movement and work on the facility are periodically removed. No paint has been applied below the surfaced draft line, but observations of this area do not reveal any rusting. The inspectors look at the bottom and sides of the sea water tank during the annual inspections, but have neither rust nor any other type of abnormality.

The sea water ballast system

During each annual inspection, the manhole lid on the center ballast tank has been removed to check the condition of its seal and the paint on its inside walls, and look for corrosion or other problem. They also visually checked on the submerged pump inside the tank and the float switch that automatically shuts off the pump, and confirmed that both items were operational.

The intake and discharge water pipes and the air vent pipe to the center tank were cleaned during the first and third inspections. Including cleaning of the two gate-valves on the water injection system and the check valve on the water discharge system in the third inspection.

None of the inspection steps has revealed any problems, and cleaning done during the third inspection restored the times required to submerge and to resurface the facility to their original values at time of installation. (Figure7)

Miscellaneous

This facility has been subjected several times to strong winds and waves caused by typhoons and low-pressure systems. During a record-breaking blizzard in February 1991, the inclinometer in the machinery hut recorded a maximum inclination in the north-south direction of 6 degrees (double amplitude of 8 degrees). During typhoon 11 in August 1993, the inclinometer recorded a north-south inclination of 7 degrees (11 degrees), and an east-west inclination of 5 degrees (8 degrees). Although the ropes attaching the abalone breeding baskets and gratings to the facility were broken, the netting on the baskets was not broken, and no abalone perished or escaped. Neither the facility itself nor the mooring system were damaged in any way, either. Even though the facility is installedin a bay where it benefits from good installation conditions, these results verify that it can withstand typhoon-level waves.

The durability of the submerging and surfacing type artificial seafloor

The submerging and surfacing artificial seafloor has now been installed in ocean waters for two years and nine months, and three annual inspections have revealed no abnormalities as yet, and confirmed that wear on the facility is clearly within the design values. They have also demonstrated that typhoon-level waves have had no detrimental effects on the facility or the living organisms cultivated upon it.

The authors believe at the end of the facility's initial 5-year service period, another five years of service can be obtained by replacing the cathodic protection aluminum anodes, touching up the paint on the inside of the seawater tank, and replacing the packing and navigation-light storage batteries. If the diesel power generator and submersible pump are replaced as precautionary measures (at a total cost of US$ 2,000), the facility can be operated without concern for durability for long time.

When such repairs are performed on the facility, it can be raised to the surface so that almost all of the repair locations are less than 2 meters from the ocean surface. When the four corner tanks are filled and drained in such a way that the facility is inclined sharply, it is possible to raise the eye plates on the bottom surface of the mooring gear (located about 2 meters under water) above the water line. With the facility in this position, the repair staff can easily weld the pins and replace shackles on the mooring chains using dry-land working methods.

CONCLUSION

This inspections program has verified that the Marine Aya No.1 is sturdy, versatile, and can be maintained at very low cost. At present the Ryori Fishery Cooperative Association and Iwate Prefecture are conducting research on practical use of this structure as an abalone cultivation facility. And we believe that similar facilities will eventually be installed in many bays along the Iwate Prefecture coastline. If we develop new facilities that can be used offshore, it will be possible to use the vast ocean space along the continental shelf region.

A simple submersible facility of this sort could also be used as a tourist resource, underwater observation facility or restaurant, simply by changing its form. It could also be used as the site of various marine recreational activities; one that could be submerged during bad weather to allow its strength to be reduced. In either case, facilities of this type are cheaper to construct than fixed structures, and could be relocated in the ocean as necessary.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the efforts of many persons from Department of Planning and Coordination, Iwate Prefectural Government, Department of Forestry and Fisheries, Iwate Prefectural Government, Fisheries Department of Ofunato Division, Iwate Prefectural Government, Aquaculture Division, Iwate Prefectural Government, Ryohri Fishery Cooperative Association, the Sanriku-cho Fisheries Section, Kawasaki Heavy Industries Ltd., and Japan Marine Science and Technology Center, who made these tests of the submerging and surfacing artificial seafloor possible.

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FROM WHALE HARVESTING TO WHALE WATCHING: TANGALOOMA 30 YEARS ON

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ABSTRACT

Tourism that is based upon the coastal and marine environment is experiencing rapid growth. In addition, the demand for opportunities to interact with wildlife in the wild, as opposed to in captive situations, is increasing. These demands are reflected in the increasing popularity of eco-tourism operations which are based on interactions with wild cetaceans.

Tangalooma Whaling Station was located in South-east Queensland, Australia from 1952 until 1962. The Tangalooma station and processing factory harvested 6,277 humpback whales (*Megaptera novaeangliae*) before significant reductions in catch levels forced its closure. The site of the whaling factory is now a tourist resort which began to conduct whale watching cruises in 1992. In addition, the resort has developed a program which allows tourists to hand feed a pod of wild bottlenose dolphins (*Tursiops truncatus*) which visit the beach area adjacent to the resort. Tangalooma provides an interesting case which illustrates the transition from a whale based industry which was destructive and un-sustainable, to one which is based on the protection of cetaceans, and which may ultimately be sustainable.

INTRODUCTION

It is now widely recognised that tourism which is based upon the coastal and marine environment is a rapidly growing industry (Miller, 1990, Miller and Auyong, 1991). The world-wide growth of whale watching activities in the past five years is indicative of this general trend. The transition from an industry based upon commercial harvesting of large cetaceans to an 'ecotourism' industry based on observing and interacting with whales and dolphins has been rapid. In the short space of three decades a shift in public perception and interest in marine mammals has resulted in a proliferation of whale watching operations in locations as diverse as Canada, California, Mexico, Hawaii, Argentina, New Zealand, Australia and Japan. Whale watching is now a significant economic industry (Forestell, 1990) and many tourist operators are looking to expand into this 'ecotourism' market (Forestell and Kaufman, 1990).

Despite this trend towards protection and whale watching the debate over commercial whaling has intensified in recent years. The International Whaling Commission (IWC), which was formed in 1946 to regulate commercial whaling, implemented a ban on commercial whaling in 1986. However, Japan, Norway and the former Soviet Union have continued to harvest limited numbers of whales, ostensibly for scientific research purposes. In May 1993, Norway announced that it was going to resume commercial whaling operations regardless of IWC policy and now, in 1994, there appears to be a push from Japan to persuade the IWC to allow the resumption of regulated commercial whaling.

Predictably, the Norwegian and Japanese moves have resulted in an outcry from environmental organisations and countries which favour the complete protection of all whales. The 'catch-cry' of 'Save the Whales', which was so popular in the 1970s and early 1980s, has been resurrected and has re-appeared on T-shirts, bumper stickers and posters in an attempt to mobilise public opinion against the re-establishment of commercial whaling. This 'Save the Whales' revival has focussed on the proposal to establish a Southern Ocean Whale Sanctuary which was adopted by the IWC in May 1994.

Tangalooma Whaling Station was located on Moreton Island in South- east Queensland and whaling operations commenced there in 1952. It has been the state's only shore based whaling facility. Located close to the annual migratory routes of the southern Humpback whale (*Megaptera novaeangliae*) the Tangalooma station and processing factory harvested 6,277 Humpbacks (Chittleborough, 1963) before significant reductions in catch levels prompted its closure a decade after its opening (Bryden, 1978). The site of the old whaling factory is now a tourist resort which began to conduct whale watch cruises in 1992. Tangalooma provides an interesting case study of a location that has made the transition from being a facility based upon the harvesting of whales to one which is, at least in part, based upon their protection and the whale watching industry. The history of this former whaling station provides evidence that supports some of the claims that whaling is destructive and non-sustainable. Whale watching, however, may be sustainable and could therefore, in the longer term, be more profitable.

WHALING IN AUSTRALIA

The first whales to be taken by Europeans in Australian waters are thought to have been harpooned from the convict transport ships which delivered prisoners to the colony. It is reported that the vessels the "Britannia" and the "William and Ann" harpooned whales (species not specified) on October 25, 1791 near Sydney (Colwell, 1969). Due to its large yields of whale oil the Sperm whale (*Physeter catodon*) was the early target of whalers around Australia. However, its primarily deep water habitat meant that Sperm whales were a difficult and expensive target. It was soon discovered that the Southern Right whale's (*Eubalaena australis*) winter migration to breed in the bays on the southern coast of the continent made them a far easier, and more economically attractive species for whaling.

By the early part of the nineteenth century British, American and French whaling fleets operated off Australian coasts. These operations soon extended to harvest the seal populations which were abundant in southern coastal areas. Australia's first whaling station was built in Hobart, Tasmania and began operations in 1803. This station became the largest in the British empire by the mid - 1800s and the whaling industry became large enough to be Australia's single largest export industry for the first part of the nineteenth century (Colwell, 1969).

However, as early as 1840 the population of Southern Right whales was already in significant decline. Additional factors such as the availability of substitutes for whale products like petroleum based fuels for lighting and the beginning of gold rushes also contributed to the decline of the industry. Australia's last bay whaling station of this era, Twofold Bay in the state of New South Wales, closed in 1928 (Paterson, 1993). The northern state of Queensland was not a common location for whaling during this time. The Southern Right whale seldom ventured that far north and few Sperm whales were found close to shore. As a result, no shore based whaling stations were located in Queensland during the nineteenth century (Bryden, 1978).

A post world war two demand for whale oil prompted a resurgence of the whaling industry in Australia. The Australian Whaling Commission was established in 1949 to coordinate the development of whaling, particularly in Western Australia. This resurgence was based upon new, more efficient catching and processing technologies and focussed on the winter migratory routes of Humpback whales. Humpback whales migrate annually from their feeding grounds in Antarctic waters up the east and western coasts of Australia to breed in warmer tropical waters. The establishment of the Tangalooma Whaling Station formed part of the re-establishment of the whaling industry in Australia (Jones, 1980).

THE TANGALOOMA WHALING STATION

The population of Humpback whales which migrated up the eastern coast of Australia was estimated at over 10,000 animals prior to the re-commencement of shore based whaling activities (Bryden, 1978). On December 15, 1950, Whale Products Pty Ltd was established in Sydney for the purpose of carrying out whaling activities off the east coast of Australia (Jones, 1980). This company investigated a number of location options on which to site their operations. The advantages of a site on the western coast of Moreton Island were many. It was close to the migratory route of the Humpbacks and it was close to the port and city of Brisbane. Additionally, the site was undeveloped, relatively sheltered from prevailing south-easterly winds and a cheap lease was able to be arranged through the Queensland state government. As a result, the company decided to establish its operations on a 12 hectare site just north of Tangalooma Point on Moreton Island.

Whale Products appointed an experienced Norwegian whaler, Captain Alf Melsom to manage the development of the station. Construction began in 1951. Three whale chaser boats were purchased and steamed from Norway to Tangalooma. Initially these chasers were crewed by more experienced Norwegian crew and assisted by Australians. A licence for five years was obtained from the Australian federal and Queensland state governments for a annual quota of 500 humpback whales to be taken between May 1 and October 31. Restrictions were placed on the taking of any whale under 10.5 metres in length, or a mother with calf. Whaling operations commenced from Tangalooma on June 6, 1952 and catch levels were extremely high with the one hundredth whale being taken on July 7, barely one month after operations began. Quotas were periodically increased so that by 1953 Tangalooma was licensed to take 700 Humpbacks per year (Jones, 1980).

Usually three whale chaser boats operated from Tangalooma. Every day throughout the season these boats would steam out to the waters north off Cape Moreton. Bow mounted harpoon guns were used to shoot a 73kg exploding harpoon head into the whale. An 11kg gunpowder grenade within the harpoon head was set at a four second time delay. The internal explosion of the grenade in, or close to, the backbone usually killed the whale. Subsequently, the whale would be inflated with compressed air, to keep it buoyant, and secured by its tail flukes to the side of the boat to be dragged back to Tangalooma.

The Tangalooma processing factory operated 24 hours a day during the whaling season. It employed 120 staff who worked two 12 hour shifts seven days a week. Boats often brought tourists out from Brisbane to the station to watch the flensing teams work on landed whales. A visitor to the Tangalooma whaling station commented that "the flensing deck was covered with pieces of whale in more or less advanced stages of treatment - bare bones, pieces of flesh or intestines littered around or heaped together. The whole deck looked like a giant sized butcher's table - fifty yards long!" (Jones, 1980, p36). Similarly, on Australia's west coast, tourists visited the whaling station at Albany which continued operating until 1978 (Commonwealth of Australia, 1978).

The factory at Tangalooma produced three main whale products. The most valuable of these products was whale oil. This was produced by placing the blubber and bone into large pressure cookers where it was cooked for three to four hours. Impurities were then removed from the oil in separators and it was shipped overseas for use in margarine and other edible fat products. Baleen or 'whale bone' was also exported for use in the fashion industry and 'whale meat meal' was cooked, dried and packaged at Tangalooma and sent throughout Australia for use as a high protein food for livestock (Tangalooma Island Resort undated).

Tangalooma's early days were particularly successful. Between 1952 and 1959 the station had no problems filling its yearly quota of whales and, whenever possible, whale chaser captains selected the largest male animals for harpooning. However, from 1960 the time needed to search for whales began to increase and catch rates began to fall. The 1959 quota of 660 whales was filled in 65 days, but in 1960, it took 75 days to land the same number. In the following year, 1961, Tangalooma was unable to fill its quota before the end of the season, 591 whales were caught.

In an attempt to maintain catch levels a 'spotter' plane began to be used and two new, faster and larger, whale chaser boats were bought. Despite this increased effort, 1962 produced a dramatic collapse in catch levels. By August 5, only 68 whales had been caught, whereas at the same time in the previous year 253 whales had been landed. It became obvious that whaling based upon the east Australian Humpback was no longer economically viable and the Tangalooma Whaling Station closed on August 5, 1962. It was estimated that fewer than 500 eastern Australian Humpback Whales remained (Paterson, 1993). Whaling of Humpbacks was banned in Australian waters in 1963 (Bryden, 1978).

TANGALOOMA MORETON ISLAND RESORT

On June 21, 1963 the Tangalooma whaling station and lease was sold to a syndicate of Brisbane entrepreneurs who proceeded to convert the site into a tourist resort. Whalers accommodation was converted into holiday units and the factory and flensing decks to a bar and lounge area. The resort opened for business in December 1963 and catered mainly for local holiday makers and recreational boaters from the Brisbane area.

In 1981 the resort was sold to new owners who began a major upgrading of facilities including the construction of 134 new self contained units, two swimming pools, squash and tennis courts. Currently the resort employs between 85 and 100 staff, caters for a maximum of 470 house guests and between 40 and 300 day visitors (J. Osborne, pers. comm.). A daily high speed catamaran ferry service is run between Brisbane and the resort. Guests are also able to fly to the island and land on an airstrip close to Tangalooma.

Little of the original whaling station is now recognisable. The water supply and power generator facilities are based on the originals and the flensing deck is now used as a shelter for building supplies. The old jetty, where the whale chaser boats used to tie up, has been replaced by a new wharf at the south end of the resort. All that remains of the ramp which was used to haul the whales up to the flensing deck is a series of pile stumps in the water shallows. In only a few decades the transformation of Tangalooma makes it difficult to recognise its original purpose.

Tangalooma whale watch cruises

The same features that made Tangalooma an attractive location for a whaling station also make it a suitable location for whale watching. It is close to a major city and arrival point for tourists to Queensland and it is within short steaming time of the Humpback migratory route. In addition, the majority of Moreton Island is national park and Moreton Bay is a marine park administered by the Queensland Department of Environment and Heritage. Tangalooma is, therefore, an attractive destination for the 'eco-tourist'.

Prior to 1992 whale watch cruises were not considered by the resort due to the low numbers of whales and the consequent problems of being able to reliably sight them. The growth of numbers of Humpback whales since whaling operations ceased has been slow but current estimates place the population at around 2,000 animals (Pacific Whale Foundation estimates). However, numbers are now sufficient that during the migration the sighting of Humpbacks in the vicinity of Cape Moreton is virtually guaranteed.

In 1992, the Tangalooma Resort ran three trial whale watch cruises using the resort ferry, the 'Tangalooma Flyer'. These trials proved successful and during the 1993 whale migration the Tangalooma Flyer conducted 43 whale watch cruises. Whales were sighted on all but three of these cruises (Tangalooma Whale Watch Records, 1993). The twice weekly cruise originated in Brisbane and proceeded via the resort, where additional whale watchers would be collected, out to the Cape Moreton area to view the whales. These cruises are proving increasingly popular and many thousands of tourists went whale watching from Tangalooma during 1994. Numbers are expected to further increase in 1995 (J. Osborne, pers. comm.).

Tangalooma dolphin feeding program

In the early part of the nineteenth century it was reported that cooperative fishing between local Aborigines and dolphins occurred on the shores of North Stradbroke Island which borders the southern part of Moreton Bay (Fairholme, 1856; Hall, 1984). More recently dolphins have been observed feeding behind prawn (shrimp) trawlers who work the bay during the summer months (Corkeron *et al.*, 1990). Employees of the Tangalooma Resort report the frequent sighting of dolphins near the resort for over two decades (M. Keeley, pers. comm.). It appears, therefore, that interaction between dolphins and humans in Moreton Bay has been common and has occurred over a significant time period.

In recent months a feeding program with a group of wild Bottlenose dolphins has been established at Tangalooma (Orams, 1994). This program appears to complement whale watch cruises and is proving to be an additional attraction for people who enjoy observing and interacting with marine mammals.

In April 1992, a mature female Bottlenose dolphin together with her young calf were visiting the area beneath the resort wharf and appeared to be particularly interested in fishers up on the wharf. Several small fish (most probably mullet, *Mugil georgii*) were thrown to her and eventually she ate some of them. Subsequently this animal was fed until she gained enough confidence to take fish which were hand held.

Throughout the remainder of 1992 additional dolphins joined the feeding. Currently between six and eight individuals visit the wharf area nightly to be hand fed. This feeding is being promoted as an attraction for resort guests and up to 100 guests feed the dolphins each evening (see Orams, 1994 for a more detailed discussion of this program).

WHAT ARE THE LESSONS?

There is a growing demand for interaction opportunities with dolphins and whales in the wild and Tangalooma is one Australian example of this trend. It is an interesting case study because it illustrates a major shift in attitudes and commercial activity associated with marine mammals that has occurred in Australia in the past 30 years. This change has occurred rapidly, in less than one human generation. More importantly, however, is the fact that Tangalooma provides us with an historical record which shows the dangers associated with exploiting wildlife with inadequate knowledge and controls. The end result being non-sustainable harvest rates and eventually an endangered species.

It is likely that whale watching can be a sustainable industry in the longer term. Certainly its non-consumptive nature means that it is more likely to be so than whale harvesting. However, more study on the impacts of whale watching on whales is needed before it can be established if whale watching will, truly be, sustainable. The future success of Tangalooma as an ecotourism destination with attractions based upon interacting with dolphins and whales will be interesting to watch. There is a need to examine natural laboratories like Tangalooma for they can provide valuable lessons with regard to wildlife management decisions. Irrespective of the moral debate over the commercial harvesting of whales, the case of Tangalooma does provide support for the argument that 'saving the whales' can simply be smart business.

CONCLUSION

There is little doubt that marine mammals and particularly cetaceans evoke a strong emotional response in people (Forestell and Kaufman, 1990). This response may be a "window" through which the importance of caring for and conserving the marine environment is able to be effectively communicated. A number of authors have suggested that ecotourism opportunities such as these can be used to educate tourists to promote a change to more environmentally responsible behaviour (Orams, 1993, Hackett, 1992, Gudgion and Thomas, 1991, Forestell, 1990, Hungerford and Volk, 1990).

It is important, therefore, that firstly these interactions are wisely managed so that they do not become another form of human exploitation of marine mammals. Secondly, it is possible that through the use of education/interpretation programs associated with these interactions that this 'window' into the marine environment can be a means through which 'ecotourists' learn and appreciate other marine life (Forestell, 1993). The aim of such programs should be ambitious. Ecotourists can be prompted to go a step beyond changing their attitudes to actually changing their behaviour so that their actions do not adversely affect the marine environment and the animals that live within it.

ACKNOWLEDGEMENTS

The authors would like to thank the directors and staff of Tangalooma Moreton Island Resort for their assistance in preparing and presenting this paper. Additional support was provided by a University of Queensland Post-graduate Research Scholarship to the first author.

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THE LONG TERM FUTURE OF THE GREAT BARRIER REEF.

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ABSTRACT

Long term participative regional planning is a relatively new and developing field in Australia. To conduct a futures project that seeks to address the serious matters of reef-related food production, jobs, recreation, cultural heritage and the conservation of the Great Barrier Reef with over 60 organisations participating, is not without its challenges. This futures project - the 25 Year Great Barrier Reef World Heritage Area Strategic Plan Development Project - has been described by the IUCN (The World Conservation Union) as having established a world model in participative regional planning for ecologically sustainable use of a natural resource. This article deals with the following questions. Why was a futures project needed? What was done? How was it achieved? And, so what?

BACKGROUND

The Great Barrier Reef is a maze of reefs and islands stretching more than 2000 kilometres along the Queensland coast. It is the largest coral reef system in the world and one of the richest in biological diversity.

In the late 1960's and early 1970's concern by the conservation movement and other groups regarding oil and limestone mining in the Great Barrier Reef led to federal legislation in 1975 - the Great Barrier Reef Marine Park Act, protecting the marine area below low water mark and the few Commonwealth islands. The majority of islands in the Great Barrier Reef and areas between low water mark and high water mark are covered by Queensland State legislation.

As the 8th wonder of the world, it was proposed by both Federal and Queensland Governments that the Great Barrier Reef be listed as a World Heritage Area. This took place in 1981 and became the first world heritage area in Australia - in keeping by Australia for the rest of the world.

The Great Barrier Reef World Heritage Area

It was inscribed, on the basis of its outstanding natural, cultural and historical features and its integrity as a self perpetuating ecological system. The Great Barrier Reef satisfied all four criteria of outstanding universal value as set out in Article 2 of the World Heritage Convention:

- an example of a major stage in the earth's evolutionary history,
- an outstanding example of geological processes, biological evolution and people's interaction with their natural environment,
- a place with unique, rare and superlative natural phenomena,
- a place which provides habitats for rare and endangered species of plants and animals.

The beauty and diversity of the Great Barrier Reef has resulted in rapidly increasing demands on the region, which currently supports a range of activities and industries. The direct and indirect economic value of the Area is estimated at over 1.5 billion dollars annually and the Area generates substantial employment opportunities. Tourism is the major and most rapidly growing economic activity in the region. Fishing is also economically important. Shipping, ports and associated activities in the World Heritage Area are of national economic significance. The health of the Reef is dependent on all these industries acting in an environmentally responsible manner.

Given this background of rapid growth, there is need for fair and equitable management practices which, while facilitating use, also ensure that the reef system does not suffer irreversible damage and so can still renew itself in a perpetual cycle for future generations.

The Great Barrier Reed World Heritage Area extends from the tip of Cape York to just north of Fraser Island, and from the low water mark on the Queensland coast to beyond the edge of the continental shelf. It is 348,700 square kilometres in area and includes the Great Barrier Reef Marine Park (93% of the World Heritage Area), Queensland waters not in the Great Barrier Reef Marine Park (2%), and islands (5%) (See Figure 1).

WHY WAS A FUTURES PROJECT NEEDED?

There are many diverse interests and users (stakeholders) in the Great Barrier Reef and in the surrounding coastal areas. There was a desire and need for a mutually agreed future of the Great Barrier Reef in order to create a context in which to view and conduct current activities and management practices and a strong need to ensure ecologically sustainable use of the Reef. Together with this, there was a need for a "reef wide" not section wide view of the area (which has been provided through zoning plans).

In short it is a large ecosystem and needs to be planned for, used and managed as such. This is best achieved within an agreed framework. Stakeholders in the region also have expressed a desire to see a framework in which they could all operate with all Great Barrier Reef participants working in the same agreed direction. The need for a strategic plan revolved around the fact that no regional strategic framework had been generally agreed as to what "conservation while allowing for reasonable use" meant. This was given impetus because critical issues needed to be addressed.

Few specific "targets" had been set for management therefore clear objectives, strategies and performance indicators were essential in order to evaluate day to day management. Though many government agencies operate in the area, no single agency has overall jurisdiction of the area. With so many agencies receiving a total of $80 - $100 million in government funding per year there was a need and desire to have integrated and joint activities to be comprehensively and holistically addressed for management and use of the area to be efficient and effective.

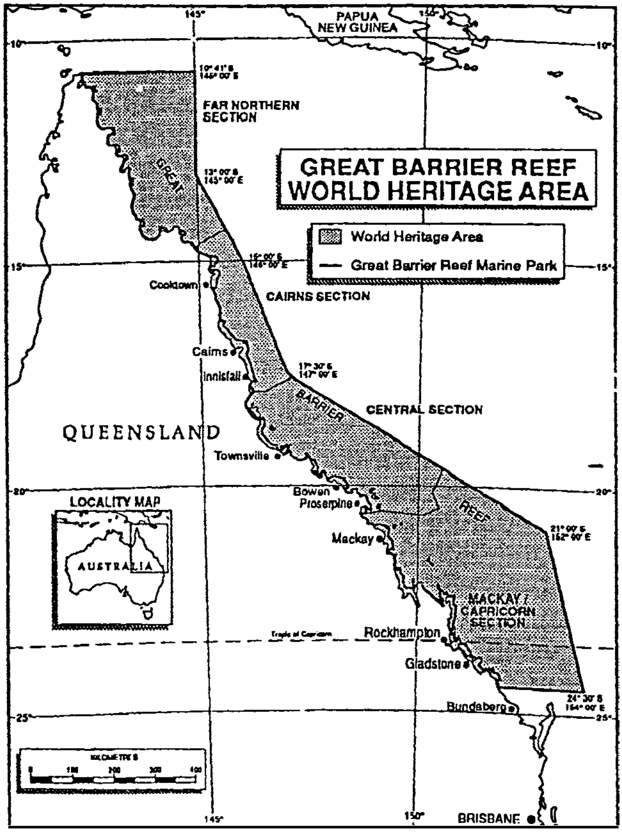
Along with this, the Great Barrier Reef Marine Park Authority that had zoned and managed the Area, was considering its own strategic direction for the coming decade and was concerned that stakeholders in and around the Great Barrier Reef could be confident of the long term, in an ecological, economic and enjoyment sense.

WHAT WAS DONE?

Developing the Great Barrier Reef World Heritage Area strategic plan.

The project commenced in 1991 with the Great Barrier Reef Marine Park Authority acting as the facilitating and co-ordinating agency. The majority of funding came from the federal government through the Great Barrier Reef Marine Park Authority with some funding from the Queensland Government and a few industries.

The aim of the project was "to describe a future long term vision for the Great Barrier Reef World Heritage Area, and to determine the objectives and strategies which will ensure this vision is achieved".



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Planning Area

- Queensland coast - tip of Cape York to just north of Fraser Island;
- low water mark on mainland coast to beyond the edge of the coninental self;
- between low water mark and high water mark on mailand coast;
- 348,700 square km in area including:
  - Great Barrier Reef Marine Park (93% of World Heritage Area)
  - Queensland waters not in the Great Barrier Reef Marine Park (2%), and,
  - islands (5%)

Figure 1. Great Barrier Reef World Heritage Area.

The World Heritage Area was selected as the planning area because it included the Great Barrier Reef and Queensland Marine Parks, Queensland islands and the mainland coast. The marine area bordering the Great Barrier Reef - Torres Strait and the Coral Sea to the east of the Great Barrier Reef - were also considered in the process. Due to the fact that it would be preferable if stakeholders in areas adjacent to and impacting the reef, along with those operating within the reef area, land based industry and agriculture were also involved.

A consulting group, Kayt Raymond & Associates, was employed as project consultants; the principal became the independent chairperson/facilitator and from the beginning gave expert advice on participative processes and strategic planning which guided how the Great Barrier Reef Marine Park Authority (the facilitating and coordinating agency) approached each step in the project. This commenced with advice to stakeholder organisations that the Great Barrier Reef Marine Park Authority was considering embarking on such a strategic plan and determining whether they would be interested in taking part if there was general support for such a proposal.

The concept of developing a long term strategy for the Great Barrier Reef World Heritage Area was welcomed by stakeholder organisations. As a consequence of support for the concept, invitations to formally participate were sent to all stakeholders. These stakeholders included industries - commercial fishing, tourism, science (that produce in excess of $1.4 billion in national revenue per annum), Aboriginal and Torres Strait Islander groups, recreation organisations, interest groups such as conservationists, canegrowers, and managing agencies - federal, state and local government.

Critical issues

All participating stakeholders were asked what concerns or critical issues needed to be addressed. Given the size and remoteness of the planning area, the number and complexity of important issues, the many and diverse organisations participating, the time scale of 25 years, and the tremendous learning curve involved for participants - the project was at times daunting.

There was a high degree of overlap between the non-government and government lists of critical issues. The issues ranged from maintaining water quality; determining the effects of trawling and fishing; run-off from the mainland; reef damage; monitoring to pick up incremental damage, to the ever present requirement for more people and funds for the project; the lack of understanding and acceptance of strategic planning by people used to developing zoning and management plans; the influence of Commonwealth and State relations and the potential effect of politics on the planning; and the positive and negative trends in the region.

A set of agreed long term and short term critical issues were developed and these together with the input of future scenarios from a project group, became the departure point for the planning.

Creating a long term vision.

Participants agreed on a written description and picture of the 25 Year Vision. The long term vision for the Great Barrier Reef World Heritage Area includes:

A healthy environment: an Area which maintains its diversity of species and habitats, and its ecological integrity and resilience, parts of which are in pristine condition.

Sustainable multiple use: non-destructive activities which can continue forever, that is, in such a way that maintains the widest range of opportunities for appropriate sustainable use, and does not adversely affect the ecological integrity of its natural systems.

Maintenance and enhancement of values: the continuation and enhancement of diverse aesthetic, ecological, economic, cultural and social values, providing for the aspirations of residents, users, Aboriginals and Torres Strait Islanders and the global community.

Integrated management: management of activities which takes into account the ecological relationship between the Area and other adjacent areas, particularly the mainland.

Knowledge-based but cautious decision making in the absence of information: decisions based on a commitment to research, monitoring and review using data and experience from all sources and erring on the side of caution in the absence of information.

An informed, involved, committed community.

Figure 2 represents the vision of the future for the Area developed by participating organisations during the planning.

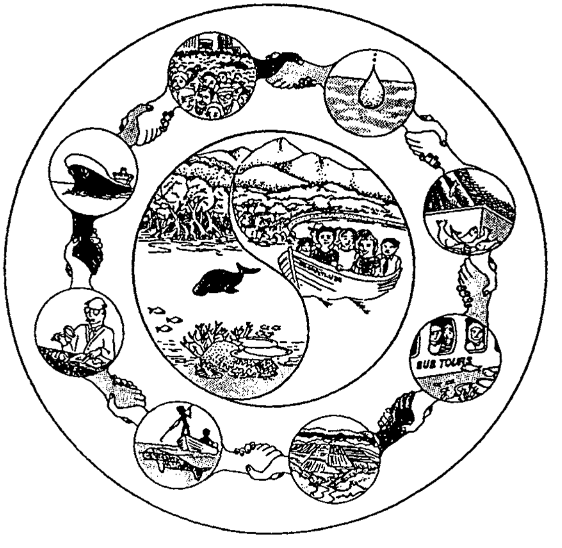


Figure 2. 25 year vision for the Great Barrier Reef World Heritage Area, developed by participating organisations during the planning process

Objectives and Strategies

The outcome of the planning is the Great Barrier Reef World Heritage Area Strategic Plan. It has two main components - a 25 year long term component of objectives and strategies, and a 5 year short term component of objectives, strategies and performance indicators. It is a 25 year rolling plan with a planning cycle involving an annual review and evaluation and a major review every five years (conducted by GBRMPA in response to the request from stakeholders to do so). The short term component has been costed with an implementation timetable.

The Plan forms a large community agreement between three levels of government, industries, the conservation movement, recreation organisations, interest groups and Aboriginal and Torres Strait Islander groups, for the future of the region. In short, it is a program of what they will do together to bring about the agreed desired future for the Great Barrier Reef World Heritage Area. The Plan addresses issues both inside and outside the World Heritage Area eg catchment management.

Critical issues identified at the beginning of the planning are cross-referenced to areas of the Plan, objectives or strategies which address the issue either particularly or generally - An issue may be addressed by a strategy within an objective.

The Plan has been endorsed by participating organisations in all sectors. Relevant Commonwealth agencies, local government agencies and the Queensland Cabinet endorsed it (and changed a loop-hole in laws to rectify legislation that put the Reef at risk). This means that all the Queensland State Departments will take direction from the Strategic Plan and incorporate relevant sections in their corporate plans for day to day implementation.

The Plan was launched nationally by the Prime Minister of Australia, The Hon. Paul Keating MP, in July, 1994, when he said, "It is an Australian solution to an Australian challenge."

Over the next 12 months arrangements for implementation will be negotiated with the industries and stakeholders as well as government agencies so that the implementation timetable can be met and properly reviewed and evaluated at the appropriate times.

HOW WAS IT ACHIEVED?

Assumptions

The planning process was designed and conducted based on a number of assumptions.

Participation and ownership: Plans where possible should not be imposed. If organisations genuinely participate in creating a plan, it is theirs - they own it. Genuine participation and ownership - not just involvement is important. Choice is critical to the quality of participation. Creating opportunities in which stakeholders make valid choices about variables (eg. content, process, communication of progress etc.) of the project hooks them in further and commits participants more to the project.

Respect for different interests and values of stakeholders: Conflicting values and activities occur in the Reef management and use which must co-exist in a cooperative and balanced way, rather than residing in a mutually exclusive way. This requires a forum in which the different organisations can meet in a win/win manner.

Equal standing and cooperation: Equal standing among diverse stakeholders is critical in order to establish a forum in which cooperation can occur. The appointment of an independent chairperson/facilitator, skilled and experienced in resolving conflict and bringing about meaningful agreement, assures participants their individual views will be appropriately considered. Independent and objective chairing and facilitation can enhance the success of participative initiatives.

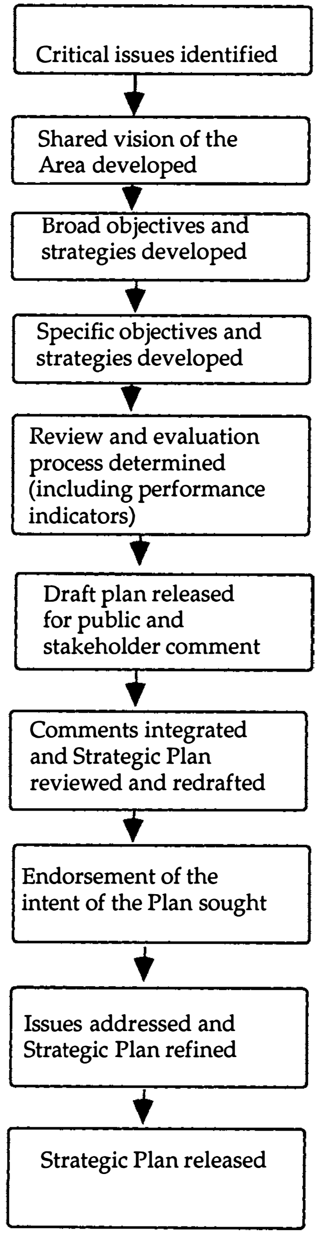
Process is as important as outcomes: How issues are addressed is as important as what issues are addressed. How a plan is developed is as important as what is developed. The outcome/product - the strategic plan provides direction and agreed actions and intended results. The process - the way the plan is developed influences whether it will be implemented and how well. The specific way the process is designed and conducted can allow for cooperation to develop, new relationships and networks to be built - this will improve the quality of implementation and ongoing co-operation to achieve results.

Leaders self select: Managing a large scale project with many participants in a nationally and politically significant region requires leadership. That leadership needs to occur at all levels of the project. That leadership is based on personal and professional initiative and commitment. The project and process must be designed in such a way as to encourage leaders at all levels within stakeholder organisations to step forward and lead in whatever activity or situation.

The Process

Developing the Plan provided an opportunity to design and conduct a process that not only delivered a Plan for the future of the region, but also an opportunity to establish alignment, strategic alliances and working interfaces among organisations such that massive inter-organisation development could take place. Both the development of the Plan and the inter-organisational alignment would contribute to ongoing regional development.

The long term perspective, the different needs, values and unwillingness of individuals and organisations to change provided this project with a high potential for conflict. In order for the challenge of bringing over 60 organisation together in a meaningful and productive way, it was critical that the process be conducted objectively. Thinking ahead 25 years, keeping everyone honest, validating different points of view and needs, resolving conflicts, managing political, executive and corporate egos, along with ensuring all interests are dealt with in an objective practical manner, requires expert facilitation. Such independent facilitation gives participants confidence that the process has integrity and that the planning will incorporate their differing perspectives and needs in a sound and practical form.



A series of workshop negotiations were designed and conducted. Initially all the interest groups came together and agreed on critical issues and a vision. Then the government agencies came together and agreed on critical issues and a vision. Then the government agencies came together and did the same thing. The consultant designed a drawing process where each participating organisation through its representative drew a picture of what they want to happen in 25 years in the GBRWHA. From these pictures, through a negotiation process, two pictures were developed - the interest groups' vision and the government agencies' vision. Representatives from each group were elected to act as negotiators on behalf of interest groups and government agencies.

These negotiators became known as the Planning Team who came together at the third workshop and developed the shared vision of the Area.

The facilitator chose to conduct the process on a joint decision making basis. This is, designing a multi-layered planning process and conducting it as a series of negotiations. Successful joint-decision making is difficult to achieve with many diverse participants.

There is more conflict due to direct negotiation and this requires more skills in negotiation than information sharing and consultation (the way many plans are developed). However the result can have great substance, credibility and ownership. Consequently, implementation is more certain.

When the draft plan was completed, detailed public and stakeholder consultation took place. Focus groups were conducted along the east coast of Australia to clarify responses to the plan. Draft plans were sent to local and overseas individuals and groups for input and feed back. Planning Team members and others conducted stakeholder and general public participation sessions on the draft plan.

Specific communication strategies for particular groups were initiated - local government, Aboriginal communities; Torres Strait Islander people (direct negotiations were held with community groups); land-based industry groups; local government agencies. Briefings were held with key government Ministers and advisers to check political acceptability.

Slides, videos and written information was available for use by individuals or groups conducting an information sharing session. All responses to the draft plan were computerised and put into an appropriate form for use at the next workshop, where input from stakeholders was assessed and incorporated into the plan.

Two issues, mining, and Aboriginal and Torres Strait Islander interests, could not be fully resolved by the Planning Team. The facilitator designed a section: "In Continuance" at the front of the plan for issues over time that would be outside the resolving ability of the participants and planners. It was the view of the facilitator that if the planning process is meaningfully addressing hard issues then there may be issues "in continuance" requiring ongoing negotiation and resolution outside the planning and implementation of the plan.

Each issue "in continuance" specifies the issue, current situation and present positions of parties unable to agree. (Both issues "in continuance" have since been partially resolved by governments.)

A few stakeholders had outstanding issues to be resolved. Accordingly, small groups focussing on specific issues were conducted to negotiate and resolve the conflicts. The plan was revised accordingly and forwarded to all stakeholders (including the Queensland Cabinet) for endorsement.

AND, SO WHAT?

Implications

More participative futures projects of this nature are needed. Given that those individuals who are elected to parliament to represent the various sectors of the country and its regions are elected for three year terms of office, there is little incentive for setting an agreed long term vision or long term planning. Certainly there have been no other futures projects of this scale in Australia.

One of the benefits of a project such as this is that the long term thinking has been done by those people who represent the groups most affected by what happens in the region. This gives reality, credibility and substance to the agreed future and plan. That this long term strategic plan for the future of the reef, its uses and benefits, forms a large community agreement, has been endorsed by state and federal governments and will be implemented over time by many stakeholders means that the strategy can continue to have effect outside the short term thinking and trade-offs that occur in politics.

This project has certainly raised a structural issue. Adjustments need to occur in how organisations function and interface with other stakeholder organisations in order to communicate effectively, coordinating activities to jointly set and achieve common goals and to cooperate across organisation boundaries. Private and public sector organisations are set up structurally or culturally to handle this well and much organisation learning happens through practice and the opportunities provided by futures projects such as this. Governments and joint venturing between corporations and governments can contribute funding to initiate large participative futures projects involving diverse stakeholders. This type of regional, state and national leaders encourages regional initiative and community development responsibility, creating partnerships, networks and strategic alliances through coming to terms with issues such as ecologically sustainable development and regional investment and employment.

Public participation while necessary and valuable assumes that the public will always be interested in participating in a project or process. In areas such as the Great Barrier Reef where there are many user demands and increasing tourism (currently growing at an estimated rate of 10 per cent per year) there are many projects and processes requiring public input. It is wrong to assume that the public will always be interested in taking the time to give meaningful input. Around the world as public participation becomes more widely accepted and practised, what community development will occur to accommodate a mechanism where the general public can give input to projects and processes that is useful, comprehensive and meaningful?

Lessons learnt

Creating a long term view is practical in that it creates a context in which to determine short term activities. Short term plans and actions make sense if directed toward a desired and agreed future. Long term strategies and strategic plans provide guidance to operational management and decision making, along with providing a congruent framework from which to do other plans/strategies like zoning plans, industry plans, business plans or conservation strategies.

Participation of all stakeholders in order to gain the variety of practical experience, specific knowledge and skills across a broad spectrum of interests and issues is important. The resulting thought and planning is thorough and soundly based. Genuine participation of stakeholders in the planning is critical and they must make the planning decisions. Politicians and their staff, and the community at large must be involved in the participative process (Raymond and Craik, 1992). The process of planning is as important as the outcome and the quality of the implementation will be dependent on the quality of the participation, cooperation and new networks and alliances formed.

It is critical that stakeholder representatives are from executive or senior management levels. Middle managers generally do not have the necessary skills and experience or authority to properly represent their organisations. Negotiators from interest groups such as conservation organisations need to be experienced negotiators capable of strategic thinking. Unless representatives are experienced they are not on an equal footing with other negotiators.

Many diverse participants with conflicting values, beliefs and practices can work together in a cooperative and productive way when interested in a long term future and when provided with a forum in which their individual and different needs and views will be treated with respect and properly considered. An independent and skilled chairperson/facilitator establishes a situation where participants have equal standing - a critical ingredient to achieve cooperation and engender mutual consideration.

It is essential to have an independent facilitator to establish the separateness of the project and to keep the non-government organisations - industries, businesses, recreation organisations, conservation groups and others - in the process. Such groups need to be confident that there is not a government agenda being run, their interests are equally valid and must be treated as such. They will leave the project if this integrity is not maintained.

Expert process design is necessary in order for the long term view, the needs of many diverse stakeholders, the size of the planning area and complexity of issues to be properly addressed and translated into a sensible, practical and defensible long and short term result. New events and demands that affect the region must be assessed and where necessary included in the planning. This means that the process needs to be constantly reviewed and refined to accommodate same so that the result is meaningful.

Each futures project has many variables and unique characteristics which must be incorporated into a process designed specifically for that project. It should not be a process duplicated from a different project. Process design assists stakeholders to approach the future, size and complexity of tasks in a constructive way.

Creative group problem solving, innovation and negotiation if well designed and conducted can bring out the best in participants and create a composite and detailed solution that is both innovative and thorough. As opposed to the commonly held view that such processes are purely about mediation and trade-offs - mediocrity and the lowest common denominator prevailing.

Validate and integrate other management strategies in the region. Alignment of effort is critical (Raymond and Craik 1992). Also coordination with industry, government and other processes such as corporate and financial planning cycles, budgets, parliamentary and government timetables is essential in implementation.

CONCLUSION

Futures are not always determined and created in the way this project has allowed. Unfortunately for the futures of our countries and their citizens not enough of this type of participative planning happens in a co-ordinated, comprehensive and congruent way. Such direction setting and participative focused strategic and critical thinking is needed.

Participative strategic and critical thinking (both long and short term) is imperative to regional and national development. This type of thinking can change the course of a region's or country's future. The absence of it has already determined the current course of the region or country.

People learn from practical examples. Futures projects such as this support the creation of a better future.

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TRACE METAL MOBILISATION AND SETTLEMENT FROM SEDIMENTS DURING DREDGING ACTIVITIES - CLEVELAND BAY

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ABSTRACT

Labile trace metal concentrations in benthic sediments and in sediments deposited on coral reefs in Cleveland Bay, central Great Barrier Reef, were investigated in relation to turbidity associated with dredging operations in the bay. Sediment plumes generated during dredging activities were also analysed for trace metals. Trace metal partitioning and subsequent adsorption onto sediment particles was investigated by elutriation experiments followed by sequential extraction in the laboratory. The copper, lead and zinc concentrations in sediments at the dredging site were not significantly different from those at control sites. In contrast sediments taken from coral reefs (Middle Reef and Cockle Bay) were richer in these metals than at other sites in Cleveland Bay. These higher metal loads were found 1 week, and in some cases, 1 month after dredging. The elutriation experiments showed that the binding of metals to sediment particles varied with particle size and mineralogy. It also provided evidence that the fine sediment remaining in suspension several hours after disturbance played a more important role in trace metal adsorption than settled particles. The longer suspension time of fine particles will allow wider transport of particles by currents within the bay and may explain high metal concentrations found in sediments deposited on corals.

INTRODUCTION

Dredging operations in Australia are controlled by both the State and Commonwealth environmental authorities through section 86 of the Queensland Harbours Act. Sea dumping of dredge spoil is controlled by the Environmental Protection (sea dumping) Act, 1991. The act is administered by the Commonwealth Environmental Protection Agency outside the Great Barrier Reef Marine Park, and the Great Barrier Reef Marine Park Authority inside the marine park. Before permits to dredge are issued, the impact of pollutant release must be fully assessed as must the environmental effects of dredged spoil dumping (Batley, 1988). In recent years there has been concern about the impact of the dredging activities in Cleveland Bay on the adjacent marine park. The Great Barrier Reef Marine Park Authority commissioned a study in 1991 to determine the major sources of trace metals within the sediments from Cleveland Bay and to assess the impact dredging has on the mobilisation and transport of these sediments as a result of the dredging activities.

There is a large amount of literature on trace metal release from sediments during dredging (Sustar *et al.*, 1976; Gambrel *et al.*, 1980; Batley 1987). Factors that can influence trace metal release include sediment type, sediment composition, pH, redox potential and salinity (Lee and Plumb, 1974). Each metal is affected differently by changes in these conditions (Moore and Ramamoorthy, 1984).

The environmental effects of fine sediments suspended by dredging activities will vary with the sediment type, the range and concentrations of contaminants in the dredged sediment and the nature of the benthic community on which the sediment is deposited. There have been very few studies of the effects of dredging of fine sediments on coral reefs in harbour areas and none have attempted to separate the effects of physical smothering by sediment particles from the biological effects of sediment associated contaminants. Brown *et al.*, (1990) studied the effects of deposition of metal rich sediments on coral reefs at Ko Phuket, Thailand and noted marked decreases in coral diversity and cover on intertidal flats associated with sedimentation. This paper deals with the process of mobilisation and transport of contaminants of dredged sediments, particularly in relation to sediment particle size.

METHODOLOGY

Study location

Cleveland Bay (Figure 1) is located near latitude 19¡S on the north coast of Queensland, Australia and faces north east to the Coral Sea. The bay is naturally shallow, is fringed largely by mangroves and sea grasses and has an area approximately 17 km^2. Magnetic Island, which is fringed by coral reefs, is situated on the northern edge of the bay about 10 km from Townsville. Townsville is the largest city in northern Australia with a population close to 120 000. There is a large port facility associated with the city of Townsville which provides transport routes for shipping, cargo and passengers. The main navigational channel (Platypus Channel) runs north-south through the bay; maintenance dredging is carried out every year to a depth of 5-6M. The major imports are nickel ore and oil and the major exports are sugar products, zinc concentrates and lead products.

Metals in deposited sediments from Cleveland Bay

Duplicate sediment samples were collected with a Van Veen grab throughout Cleveland Bay (Figure 1) and at control sites in Bowling Green Bay. Sample were stored in 500 mL polyethylene containers and immediately frozen. Sediment samples were thawed and wet-sieved through a 63-70 μm nylon mesh with filtered seawater, then dried at 105°C. 0.50 g ± 2% of sediment, in duplicate, from each location, was weighed into a 100 mL acid-cleaned Pyrex Erlenmeyer flask. 15 mL of 0.50 M hydrochloric acid was added and the flasks were shaken with constant agitation for 16 hours (Chester *et al.*, 1988). After shaking, each sample was filtered through 'Whatman No. 1' filter papers and made up to 25 mL with 0.10 M hydrochloric acid. Blanks and internal standards were used throughout the leaching procedure. Copper, lead and zinc were analysed by flame atomic absorption spectrophotometry (AAS).

Metals in sediments from coral surfaces within Cleveland Bay

Coral sediment samples were collected from Middle Reef, Cockle Bay, Picnic Bay, Geoffrey Bay, Florence Bay and Radical Bay, Magnetic Island, (Figure 1) by scuba divers. Each sediment sample was carefully scraped from coral surfaces into 30 mL acid-cleaned polypropylene containers. Five random locations (mostly consisting of one coral colony) were sampled in duplicate at each site. The samples were stored on ice during field collection and immediately frozen back at the laboratory. The coral reef sites were sampled one week before dredging, one week after and one month after dredging for two separate dredging events in 1991. Coral sites were not identified at Radical Bay during the first dredging event, consequently it was sampled only over the second dredging event in 1991. Sediments were analysed in the same way as sediments from Cleveland Bay.

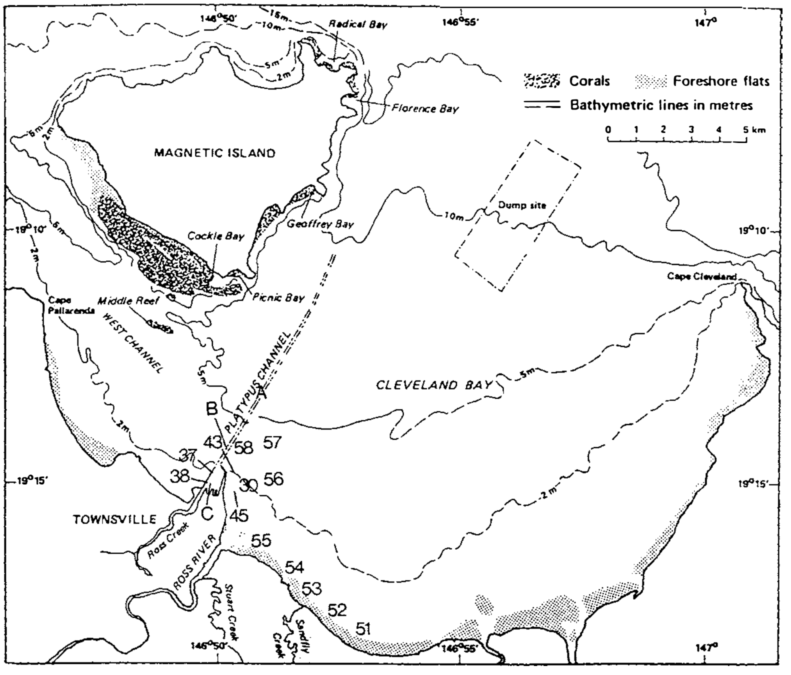

Figure 1. Location map of the study area, Cleveland Bay and site locations for sediment collection.

Metals in suspended sediments

1 litre samples of water collected at the surface and bottom of the water column were filtered the day after collection using cellulose acetate filters. Samples were taken in the dredge plume, in the dump plume and at control sites within Cleveland Bay. They were then digested and analysed for trace metals by ICP - AES at ANSTO, Lucas Heights, Sydney. Blanks were determined throughout the procedure.

Elutriate experiments and sequential leaching

Sediment samples for the elutriate experiments and sequential leach analyses were collected in duplicate from two sites in Platypus Channel (sites A and B) and one site in Townsville Port (site C) (Figure 1) by scuba divers using specially designed collection devices made of UPVC piping. Samples were immediately processed and placed in a nitrogen atmosphere to ensure minimal oxidisation of the sediments. Samples were thawed under refrigeration prior to experimentation. Seawater was collected from Cleveland Bay on the morning of each experiment in order to maintain natural seawater condition, particularly pH. The disturbance device was filled with a water:sediment ratio of 20:1 v/v. This ratio was used because it reflects, to scale, the dredging of 0.3 meters of sediment in approximately 6 meters of water. The sediment/water mixture was stirred for one hour at a rotation rate of 60-70 rpm to ensure the sediment stayed fully suspended in the water column, and then allowed to settle for three hours. Triplicate samples for each sediment sample were analysed from each of the following treatments:-

1) Before the disturbance.
2) Directly after the disturbance.
3) The settled fraction three hours after the disturbance.
4) The fluid mud layer above the settled layer three hours after the disturbance.

The sequential extraction technique used for each sample was adapted from Tessier *et al.*, (1979). All acids used were AR grade and blanks were used throughout the procedure. After each extraction phase the remaining solution was centrifuged, decanted and acidified for analyses, and the remaining sediment sample was used in the following steps:

1-Exchangeable phase: The sediment was continuously agitated at room temperature for 1 hour with 5 mL of 1M magnesium chloride solution at pH 7.

2-Carbonate bound metals: The residue from step 1 was leached at room temperature with 5 mL of 1M sodium acetate and adjusted to pH 5 with acetic acid. Continuous agitation was maintained for 5 hours.

3-Easily reducible, manganese bound metals: The residue from step 2 was leached with 5 mL of 0.1M hydroxylammonium chloride and 0.01M nitric acid. Continuous agitation was maintained for 30 minutes at 23°C (Gibson and Farmer, 1986).

4-Moderately reducible, iron bound metals: The residue from step 3 was leached with 5 mL of 1 M hydroxylammonium chloride and 25% acetic acid. Continuous agitation was maintained for 4 hours at 23° C (Gibson and Farmer, 1986).

5-Organically bound metals: The residue from 4 was leached with 3 mL of 0.02M nitric acid and 5 mL of hydrogen peroxide at pH 2. The solutions were heated to 85°C for 2 hours and agitated periodically. After 2 hours another 3 mL of hydrogen peroxide was added and heated at 85°C for 3 hours. The samples were cooled and 3.2M ammonium acetate and 20% nitric acid was added, made up to 20 mL with double distilled water and agitated for 30 minutes.

6-Residual metals: 2 mL of hydrochloric acid, 2 mL of hydrofluoric acid and 1 mL of nitric acid was added to the residue from step 5. Each polyethylene container was sealed firmly and placed in screw cap glass jars. The jars were then microwaved for 30 minutes on low power. The leachate from each step were analysed for copper, lead and zinc using AAS.

X-ray diffraction

Selected samples were analysed from Cleveland Bay and samples from each treatment of the simulated disturbance at site B were analysed. The sediment was ground to a powder with a mortar and pestle, wetted with distilled water, smear mounted on a microscope slide and allowed to dry. Sediments were analysed using a Rigaku - Denki powder x-ray diffractometer (D max 500), equipped with graphite curved crystal post diffraction monochromator. Each sample was run using CuKa radiation at 40 kV and 20 mA with 5 ° divergence and anti scatter slits a 0.15 mm receiving slit. The scan rate used was 0.5° per minute with a time constant of 5. For clay particle determination each sample was glycolated at 60°C overnight. The semi-quantitative abundance of each mineral was determined by calculating the relative peak area of each mineral component from the XRD trace (Edzwald *et al.*, 1974; Ward, 1990).

RESULTS

Trace metal concentrations in sediments throughout Cleveland Bay

Bioavailable (acid leached) copper, zinc and lead in sediments in the port area were higher than in sediments at other sites in Cleveland Bay. Sediments sampled from around the sewage treatment discharge point were not as high as in the port area. Figure 2 shows copper, zinc and lead concentrations in sediments in a transect from the sewage treatment discharge point (site 53) to the inner port area (sites 37 and 38) compared to control sites (sites 75, 76 and 77) in Bowling Green Bay, a relatively pristine site further south.

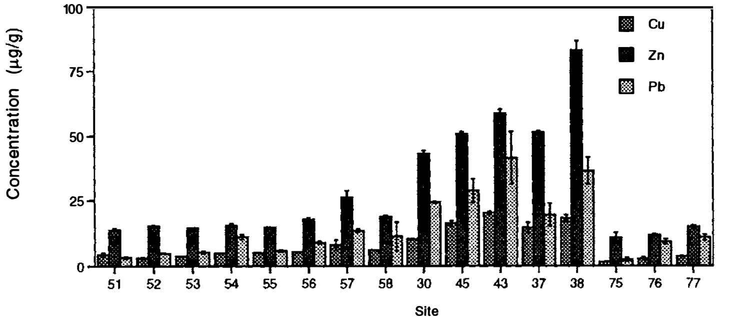

Figure 2. Copper, lead and zinc concentrations in benthic sediments from a transect from the sewage treatment discharge to the inner port area in Cleveland Bay.

Metal concentrations increase closer to the port area. Copper, zinc and lead concentration in or near Platypus Channel (the site of dredging) are 5.3-6.1 µg/g, 15.3-19.1 µg/g and 3.9-8.4 µg/g respectively. These concentrations were significantly lower than the port area but are typical of, or slightly higher than, metal concentrations throughout the rest of the bay.

Trace metal normalisation to iron concentrations in sediments can indicate to what extent particular elements are unnaturally enriched. Figure 3 shows that sediments high in copper, lead, zinc or nickel are elevated as a result of anthropogenic sources. The highest values of copper, lead, zinc and nickel in sediments were from samples collected from in or near the port area. In contrast, values from the rest of Cleveland Bay were correlated with iron concentrations.

Metal concentrations in sediments from coral surfaces in Cleveland Bay

Bioavailable (acid leached) copper, zinc and lead concentrations were analysed in sediments taken from coral surfaces before, one week after, and one month after two dredging events in Cleveland Bay in 1991 and statistically compared between collection dates using one way ANOVA. Sediments at Middle Reef and Cockle Bay showed elevated concentrations of copper, zinc and lead ($P < 0.001$) one week after dredging (Figure 4). Geoffrey Bay and Florence Bay were also significantly higher in copper (P <0.001), and zinc (P <0.005) but not in lead one week after dredging. In samples taken one month after the first dredging event and also before the second dredging event metal concentrations were lower except for Middle Reef where all three metals were significantly higher (P <0.001) in concentration. Sediment samples from Radical Bay showed some signs of elevated metal concentrations for zinc and lead (P <0.001) after the second dredging event, probably as a result of dumping of dredge spoil nearby.

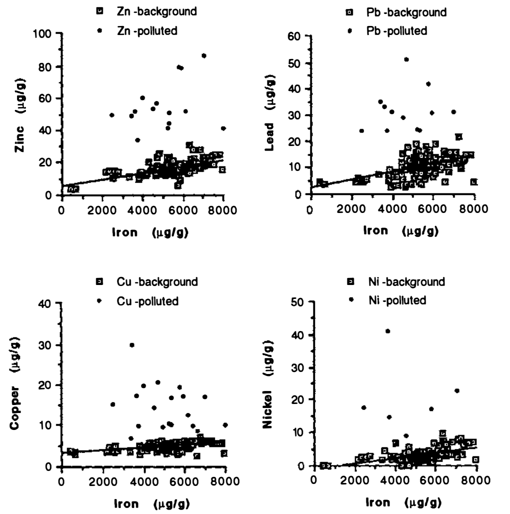

Figure 3. Copper, lead, zinc and nickel correlations with iron in benthic sediments from Cleveland Bay.

Simulated disturbance

Metals leached in the exchangeable phase (step 1) were below detection limits. In step 2 leaching of carbonate bound metals showed that lead increased significantly (P <0.001) in the disturbed fraction and the fluid mud layer at sites B and C but not A (Figure 5) and zinc increased similarly at sites A and B but not at C. Zinc (Figure 5) and lead were more concentrated in the fluid mud fraction than in other fractions in the iron oxyhydroxide bound extraction (step 4). The copper was mostly bound to organics (Figure 5) and was significantly higher (P <0.001) in the fluid mud phase at sites A and B. Copper and zinc were also extracted in the residual fraction and were significantly higher in the fluid mud layer at sites A and B. Lead was not detected in the residual extractions.

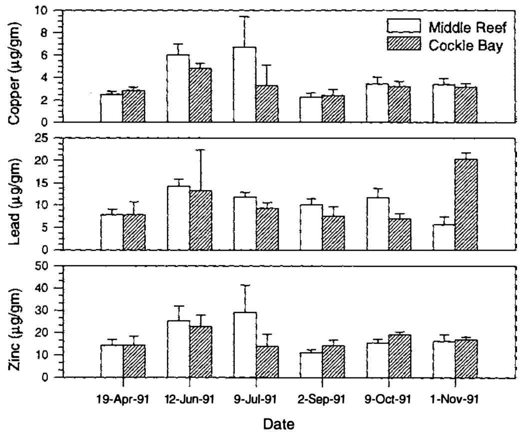

Figure 4. Copper, lead and zinc concentrations in sediments from coral surfaces at Middle Reef and Cockle Bay before, 1 week after, and 1 month after two dredging events in Cleveland Bay in 1991.

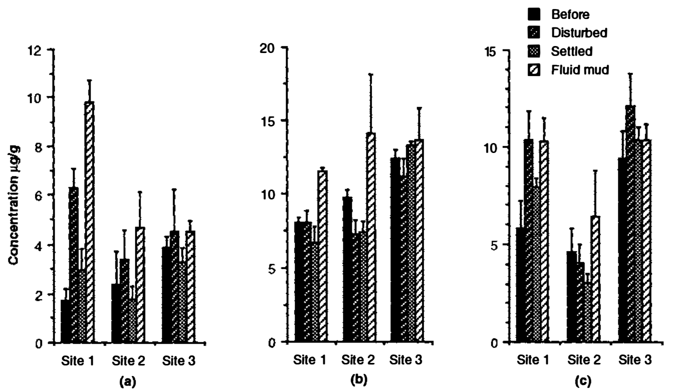

Figure 5. Metals bound to different types of sediment particles. An increase can be seen in the fluid mud fraction where finer sediment particles are more dominant. a = lead bound to carbonates, b = zinc bound to iron and c = copper bound to organics.

Trace metals in suspended sediment

The aluminium concentrations increased in a linear relationship with increases in suspended sediment load (Figure 6). Figure 6 also shows the aluminium:iron and aluminium:zinc correlations. These results suggest that the disturbance of anoxic sediments can cause iron oxides/oxyhydroxides to successfully scavenge zinc. The iron oxyhydroxides are commonly associated with clay particles and these particles are naturally high in aluminium, hence suggesting that the higher the aluminium content the higher the absorptive capacity for other trace metals such a zinc.

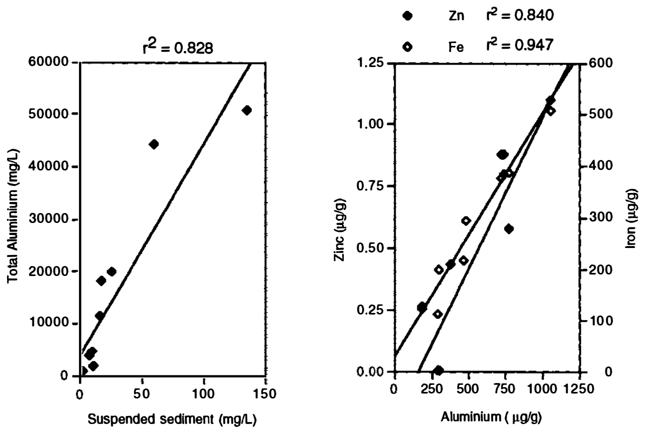

Figure 6. Suspended sediment concentrations and their relationship to aluminium concentration. The aluminium can then be linearly related to iron and zinc concentrations in suspended sediment.

Sediment composition

The semi-quantitative values for the major minerals in sediments within Cleveland Bay show that quartz was most abundant and ranged from 24 to 69%. At sites close to coral reefs aragonite was a large component of the sediment. For example, Florence Bay (29%) and Middle Reef (23%). Iron oxide and oxyhydroxide ranged from 4 to 14% throughout Cleveland Bay including the port area. Higher iron concentrations were generally found closer to shore and around some fringing reefs including Middle Reef 10% and Picnic Bay 9%. The abundant clay mineral was smectite/mixed layer comprising 72 to 89% of the total clay content. The clays were also composed of illite and kaolinite making up 6 to 23% and 5 to 12% respectively of total clay.

The sediment composition was also determined for sediments after the simulated laboratory experiments. A large fraction of the fluid mud layer was composed of clay mineral. Smectite/mixed layer dominated all fractions resulting from the elutriation experiments except for the fluid mud layer where illite was more abundant.

DISCUSSION

Bioavailable copper, zinc and lead concentrations within and around the port area of Townsville were higher than normal background concentrations throughout the bay, and at control sites in Bowling Green Bay (south of Cleveland Bay). When normalisation is applied by comparing iron: metal abundances in bottom sediments in Cleveland Bay (Figure 4), the polluted sites clearly stand out from the unpolluted sites. However metals in sediments taken directly from the dredging site were not high and did not stand out in the metal:iron comparison. The low metal concentrations found in 'Platypus Channel' contrast with the high metal loads found in sediments that had settled on coral reefs after dredging activities in Cleveland Bay.

Hydroxides and hydrous oxides of polyvalent cations such as aluminium, iron and manganese, which have a high absorptive capacity for some trace metals, are often found coating clay minerals (Yariv and Cross, 1979). These coatings are not permanent and when sediments are disturbed and in suspension it is possible that new conditions, particularly redox conditions, will play an important role in trace metal speciation (Drever, 1982). The metals in suspended sediments show a correlation between aluminium and iron and aluminium and zinc (Figure 6). This relationship suggests that as aluminium and subsequently clay concentrations are increased in sediment the adsorptive capacity for iron and zinc is also increased.

The laboratory investigation indicates that each metal has a different preferential binding capacity to adsorb on to different sediment components, similar to previous observations by Tessier *et al*., (1979). Zinc was strongly associated with iron, particularly in the fluid mud layer that remained in suspension after the simulated disturbance. From 20% to 60% of the total extracted lead was bound to carbonates, while zinc was also strongly bound to carbonates. The fluid mud layer and the disturbed fraction had the highest percentages of carbonate-bound lead and zinc, and in general the undisturbed sediments had the lowest concentration. Copper and zinc were strongly bound to organics. In most cases the fluid mud layer had the highest adsorptive capacity for metals regardless of the extraction step.

When sediments are disturbed, the larger more dense particles will settle more quickly than the finer particles. The finer particles that remain in suspension provide more binding sites for metal ions. The mobile suspended particles then may act as a transport mechanism for trace metals bound to their surfaces. The fluid muds had a high clay mineral content, with illite being the dominant mineral form. Trace metals bound to clay minerals are available to scavengers and filter feeders such as fish, worms and bivalves (Moore and Ramamoorthy, 1984).

The dominant current patterns in Cleveland Bay move from Platypus Channel towards Middle Reef and Magnetic Island (Wolanski *et al.,* 1991; Reichelt, 1993) and provide transport mechanisms for the fluid muds. The fluid muds settle in areas of reduced current velocity such as coral reefs, carrying with them enhanced concentrations of trace metals.

CONCLUSION

Bioavailable copper, lead and zinc are high in trace metals at some sites within Cleveland Bay and in particular around the port area. These elevated metal loads are confined mainly to the port area and decline with increased distance from the port. Trace metals in sediments that have settled on coral surfaces within Cleveland Bay have higher than background concentrations of copper, lead and zinc. Much of this sediment has been mobilised by dredging activity in Platypus Channel and transported to the adjacent coral reef by current action. The sediments that remain in suspension after dredging are much finer and therefore have a higher metal adsorptive capacity. Middle Reef showed the most notable increase in metal concentrations in sediments after dredging and is also in the direct path of the dredge plumec. Investigations on the effect of such elevated concentrations of trace metals on corals are in progress.

ACKNOWLEDGEMENTS

Townsville Port Authority, Townsville City Council, Great Barrier Reef Marine Park Authority and James Cook University are thanked for financial support of this project. ANSTO is thanked for commercial analyses of suspended sediment samples. Southern Cross University and James Cook University are thanked for financial support to attend PACON 94.

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RECREATIONAL SCUBA DIVING AND ITS POTENTIAL FOR ENVIRONMENTAL IMPACT IN A MARINE RESERVE

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ABSTRACT

While scuba diving is generally assumed to have little impact on the marine environment, recent studies have suggested that popular diving sites may suffer significant damage as a result of diver behaviour. In this study, the behaviour of scuba divers was observed and their contacts with the benthos were quantified to determine potential impacts of divers at a popular diving location in Eastern Australia.

The study was conducted in the Julian Rocks Aquatic Reserve, approximately 2 km offshore from Byron Bay in Northern New South Wales. It is a sub-tropical reef with over 20 species of coral, and abundant fish and algal communities. In 1992, more than 20,000 dives were recorded in the Reserve, with 86% of these dives being made within an area of approximately 0.8 hectares. Recreational divers made an average 35 contacts with the substratum or marine organisms per dive, of which approximately 65% were "uncontrolled" (i.e. accidental), and 7% resulted in visible damage to biota. Hard corals and sponges received the majority of damaging contacts. Uncontrolled contacts with fins and other diving equipment caused most of the damage. Divers with further training made significantly fewer uncontrolled contacts than those with only basic level training.

The results indicate that at this heavily-used site, recreational divers have the potential to make over 700,000 contacts per year, and approximately 49,000 of these could result in some impact on the biota. Management policies that might reduce potentially detrimental impacts are discussed and education of divers, particular regarding the importance of buoyancy control, is seen as a key management tool.

INTRODUCTION

Recreational SCUBA diving is a rapidly growing sport in Australia and worldwide. According to a national study of the Australian SCUBA diving industry, 50,550 new divers were certified at the entry (or open-water) level during 1988 and the industry has an estimated growth rate of 20% per annum (Esguerra *et al.*, 1989). It has been estimated that 884,000 recreational dives are made each year in Queensland alone (Wilks, 1993).

The marine environments that support this industry include many potentially fragile ones, that are subject to stress and damage from natural and human-induced effects. SCUBA diving in general has been promoted as a relatively benign activity which allows people to observe the underwater environment without harming it, but impacts of snorkellers and SCUBA divers on reef ecosystems have scarcely been considered from a scientific viewpoint (Tilmant, 1987). Studies that have looked at the impacts of these activities, have mainly focused on the impacts to corals in tropical locations, perhaps because coral reefs are one of the more popular dive destinations and corals are perceived to be among the more fragile of reef organisms. However, the impacts of recreational activities such as SCUBA diving on subtropical marine ecosystems are largely unknown.

Salm (1984, p. 103), states "almost all diving has the potential to result in damage to corals and other reef biota. In frequently dived areas damage can be significant and can lead to local loss of fragile species". Studies conducted on coral reefs in the Virgin Islands (Rogers, 1988) and Egypt (Hawkins & Roberts, 1992), found that recreational diving has both direct and indirect effects. Direct effects include, handling, kicking, trampling, kneeling or standing on benthic organisms, damaging or displacing them. Resuspension of sediment may stress some organisms (Rogers, 1983) and can result in loss of zooxanthellae and polyp swelling in corals and increased rates of mucus secretion in sponges and corals (Brown & Howard, 1985; Marszalek, 1981).

Indirect effects may occur if damage caused by divers exposes tissue to possible invasion by pathogens, possibly accelerating mortality rates of organisms such as corals (Hawkins & Roberts, 1992). Injuries to corals from snorkellers and divers, in combination with adverse environmental conditions, such as high turbidity and sediment may increase the frequency of occurrence of white band and other coral diseases (Peters, 1984). Marine ecosystems are obviously tolerant to a certain amount of diver intrusion, since a number of popular dive sites around the world continue to support relatively healthy systems (Tilmant, 1987). The point at which the level of use begins to cause significant alterations in community structure needs to be determined. This level will change with the type of reef and the recreational activities that are permitted.

In spite of the growing awareness of the detrimental effects of recreational activities on marine environments, there have been few studies that have tried to quantify this damage (Rogers, 1988). The aim of this study is to assess and quantify SCUBA divers" behaviour patterns and their potential to impact on benthic communities in a sub-tropical marine reserve in Eastern Australia.

METHODS

The study was conducted at the Julian Rocks Aquatic Reserve, located approximately 2 kms offshore from Byron Bay on the North Coast of New South Wales (Figure 1). An area of approximately 80 hectares around the Juan and Julia rocks (collectively known as the Julian Rocks) was declared an aquatic reserve on the 26th of March 1982. The popularity of the Julian Rocks as one of the prime dive sites on the east coast of NSW has been well documented (Cufer, 1989; Byron, 1984; Wright, 1990). Factors which contribute to its popularity include generally high water clarity, accessibility in most weather conditions, and proximity to population and tourist centres. It has a diverse topography and abundant biota which is a mixture of tropical and temperate marine life, including sponges, gorgonians, tunicates, sea fans, soft corals and diverse fish assemblages (P. Parker, personal communication). From December to April warm, clear tropical currents flow from the north, introducing larvae of tropical organisms to the reserve. Over twenty species of scleractinian (hard) corals have been recorded in preliminary surveys (Harriott, unpublished data). Other species of particular interest to divers are rare black corals (Antipatharians), grey nurse sharks (*Odontaspis arenarius*), wobbegong sharks (*Orectolobus* spp.), sea anemones and their clown fish (*Amphiprion* spp.), and moray eels (*Gymnothorax* spp.).

The total number of boats, divers and snorkellers that visited the reserve in 1992 was obtained from an audit of charter bookings, supplied by the three commercial dive operators who used the Reserve that year. Location maps were compiled in consultation with divers with a sound knowledge of the local area and who dive in the Reserve on a regular basis. Interviews with long term divers of the Julian Rocks Aquatic Reserve were conducted to determine their perceptions of the area's degradation or otherwise.

Randomly selected recreational divers were followed throughout their dive to assess the frequency, duration and type of contacts that each diver made with the substratum and benthic organisms were recorded. Contacts were classified as either controlled or uncontrolled. Controlled contacts were usually deliberate and required some element of decision by the diver as to where and what they touched and the amount of pressure they exerted. Any observed damage to organisms was recorded and given a subjective rating of either minor damage, (marked, abraded, but structure still complete, or the release of mucus by corals which indicates stress) or major damage (where the structure of the organism was broken). A small, inconspicuous underwater note pad was used to record contacts. A table of codes was used to record the types and nature of these contacts. A simple code was given to each type of contact and benthic organism contacted.

To reduce bias in sampling (awareness of divers that their contacts were being monitored) divers were not told the true purpose of the study until after the dive. Divers were interviewed after their dive to determine their experience (years and number of logged dives since initial certification), when they last dived, their certification level, where they were first certified and with what agency. Divers were also asked if they were aware of contacts they had made during their dive, and how comfortable they were with their buoyancy skills.

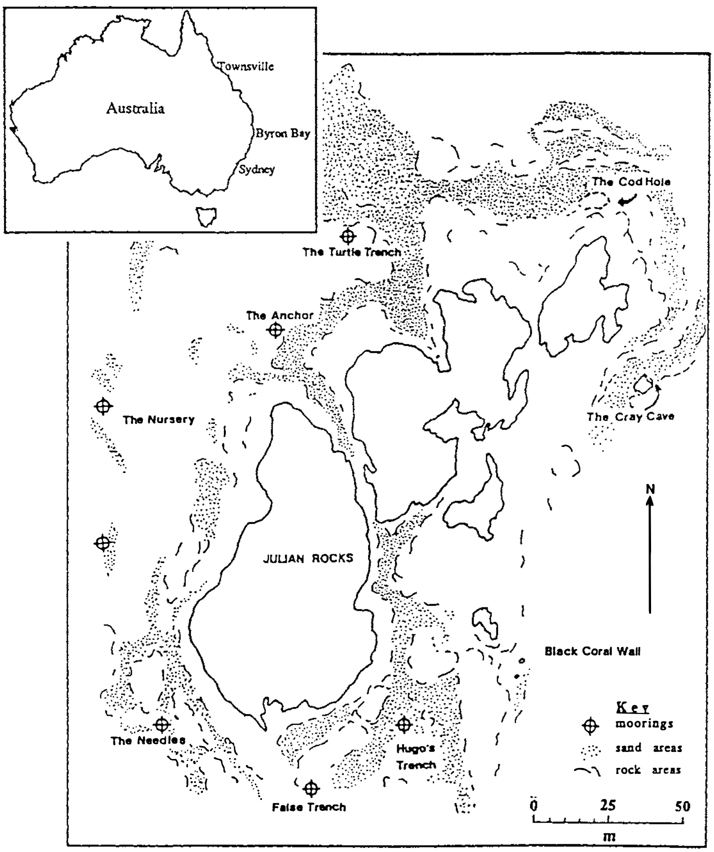

Figure 1. Location of the main dive sites at the Julian Rocks Aquatic Reserve. (Inset. Location of Byron Bay, Northern New South Wales, Australia).

RESULTS

There are currently three commercial dive operators using the Julian Rocks for dive and snorkel charter, certification of new divers, and continuing education courses. Another operator has recently commenced a fourth charter service. Several other private and commercial dive boats, both local and interstate also use the Julian Rocks on an infrequent basis (accounting for less than 1% of the total dives). The combined number of boat trips in 1992, made by the three main dive operators was 3795. A count of the dives made from charter bookings from the three dive operators showed that there were 20,787 bookings made in 1992. S. Phillips (unpublished data) established that 97% of dive trips from Byron Bay in 1992 were to the Julian Rocks Aquatic Reserve. It can therefore be estimated that at least 20,163 dives were made in the reserve in 1992. The peak season for the dive industry is in November, December and January (the Christmas holiday season), with another peak in April which coincides with the Easter break. The most frequently visited sites within the reserve are the "Cod hole" and "The Nursery" (Figure 1).

A total of 30 recreational SCUBA divers were sampled; twenty two male and eight female. The average number of times a diver came into contact with the substratum or benthic organisms was 35 contacts/diver/dive. Variation about this mean was very high (SE = 5.80) with a minimum of 2 contacts/dive and a maximum of 121 contacts/dive. The most frequent type of contact (>50%) was made with fins (Figure 2a). Controlled contacts included nearly all hand, body and knee contacts, whereas uncontrolled (accidental) contacts were most often caused by fins, and other equipment (Figure 2b). Sponges and hard corals were the most frequently contacted invertebrates, which could be expected as they are amongst the most abundant invertebrates found in the area. Most contacts from divers resulted in very little observed damage. The percentage of contacts that caused some type of damage was 7.2%. Fins caused 55% of all damage recorded and the majority of damage recorded was to hard corals (Figure 3).

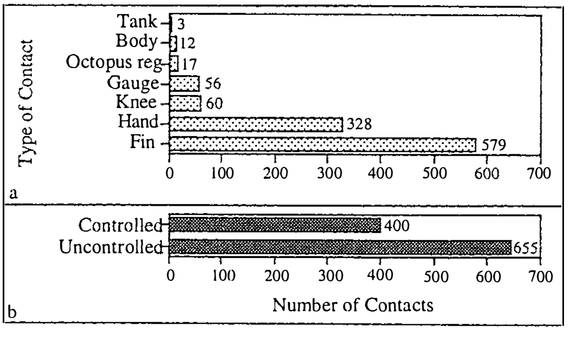

Figure 2a. The frequency of different types of contacts, n = 1055 (2b). The number of controlled and uncontrolled contacts recorded.

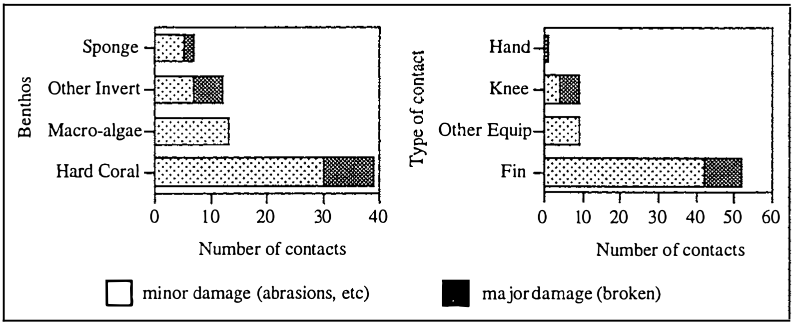

Figure 3. The number and type of contacts that caused minor or major damage to benthic organisms.

The relationship between the number of contacts and the divers' experience and training level were compared using unpaired t-tests (Table 1). Divers were grouped according to the number of logged dives that they had made since certification. While the mean number of uncontrolled contacts made by divers who had logged over 100 dives was much lower than those divers with fewer than 100 dives, this difference was not statistically significant (P = 0.052). To determine if there was any effect of further training, on the number of contacts made by divers, the thirty divers were grouped according to their certification level into those with basic entry level training (Open water diver) and those with further training (Advanced, Divemaster or Instructor). Divers with further training had fewer than half the number of uncontrolled contacts than the divers with basic training, and the differences were statistically significant (P = 0.032).

Table 1. The mean number of contacts made by divers with different experience levels. (no of logged dives) and different training levels (certification).

Number of dives.	Mean	Std. Dev.	n
< 100	26.3	20.94	21
>100	11.4	9.48	9
	t = 2.02	P = 0.052	

Training Level	Mean	Std. Dev.	n
Entry Level	27.1	19.73	20
Further Training	11.3	14.20	10
	t = 2.25	P = 0.032	

The major behavioural differences observed between divers of different experience levels, was that less experienced divers tended to swim with fins angled to the bottom, rather than parallel with the bottom. This increased their tendency to disturb the substrate with their fins, and their overall buoyancy control was less well developed.

DISCUSSION

The number of dives completed at the Julian Rocks, and in particular the concentration on the relatively small "Nursery" and "Cod Hole" areas, exceeds the usage levels of many popular dive sites, both in Australia and overseas. In a survey of the dive tourism industry in the Great Barrier Reef region, Thomas (1992) found only three of the more frequently dived sites to have greater usage levels than that obtained for the Julian Rocks.

A problem for managers of reserves is to provide for appropriate recreational use of an area while keeping impacts at an acceptable level. While research into the recreational carrying capacity of natural environments has failed to establish any predictable links between different levels of use and their impacts on the environment, any human use of natural areas can lead to changes in the condition of the area (Prosser, 1986; Graefe *et al.*, 1984). Dixon *et al.* (1993) recommended that the maximum level of visitation of dive sites in Bonaire Marine Park be set at approximately 4,500 dives/site/year. It was determined that if this capacity was exceeded, then rapid loss of reef biodiversity could result. Tilmant (1987) found that the level of recreational use on the reefs at Biscayne National Park did not exceed 1,500 people/reef/year, and suggested that at higher levels of use, diver impacts could be more severe.

It is difficult to compare the level of use that different dive sites or reefs can sustain unless the size of the dive site or reef is known. Dixon *et al.* (1993) found that damage from divers declined over distances of between 100m to 260m away from the mooring or entry point, with the highest damage being recorded in close proximity to the moorings (0-45m). He suggested that individual dive sites should be placed at least 600m apart to provide a buffer zone between dive sites. The Julian Rocks Aquatic Reserve extends in a 500m radius from a point on the most southern rock outcrop, with less than 50m between some of the more popular dive sites. There is a greater potential for impacts from divers to be increased due to the relatively small area to which divers are confined. The two most frequented sites at the Julian Rocks (The Cod Hole & The Nursery) are separated by approximately 150m and both sites can easily be visited on a single dive. In total, they receive approximately 17,200 dives/year. While the estimate of sustainable usage levels calculated for tropical coral reefs can not be transferred directly to the Julian Rocks, it seems likely that such a high level of usage may not be sustainable.

In this study, an average of 35 contacts were made by divers in an average dive of 32 minutes. This is much lower than the 57 contacts/30 min dive estimated in a study of diver behaviour on an artificial reef in Florida (Maiselson, 1992). With the estimated number of dives made in the Julian Rocks Aquatic Reserve in 1992 of 20,163, there is the potential for divers to make over 700,000 contacts per year. Of the contacts recorded in this study, 7% caused damage, with 5% causing minor damage and 2% resulting in major damage. Consequently there is the potential for over 35,000 incidences of minor damage and over 10,000 incidences of major damage per year.

Hard corals received the most damage; of the 88 contacts recorded to corals 34% caused minor damage (abrasions and release of mucus) and 10% resulted in coral being broken. Therefore it is possible that over 6,000 corals could be broken by divers each year. The degree of damage varied with growth form. Major damage (organism broken) was confined to the more fragile branching species of corals *Acropora* spp. and *Pocillopora damicornis* while all minor damage (abrasions) were to encrusting forms.

Buoyancy control is one of the most difficult skills for divers to master. Proficiency in buoyancy control has been identified as a key indicator of an "experienced diver" (Rhea *et al.*, 1993). Some of the factors that have been cited in contributing to poor buoyancy control are lack of experience or adequate training and divers being overweighted, again a result of inadequate training (Lippmann, 1993; Bowdey & Beaty, 1992; Serlin, 1989). Buoyancy control is a skill that requires practice, and divers with greater experience would be expected to have a greater degree of control over this skill. A diver who is correctly weighted and has mastered the skill of buoyancy control should maintain a horizontal swimming position, unlike many of the inexperienced open-water divers in this study. All major damage recorded was caused by openwater divers with less than 100 logged dives, and the majority of damage was caused by fins.

A lack of awareness by divers of the damage they can cause is also seen as one of the factors contributing to the number of times they contact benthic invertebrates and other marine life. Many divers are not aware of the nature of aquatic fauna and flora (Richardson, 1989). Many of the divers in this study were unaware of the number of contacts they had made during their dive and felt they had caused very little disturbance to the marine communities in the reserve. Many divers were amazed and concerned, about the number of contacts and damage they had caused. These observations indicate that advanced education of divers both in diving skills and marine awareness could be a key issue in reducing the amount of damage to marine communities and therefore increasing the carrying capacity, or level of sustainable use of popular dive sites.

The results indicate that divers have the potential to cause impacts at the Julian Rocks, but whether the amount of damage attributed to divers is translated into a measurable long term impact on benthic organisms still needs to be determined. While Tilmant and Schmahl (1981) found a significant correlation between the level of recreational diving and the incidence of coral damage, they concluded that the amount of damage from recreational activities was negligible when compared to storm damage. The episodic nature of storm damage may allow for periods of recovery between storm events, whereas diver impacts are chronic. Therefore, the natural level and frequency of damage experienced by a reef needs to be considered in order to place diver damage in proper perspective.

Anecdotal evidence suggests that the increased use of the Julian Rocks by divers has coincided with changes in the benthic communities of the reserve. Much of this damage can be attributed to anchor damage from boats before the installation of the moorings, and debate continues amongst local divers as to the amount of damage directly attributable to recreational diving. To date, very little work has been done on the diversity and abundance of benthic communities in the reserve and without this baseline data, no conclusions can be reached about the possible detrimental impacts from divers. A benthic community baseline study is in progress.

CONCLUSIONS AND RECOMMENDATIONS

Specific recommendations for management of the Julian Rocks Aquatic Reserve include the following:

1. Research and monitoring

The management of recreational SCUBA diving is possibly the biggest issue in the Julian Rocks Aquatic Reserve at present. It is recommended that the number of divers, and number of boats using the reserve and the patterns of resource use continue to be monitored. Before any management policies can be formulated or implemented, it must first be determined whether the impacts from divers constitute any long-term threat to the marine communities at the reserve. We recommend mapping of the marine habitats within the reserve to identify potentially fragile or sensitive species and surveys to provide quantitative base-line data on benthic communities against which future changes can be measured. Controlled experiments in which the intensity of impact is manipulated and community or organism responses are identified would also be beneficial.

2. Diver education and awareness

The fact that many divers in this study were unaware of the number of contacts they had made or that they had caused damage illustrates the need for diver education. Education of divers concerning the potential they have to cause impacts on underwater environments is probably the most effective way of reducing damage by divers in the reserve. Commercial dive shops can promote marine awareness through placing more emphasis on marine education during courses, by emphasising effective buoyancy control techniques and correct weighting during training, by provision of continuing training courses, and by training divemasters to emphasise the status of the marine reserve and the potential that divers have to cause damage.

3. *Rotation of mooring sites*

At present, commercial dive shop operators utilise sites away from the most popular areas whenever possible depending on consumer demand, the experience level of divers, weather and current conditions. Until adequate data is available about the long-term impacts from divers, and some estimate of the sustainable usage levels of the reserve are made, interference in current practices by commercial dive shop operators is not recommended.

4. *Closure of dive sites*

In some marine parks it has been necessary to close areas to allow for recovery. Due to the small size of the Julian Rocks reserve it is not viable to have closures of some sites to divers as most sites can be accessed on a single dive. However, appealing for voluntary restrictions from sensitive areas with the support of the charter operators may be effective.

5. *Underwater dive trails*

Underwater dive trails have been used in some marine environments to confine mechanical damage from recreational SCUBA diving and reef walking to specific areas, which are chosen for their ability to sustain heavy usage. Guided marine tours on SCUBA and snorkel have been used successfully as a management tool in a reserve in Trieste, Italy (Spoto & Franzosini, 1991). In the present study, dive shop staff indicated that many dives are already guided by divemasters and that this is seen as a way of minimising damage from divers and confining them to particular areas. There is a belief that the sign posting and chains that are used in underwater trail marking could detract from the natural appearance of the underwater environment.

6. *Artificial reefs*

The placement of an artificial reef in Byron Bay could help to alleviate many of the problems with potential conflicts between user groups, reducing the current dependency on moorings in the reserve. It would provide an alternative fishing site for anglers, and an alternative dive site. The feasibility and suitable location of an artificial reef in Byron Bay is currently being investigated.

7. *Anchor damage*

Anchor damage in the Julian Rocks Aquatic Reserve has been minimised by the installation of moorings, and the draft management plan for the Julian Rocks (Copeland & Phillips, 1993) recommends that additional moorings be installed within the reserve as funds become available. This will help to alleviate the impacts from smaller fishing vessels but the occasional anchoring by trawlers is likely to present a more serious threat to benthic communities. Once sufficient small boat moorings have been provided, and if heavy-duty mooring can be installed for use by larger vessels, anchoring could be prohibited in the reserve.

The aim of managers and researchers is to achieve an understanding of the reef system, with which it is possible to predict confidently and accurately the response of the system to known impacts (Kenchington, 1988). Until information is available about the responses of sub-tropical reef systems to human activity, management decisions concerning their potential impacts must, of necessity, be cautious. The most immediate challenge to managers of marine protected areas, such as the Julian Rocks Aquatic Reserve is to document and interpret potential threats to the reserve and to establish at what point the benefits of the dive tourism industry will outweigh the environmental costs.

ACKNOWLEDGEMENTS

The authors would like to thank the staff at the Byron Bay Dive Centre, Bayside Scuba and Sundive Dive Centre, for their time and assistance during this study.

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THE EFFECTIVENESS OF REEF CLOSURES AS HARVEST REFUGIA IN THE GREAT BARRIER REEF MARINE PARK

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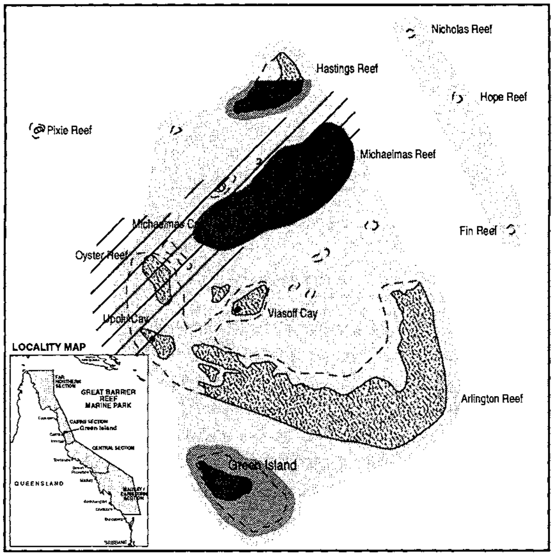
ABSTRACT

Under the management regime developed for the Great Barrier Reef Marie Park, specific coral reefs are protected from fishing through the use of zoning. Over the last decade, numerous surveys have been conducted to determine the effects of protection on abundance and the mean size of targeted fish, principally the common coral trout, *Plectropomus leopardus*. The results of these surveys are not always conclusive. A number of confounding factors such as low fishing pressure, infringements of closed areas and the resilience of the species may explain why no difference exists between protected and fished reefs in many studies. There are indications that the red-throat sweetlip, *Lethrinus miniatus* may be more susceptible to fishing pressure. However, whether reef closures are effective for *L. miniatus* remains to be substantiated as very little is known about the biology of this species.

INTRODUCTION

The Great Barrier Reef Marine Park covers an area of 350 000 km^2 and supports an extensive reef line fishery comprised of commercial and recreational sectors. The commercial fishery is a limited entry fishery and involves 200 - 300 commercial operators with an annual catch of 4000 tonnes (Gwynne, 1990). Restrictions are placed on the type of gear used and minimum size limits apply to the major species targeted. The recreational fishery, on the other hand, contains two major components: the private speed boat fleet in which there are approximately 24 000 registered boats in the Great Barrier Reef Region, and secondly, the charter boat fishery which includes boats that provide fishing charters and larger vessels owned by fishing clubs. The number of charter boats which offer fishing as a primary activity amounts to about 260. It is estimated that the annual catch of the recreational fishery is between 3500 - 4000 tonnes annually (Blamey and Hundloe, 1993). Like the commercial fishery, recreational fishing is restricted by minimum sizes for the major species. Additionally, bag limits have been recently implemented for the majority of species taken. Even under the present management arrangements for both fishing sectors, concerns have been expressed by management agencies and fishers that there is too much effort in the fishery and the resource could be under threat in some areas.The management of most fisheries in the Great Barrier Reef Marine Park is the responsibility of the Queensland State Government. The Great Barrier Reef Marine Park Authority in its aim to protect the natural qualities of the Great Barrier Reef, whilst providing for reasonable use of the Reef Region, does have control over fishing by virtue of the use of a series of management zones which restrict certain fishing activities in specific areas (Figure 1). Reef closures are an integral part of these management strategies. Their primary function, however, has been for conservation purposes and the maintenance of biodiversity rather than as a fisheries management tool. Areas are set aside free from extractive uses in order to minimise the effect of these activities on the reef ecosystems and also to provide areas for appreciation and enjoyment by the public.



Zoning Classifications

General Use Zone	To provide areas of Marine Parks for a diverse range of recreational and commercial activities, consistent with the Region's long term conservation. All types of fishing activities are allowed.
Habitat Protection Zone	To provide areas of Marine Parks free from effects of trawling, while allowing for a diverse range of recreational and commercial activities, including reef fishing.
Buffer Zone	To provide protected areas of Marine Parks and allow opportunities for their appreciation and enjoyment. Buffer Zones allow mackerel trolling in areas adjacent to reefs zoned National Park ,but do not allow commercial or recreational demersal reef fishing.
National Park Zone	To provide protected areas of Marine Parks of high conservation value, but allow public access for appreciation and enjoyment - a 'look but don't take' area.No fishing activities are allowed.
No Structures Subzone	To provide areas of Marine Parks that remain in a natural state. This subzone is an additional condition to other Marine Park zones which allows for tourist programs to operate but ensures the area is free from structures such as pontoons and permanently moored facilities.

Figure 1. Sample of Marine Park zoning, offshore Cairns region.

The siting of reef closures is done through consultations with other management agencies, scientists and user groups. Reef closures were initially on an individual reef basis and the aim was to have a reasonable spread of protected areas throughout the Great Barrier Reef Marine Park. In more recent zoning plans, larger areas have been set aside and also a sink source model which predicts major areas providing sources of fish larvae to other downstream receiving reefs or sinks has been used as an aid to zoning (James *et al.*, 1990).

As targeted reef fish stocks are coming under increasing pressure from both sectors in the fishery, the possibility of using closed reefs as an additional strategy along with traditional fisheries management has been discussed on several occasions. Arguments for reef closures as viable fisheries management tools have also been expressed in other areas of the world (Bohnsack, 1990; Roberts and Polunin, 1991; Carr and Reed, 1992). Marine fishery reserves, that is, areas where no consumptive fishing is allowed, have been purported to be superior to other fisheries management actions such as minimum and maximum size limits, gear restrictions, limited entry, closed seasons, pulse fishing, bag limits, quotas, artificial reefs and stocking programmes (Bohnsack, 1990).

In the Great Barrier Reef Marine Park, a number of comparative studies have been conducted of fished and protected unfished reefs to evaluate the effectiveness of protection in maintaining the abundance and size structure of reef fish populations. Most of this research and the techniques has centred on the common coral trout (*Plectropomus leopardus*) as it constitutes approximately 75% - 85% of the catch in both the recreational and commercial sectors. These studies do provide, however, the opportunity to evaluate whether reef closures act as effective harvest refugia.

THE DEFINITION AND POTENTIAL ADVANTAGES OF HARVEST REFUGIA

The definition of harvest refugia and their intended objectives vary quite considerably and in many cases are not well documented (Roberts and Polunin, 1991). In this paper, the definition of harvest refugia is intended to be very broad. It is the allocation of restricted fishing or no harvesting for the purposes of protecting stocks of targeted reef fish populations. This allows for the replenishment of exploited fish populations outside the refugia through larval recruitment and emigration of juvenile and adult fish. This definition differs from Carr and Reed (1992) who emphasise larval dispersal rather than the emigration of older life stages as the mechanism of replenishment to areas outside the refugia. It is felt, however, that the emigration of older life stages should be included as an objective in our definition of harvest as studies by Alcala and Russ (1990) have found this to be an important mode of replenishment of reef fish populations in areas surrounding the refugia. It is unfortunate that at present there are insufficient data to assess whether in the sink source model reef closures can act as effective larval sources for other areas.

There are several potential advantages expounded for harvest refugia (Bohnsack, 1990; Roberts and Polunin, 1991). These include:

1. Protection of spawning stock biomass
2. Providing a recruitment source for surrounding areas
3. Supplemental restocking of fished areas through emigration
4. Maintenance of natural population age structure
5. Maintenance of areas of undisturbed habitat
6. Protection of intraspecific genetic diversity
7. Insurance against management failures in fished areas
8. Reduced data-collection needs
9. Simplified enforcement
10. Ease of public understanding and acceptance of management

Given that many of the studies conducted between protected and unprotected reefs in the Great Barrier Reef had limited objectives, it is not possible to assess the merit of harvest refugia for each of the ten advantages listed above. In this paper, I will be discussing the effectiveness of reef closures in respect of three of the potential advantages.

1. Protection of spawning stock biomass
2. Maintenance of natural population age structure
3. Supplemental restocking of fished areas through emigration of adults

A number of studies have been conducted in the Great Barrier Reef which have assessed the protection of the adult stock and age/size structure of the major species. The studies which address the first two potential advantages are presented in Table 1. In Table 2 the third advantage is assessed by reporting on fish movement studies that have been conducted in the Great Barrier Reef. In the most part these studies have been restricted to the common coral trout *P. leopardus.*

Table 1. The results of studies conducted in the Great Barrier Reef Maine Parkto determine the differences in the size, age and density on protected and unprotected reefs of the common coral trout, *Plectropomus leopardus*, and the red-throat sweetlip, *Lethrinus miniatus*.

Area	Investigators	Years of Protection	Findings
Capricorn Bunker Group	Ayling and Ayling (1986)	2.5 - 6	16% more coral trout on protected reefs> 35 cm: twice as many on protected reefs< 35 cm: more than twice as many on fished reefs. Density of red-throat sweetlip almost three times greater on protected reefs
Boult Reef	Beinssen (1989)	3.5	Coral trout 13.5 cm bigger on protected reef. Once fishing recommenced mean size decreased 5 cm
Cairns Reefs	Ayling, Ayling and Mapstone (1992)	7	Grand mean size of coral trout same on protected and unprotected reefs. More adults on protected reefs 50% more juveniles on back of fished reefs
Bramble Reef	Ayling and Ayling (1994)	3	Mean coral trout density similar on protected and unprotected reefs due to recruitment success. Marginal increase in red-throat sweetlip relative to fished reefs
Cairns Section Outer Shelf Reefs	Ayling and Ayling (1992)	7	No difference in the length or density on protected or unprotected reefs. Red-throat sweetlip an order of magnitude higher on protected reefs
Cairns Section Outer Shelf Reefs	Brown *et al.* (1992)	7	Greater abundance oflarger fish on protected reefs. Greater proportion of fish ages 1-3 years on fished reefsRed-throat sweetlip more numerous on protected reefs
Cairns Section Mid-shelf Reefs	Davies (1994)	7	No difference in size structure for coral trout between protected and open reefs. Higher CPUE for coral trout on protected reefs

Table 2. The results of studies conducted in the Great Barrier Reef Marine Park to determine the inter- and intra-reefal movement of the common coral trout, *Plectropomus leopardus*.

Area	Investigators	Findings
Capricorn Bunker Group	Beinssen (1989)	Little migration of coral trout - 90% recaptured in the same block in which released
Capricorn Bunker Group	Craik and Mercer (1981)	Most tagged coral trout recaptured within 1 km of release
Cairns Section Mid Shelf Reefs	Davies (1994)	Greater than 95% of coral trout recaptured by researchers, taken in same area as released

ARE REEF CLOSURES EFFECTIVE HARVEST REFUGIA?

Plectropomus leopardus

From the studies conducted in the Great Barrier Reef Region, the evidence suggests that the common coral trout *Plectropomus leopardus* does not move substantially between reefs. Movement, if it occurs, is largely restricted within reefs and is commonly associated with spawning activities (Davies, 1994). Consequently, it seems quite conclusive that in the case of *P. leopardus*, closures of individual and well defined reefs do not support surrounding areas through the emigration of older life stages. If closures were implemented within a contiguous patch of reef, or if closures were made on a section of a large entire reef, then greater significance could be afforded to the emigration of adult fish to the surrounding areas. This emigration may occur in response to factors discussed by Alcala and Russ (1990) such as redistribution of the organisational structure of fish communities or density-dependent relocation.

Whether reef closures are effective in the protection of spawning stock and age structure of *P. leopardus* is unclear. In the Capricorn Bunker Group (Ayling and Ayling, 1986), in the Boult Reef replenishment study (Beinssen, 1989), and in studies of age structure differences between fished and protected reefs in the Cairns Section of the Great Barrier Reef Marine Park (Brown *et al.*, 1992), the evidence suggests that the density of larger and older fish is higher on the protected reefs. However, there are a number of other studies where the differences between open and protected reef are not so apparent. In such studies, (Ayling and Ayling, 1992, 1994; Ayling *et al.*, 1992; Davies, 1994) either the mean size or the density of coral trout were the same on protected and unprotected reefs. It is possible that other factors may be confounding any apparent differences.

At least three factors could contribute to the ambiguity of whether reef closures provide protection of spawning stock and age structure for *P. leopardus*. Firstly, it is very possible that fishing pressure on many of the reefs studied is not high enough to display a significant difference in the size and density of *P. leopardus* stocks between protected and unprotected reefs. Reef proximity to population centres, position in the reef matrix and reef accessibility all impart on whether a reef is frequently fished. It is most probable that fishing pressure on many Great Barrier Reef reefs has not reached the heights that have been experienced in other parts of the world (see Roberts and Polunin, 1991) and hence fishing effects are not so apparent or detectable.

Secondly, it is known that a certain degree of illegal fishing of some protected areas does occur although it is difficult to measure its intensity as much of the evidence is anecdotal. Infringements of protected areas are a continual problem given the size of the Great Barrier Reef Marine Park and the expense that surveillance of such an extensive area demands. Consequently, it is not known how much of an effect illegal fishing would have in dampening real differences between protected and opened areas.

Thirdly, there is mounting evidence from these studies that suggests the common coral trout *P. leopardus* is a very resilient species and appears to be capable of tolerating a considerable degree of fishing pressure. This resilience may in part be attributed to the powerful ability of this species to restock reefs through the successful recruitment of juveniles. The potential for this species to reseed reefs is evident in the replenishment study conducted at Bramble Reef (Ayling and Ayling, 1994). In the Bramble Reef study, the successful recruitment of juvenile *P. leopardus* in 1992 and to a lesser degree in the following two years, was so profound that it masked any protection that a three year closure may have provided. The recruitment success was not confined to Bramble Reef as coral trout densities were similar on all protected and unprotected reefs included in the study. There is also some suggestion that the catchability of this species can alter substantially when exposed to high fishing pressure (Beinssen, 1989). Change in catchability of reef fish species is a relatively unexplored area yet the indications are that it may provide an innate mechanism which protects to some degree the over exploitation of *P. leopardus* populations.

Lethrinus miniatus

Reef closures may be more effective for other species. The red-throat sweetlip *Lethrinus miniatus* has been found to be much more abundant on protected than unprotected reefs. These differences in density of *L. miniatus* occur in cases where there has been no apparent difference in the densities of *P. leopardus* (Ayling and Ayling, 1992). It could be supposed from such evidence that *L. miniatus* is more susceptible to fishing pressure and therefore a better indicator of the impacts of fishing. Further, there are indications from the Bramble Reef replenishment study (Ayling and Ayling, 1994) that *L. miniatus* may not have the resilience to recover that *P. leopardus* is capable of. Assumptions of this nature are purely conjecture on the part of the authors as it is well recognised that very little is known on the life history or movements of *L. miniatus* (Williams and Russ, 1994). The studies do suggest that perhaps a greater research and monitoring effort should be focused on this species.

REEF CLOSURES AS AN ADDITIONAL STRATEGY IN TRADITIONAL FISHERIES MANAGEMENT

The effectiveness of reef closures in the Great Barrier Reef Marine Park in reference to three of the cited potential advantages of harvest refugia is not as clear cut as many would like and is possibly constrained by a number of confounding factors. The results also indicate that the effectiveness of harvest refugia may differ between reef fish species. Consequently, the objectives of harvest refugia must be clearly defined and confounding factors must be identified and accounted for in the design and siting of closed areas. As Carr and Reed (1992) have highlighted, the success of multi-species refuges will be greatly enhanced if the different species have similar resource requirements, modes of reproduction and patterns of larval replenishment. This predisposes that a sufficient amount of information is known about the species intended for protection, which, for many commercially and recreationally important species in the Great Barrier Reef, is not the case (Williams and Russ, 1994).

There is sufficient evidence from these studies and from other parts of the world to suggest that protected reefs can be effective in providing harvest refugia for targeted reef fish populations. Assuming that a commitment is made that the design, management and performance assessment are clearly defined and effectively undertaken and appraised, the authors feel that reef closures can provide a valuable additional strategy for fisheries management and should be integrated into overall fisheries management plans. The incorporation of reef closures in management plans is particularly important in complex multi-species fisheries that exist in coral reef environments.

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EDUCATION AND TRAINING FOR SAFER SHIPS AND CLEANER SEAS

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ABSTRACT

There is increasing international concern about the safety of shipping. Freight rates are such that many owners are unable to replace ageing tonnage. Old ships with poorly trained crews threaten maritime safety and the marine environment. There is a growing shortage of well-trained ships officers and the industry is employing more of its personnel from countries with inadequate training resources.

The International Maritime Organisation is conducting a major review of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978. All members of IMO have the opportunity to participate. Modern technology, particularly in communications and simulation, provides opportunities to greatly improved educational opportunities for seafarers. Maritime training institutions are networking and cooperating more. Maritime qualifications are increasingly being linked into higher education, with university courses in maritime disciplines increasing in number.

The paper argues that Australia, with its established national centre for maritime education training and research and its effective system of certification, is well positioned to take a significant role in improving maritime education and training in the Asia Pacific region. The steps whereby this is to be achieved are outlined.

EDUCATION AND TRAINING FOR SAFER SHIPS AND CLEANER SEAS

Increasing international concern

"A quick glance at the statistics is quite encouraging. The number of lives lost at sea in 1992 was the lowest for 13 years. The amount of oil getting into seas as a result of shipping operations fell by 60% during the 1980's, according to the best available estimates. Shipping has become safer over the years and this means that the number of major oil spills is only a third of what it was in the 1970's....But, there are signs that the progress made over the years could be under threat."

William O'Neil, Secretary General, International Maritime Organisation
World Maritime Day 1993.

Two major factors underlie the Secretary General's concern:

- the world fleet of merchant ships is ageing rapidly and older ships tend to have more accidents; the fleets with poor records tend to grow while those with good records tend to shrink
- current freight rates are insufficient to generate the funds required to replace ageing tonnage.

The situation is clearly expressed by a leading shipping economist:

"The international merchant fleet has become critically overaged, and its safety record is deteriorating. There are frequent reports that freight earnings are below the cost of operating ships, which is ascribed to substantial tonnage overhangs that have developed in many segments of the industry. Because of inadequate revenue incomes, neglect of maintenance appears to be widespread. The decline in overall vessel productivity and service reliability is said to be largely due to tonnage in poor condition. There are indications that financial resources for fleet renewal and tonnage overhaul are becoming more limited. All in all, the status and appearance of the industry in the early 1990s could be interpreted as signals that the ocean transport sector has drifted into a deeply rooted crises."

Hans Jurgen Peters
"The International Ocean Transport Industry in Crisis", World Bank WPS 1128 1993

Crewing

The "Ships of Shame" Report of the December 1992 Australian House of Representatives Inquiry into Ship Safety identified several major issues associated with crewing (paras 3.21-3.34):

- reduction in the size of crews - on many ships crew numbers are about 1/3 of the crew size of the 70's; the situation has now arisen where it is questionable that crew sizes approved by some flag states in respect of older less automated vessels would be able to operate the ship in an emergency situation
- the polyglot nature of some crews - it is not uncommon for there to be four different nationalities on board, which, in the absence of a common language, can give rise to communication difficulties
- abuse and exploitation of some crews hired from non-traditional sources damages morale and weakens motivation
- the level and quality of training available - in some cases the training of crews from non-maritime sources is insufficient to ensure the safe operation of a large ship and may be practically non-existent - this is a major concern as human factors are a major contributor to maritime accidents
- it is undeniable that the quality of crew training is a central factor in maintaining ship safety, particularly with old ships
- a good crew can save a bad ship in a time of crisis, a bad crew can ruin the best of ships

In summary, the global shipping industry is characterised by:

- an ageing fleet and an inability to generate sufficient funds to adequately build replacements
- a regulatory structure which allows substandard ships and crews
- a shortage of well trained crews
- political pressures, which, although increasing, are not sufficiently strong to ensure that appropriate standards are maintained - unlike the airline industry.

In overcoming these problems, improving the training of seafarers is the least difficult to achieve and is currently being addressed.

Australian crews are competent

Australian crews are competent because, generally speaking, they are well trained and attitudes are healthy. Conditions aboard Australian ships are such as to attract good people, who quickly develop an awareness of the fundamental need for minimum standards of safe and efficient operation. There is a will to ensure the survival and growth of the Australian shipping industry, which is clearly evidenced by the cooperation of the major elements of the industry and the success of the shipping industry reform program.

Australia inherited the British system of training and certification, an excellent system that stood the tests of time. It has adapted this system to better suit Australian needs. Australia now possesses maritime education and training of a high standard, supported by an incorruptible system of examination and certification. In response to new technology, reduced manning and other changes in the Australian shipping industry, it is actively reviewing and adapting its systems of training and certification.

Unlike the majority of developed maritime nations, Australian owned ships fly the national flag and are manned by nationals. Australian shipowners, maritime employers and employees' organisations and government officials actively liaise in ensuring the quality of training programs. All new entrants to the industry receive common training at the Australian Maritime College (AMC), the national maritime education and training centre, a commonwealth funded institution of great benefit to Australia's maritime interests, with great potential to assist with the development of maritime training in the region.

Many other crews are not competent

The majority of crews are predominantly composed of nationals of developing countries; 60% of officers and 75% of ratings in the world fleet [(1)] come from developing countries. Many of these countries do not have maritime training of a high standard, nor an effective system of examination and certification, despite being signatories to the International Convention on Standards of Training, Certification and Watchkeeping 1978 (STCW 78).

The deficiencies of these substandard crews are many, characterised by a lack of appreciation of operational standards necessary to assure safety and efficiency and of the need to comply with those standards, as well as an inability to communicate effectively in English. Where a crew is comprised of nationals from differing countries, there is often a serious inability to communicate with each other, which impinges on the routine operation of the ship and can be disastrous in the event of an emergency.

With many third world crews there is little association with or understanding of the ship, the crew members being impelled to work at sea through economic necessity. The concept of a career hardly applies; seafaring must be endured in order to earn a subsistence wage, much of which may be taken by unscrupulous manning agents.

Improving crew competence globally

We need to achieve the following goals:

- internationally agreed and appropriate minimum standards of training and certification implemented through an effective international regime;
- quality training for all seafarers through recognition of quality training institutions and the provision of resources and development of infrastructure whereby leading institutions assist the development of others;

(1) Juan Kelly, President, International Shipping Federation, 13 July 1993

- greater use of functional training, modern communications, distance learning, on-board training and shore-based simulation;
- an attitudinal change by seafarers, so that training is seen as part of routine shipboard activities.

Revise the STCW 78 convention

Many recent maritime accidents resulting in loss of life and environmental pollution have been due to human error. To improve maritime training globally, the International Maritime Organisation (IMO) has embarked on an urgent and comprehensive review of STCW 78, whereby modern training and certification arrangements can be incorporated. The need for this review is widely accepted by the international industry.

Australia's submission to the IMO Standards of Training and Watchkeeping Sub-Committee (STW24) supports incorporation of requirements for training and certification which allow alternatives to present traditional crew structures, content based education and training and time-based practical experience elements. STCW 78 is seen as rigid and unresponsive to change and reflecting traditional divisions of officer and rating and of deck, engine and radio departments, with standards of education and training specified in terms of minimum syllabus content and related minimum time-quantified practical experience. Competencies are not identified as the basis of standards.

It is Australia's view that "the convention should include a variety of training and certification streams that allow administrations to harmonise crew training, shipboard organisation and operational practices, but which retain specified minimum standards of certification as an indicator of skills." Australia expresses support "for the inclusion of what is commonly known as the functional or skills-based approach to education and training".

IMO aims to have a revised STCW Convention agreed in mid-1995. This is a very tight schedule. Australia, with its high level of maritime training expertise, is playing a significant role in this revision.

Develop and recognise quality training institutions

Too many nations do not apply sufficient resources for the maritime training provided by their institutions to be of an appropriate standard. Considerable financial and expert assistance is needed. This is despite considerable effort over the last two decades or so by IMO, ESCAP and other regional and national organisations, through the provision of experts, equipment and teaching materials. In many countries it has proved very difficult to obtain local funding, to transfer expertise and an awareness of minimum standards and thereby to ensure adequate standards of maritime training in the face of indifference, corruption and economic expediency.

While appropriate revision of STCW 78 will be a major step, obtaining compliance with its requirements is likely to be even more difficult. Fortunately, increasing global concern is generating the political pressures that will be essential if there is to be effective implementation. In response to these pressures, maritime safety and environmental protection and the important role that maritime training plays therein are likely to receive greater recognition. The optimist senses a growing political will to ensure *"safer ships and cleaner oceans"*. There is need for this political will to be much stronger, however.

Given that there is this will, that maritime training which ensures crew competence receives adequate priority and resources, a major global/regional effort will be needed to develop effective institutions and to ensure that it is the quality institutions that are the providers of training for those who man the world's fleet. A system of inspecting, recognising and accrediting quality institutions must be developed. Training centres of low quality with profit as their raison d'etre, associated with questionable certification processes and expediency, must not be allowed to flourish.

The international airline industry has developed a satisfactory system of training and certification. It is surely not beyond the bounds of possibility for the shipping industry to do so.

Network maritime education and training centres

With increasing use of technology and distance learning, maritime education and training is likely to consolidate the following structure:

- pre-sea induction education and training at a shore-based institution;
- at-sea education, with more functional training, utilising distance education;
- advanced and specialist education and training, both on-board and in shore-based institutions, using more simulation than at present.

Pre-sea induction education and training will concentrate on basic knowledge and skills and will require relatively limited training resources, such as can be provided by most countries wishing to train maritime personnel, including the developing countries currently providing much of the manpower for international shipping.

At-sea education with more functional training utilising distance education - the very important learning on-the-job element - will require:

- personnel on board ship who understand the needs and methodologies of training and can assist with its on-board implementation and assessment;
- advanced interactive telecommunications technology;
- shore based maritime distance education centres; and
- an international system of monitoring, recording and recognition, the considerable resources required being likely to be concentrated in large institutions, key to the operation of a global system that accords with internationally agreed standards of training and certification.

Similarly, the simulation and other equipment required for the provision of advanced and specialist training and education, because of its cost and maintenance requirements, will be located in these key institutions.

A network of centres of maritime education and training should evolve. Regional networks will link smaller, low-budget institutions involved in providing basic training - the primary nodes in the network - with one or two large institutions providing distance education, advanced training using simulation and other state-of-the-art training technology, as well as monitoring and recording. These high-budget key nodes will be linked with other key nodes in a global network.

Integration of the regional networks would be through regional associations of maritime education and training centres which would perhaps meet annually, consider regional needs and the means for meeting those needs. Representatives of the regions would meet internationally, perhaps every two years, to consider global issues. (2) Input from the International Maritime Organisation could be through the World Maritime University as the major key node.

(2) The Forum for Maritime Education and Training in Asia Pacific (FMETAP) is to hold its fourth regional meeting in Vladivostok in September 1994. Initiated with a meeting at the Australian Maritime College in 1989, the meetings have also been held in Dalian, China and Suva, Fiji.

Funding of this global system of maritime education and training could be:

- for primary nodes, national funding, including funds received through overseas aid programs, as well as funds from the local shipping industry;
- for key nodes, in addition to sources of funding similar to those listed for primary nodes, income would be derived from fees for use of distance education services and advanced training facilities, such as simulators;
- for regional network meetings, regional funding;
- for global network meetings, international funding.

Development of these networks will enable an increasing flow of staff and students between nodes, particularly to the key nodes as they seek more advanced training and education, but also from the key to the primary nodes when there is need for more advanced work to be carried out locally, as well as for skills transfer.

Whether or not maritime education is linked into higher education through having graduate and post-graduate qualifications, as it is in Australia, will be a national matter, as also will be the linkage with education in other "matters maritime", such as the marine sciences, marine resource regulation, maritime law, and port and terminal operations. For the seafarer wishing to develop a career in the shore-based side of the shipping industry, there are obvious benefits in possessing a nationally recognised higher education qualification. The initiatives taken in establishing the World Maritime University could be indicative of the evolution of a system of internationally recognised higher education qualifications in which networked institutions could be participants through a modular curriculum structure.

There should be a steady move to do more functional training. In its submission to STW24, Australia advocated the inclusion in the revised STCW Convention of a functional or skills-based or competency-based approach; viz:

"A program of skills-based training is one designed to achieve assessed skills standards, with the emphasis on outcomes rather than content. Typically the curriculum consists of essential core skills and additional specialist skills. The first step in achieving skills-based training is to identify those skills and the necessary standard essential for safe and efficient ship operation. Skills include higher level cognitive, decision making and work organisation skills as well as physical/motor/practical skills related to relevant activities. Skills training, moreover, should encompass adaptation to work-place change. Under this model, STCW would incorporate a consistent statement of requisite skills standards.

Certification follows on satisfactory completion of a suitable program. Completion should be dependent on achievement of competencies. The length of a training program or course of study should be flexible, although it may be appropriate to specify minima and maxima within which a program should be completed. Otherwise, students and their sponsors, if any, should be free to individualise their training programs and to complete their training more quickly than others, should they so choose.

Advantages of skills based training

It is possible to replace current narrow job assignments by broader job classifications and to place heightened emphasis on quality, technical understanding, multi-skilling and team-work. Australia for example has overcome traditional demarcations for ratings and implemented an integrated model of training and certification. The industry's experience is that there is no need to refer to a particular organisation structure in establishing crew and qualifications needs.

The skills-based training system offers greater flexibility in the use of crew skills. Crews may be defined and selected in terms of the skills required for a particular vessel operated in a particular way, bearing in mind that minimum skills standards will be specified in STCW.

For crew members, skills-based training and ship-board work organisation offers the benefits of multi-skilling, the recognition of the skills they have and the opportunity for their use, with multi-skilling and the effective use of skills goes the opportunity for exercise of personal responsibility and for job satisfaction."

Increase and improve distance learning

For the shipping industry to move to comprehensive functional training, a combination of modern technology and distance learning techniques will be required. Together these provide the means whereby a significant amount of maritime education and training can be transferred back to the ships, where functional training and assessment have the potential to bring marked improvements in performance.

An internationally effective system must be developed whereby education and training resources principally located ashore are made available to seafarers both when ashore and at sea, coupled with effective monitoring of the education and training being carried out and assessed, including training and monitoring of the assessors.

Modern, efficient and low cost, interactive telecommunication technology provides the means whereby the links between ship and shore can be used. Modern distance learning techniques provide the methodology enabling education and training of students at sea to be carried out.

Increase ship board learning

The development of satellite communication technology enables large scale integration of the many activities associated with international shipping. Satellite communications are leading to rapid expansion of improved maritime radio communication. There are now thousands of satcoms terminals on board ships and the number is likely to grow rapidly as new systems are introduced, miniaturisation progresses and prices reduce. Satellite communications are so highly reliable that, in many respects, it is no more difficult to monitor the functioning of a ship thousands of miles away, than it is for a factory manager to monitor what is happening on the factory floor.

The availability of this technology provides the opportunity to quickly develop effective links between the maritime education and training institutions which will enable distance learning by those at sea. **The crucial marriage of technology and distance learning methodology has the potential to transform the education and training of seafarers - with far more being done on board ships at sea.**

As the cost to the shipping industry of personnel spending long periods ashore to study by traditional methods for certificate of competency examinations increases rapidly, as well as to the seafarers themselves, the technology to support maritime education by distance learning is becoming less expensive and more widely used. The time spent studying ashore can now be reduced as effective academic links between the seafarers and their maritime distance education centre are developed so that they can be tutored and their progress monitored while at sea, irrespective of where their ships are.

The provision of a direct link between the tutor in the maritime distance learning centre ashore and the pupil aboard the ship at sea, will go a long way towards overcoming many current distance learning difficulties. Satellite communications will provide this link, whether by telephone, telex, facsimile or data transfer, with the latter likely to be used more frequently because of the lower cost. With the potential that there is for heavy utilisation, an economic rate for the use of satcoms for educational purposes should be introduced.

Developments in the technology and manning of merchant ships are enabling heavy reductions in crew numbers. The role of the watchkeeper is becoming more one of surveillance and data-handling. Familiarity with the use of computer and telex terminals and with communications by satellite will be a fundamental part of this role. The seafarer of the future could use a keyboard or its equivalent as readily as he or she uses pen and paper and efficient communication with the manager ashore will be routine.

Increase simulation in shore-based learning

Despite efficient communications providing effective distance education, the seafarer will still need to attend shore-based courses for both induction and post-entry upgrading training. Simulation will be used on many of these courses to provide a sufficiently realistic work place environment. Maritime training in simulated situations, though still in its infancy, is developing rapidly and will play a much greater role in future. More recognition of this role is necessary and regulatory requirements need to be amended to recognise competencies developed and assessed under simulated conditions.

The recent moves in Sweden to translate to maritime training the use of simulators by the aviation industry for filling in the "human factors gap", is indicative of how future bridge teamwork training could evolve. The problems associated with mixed crews, which have been identified as contributing to maritime disasters, such as the "Scandinavian Star" fire off the Norwegian coast in 1990, can be addressed by dealing with differences in language and culture, especially in emergency situations. Human factors - stress, fatigue, panic, poor teamwork, poor communication, misunderstanding, the need for a good command of "Maritime English" - have not been given sufficient attention.

Simulation provides the means for overcoming many of the difficulties inherent in this type of training. Simulators are particularly useful for testing reaction to emergency situations. Development of the "seacockpit" concept for the bridge on high speed vessels is likely to lead to much greater use of the simulation training methodology already used in the training of airline pilots.

Australia's role in raising crew competence

Australia is held in high regard for the progress it has made in reforming its shipping industry through reduced manning and quality training. Recognition of these achievements is likely to lead to more requests for Australia to assist with the global reform that is essential if crew competence is to be improved, particularly in the Asia Pacific Region.

The "Ships of Shame" Report [3] recommends that opportunities should be explored to attract increased numbers of international students to study maritime education and training in Australia and comments that Australia could help raise crew training levels by extending crew training facilities and programs to Australia's Pacific and Asian neighbours.

Maritime students are already coming to Australia from SE Asia and the Pacific and from countries as distant as Nigeria, Russia and Peru. AMC staff are out in the region conducting courses, the most recent being in Malaysia, Singapore, Fiji, Papua New Guinea and Federated States of Micronesia.

It would be to the mutual benefit of both Australia and of the international shipping industry if this provision of maritime training, both through greater numbers of overseas students studying in Australia and through more Australian expertise flowing into the region, were to be significantly increased.

(3) "Ships of Shame", Inquiry into Ship Safety, Report from the House of Representatives Standing Committee on Transport, Communications and Infrastructure, December 1992

The challenge for Australia

A golden opportunity now exists for Australia to play a leading role in improving maritime safety and marine environmental protection, through the provision of Australian expertise to assist the development of maritime training in the region. While there will need to be more resources available, both directly for the development of maritime education and training in Australia and through overseas aid to developing countries, the service provided to the international maritime community is likely to bring to Australia benefits of value far beyond the required increased resource input. Australia would be seen not only to be taking a stand on sub-standard ship operation, but also to be taking specific action in assisting other maritime countries overcome their difficulties in improving maritime safety and efficiency through improved crew competence. Greater competence would mean that Australia with its magnificent coastal resources would also benefit from the diminished risk of a shipping catastrophe in its waters.

PRODUCT QUALITY AND RESOURCE MANAGEMENT: BIOECONOMIC ANALYSIS OF THE PACIFIC WHITING INDUSTRY

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ABSTRACT

The Pacific whiting fishery is analyzed to illustrate the relationships between marine resource management, intrinsic seafood quality, and economic benefits. The stock is characterized by biological and environmental factors that can affect the quality and market price of processed products such as surimi, fillets, and headed and gutted. Temporal variation in proximal content (protein, moisture, and lipids) and fish size can affect product recovery rates, seafood quality, and economic benefits.

To investigate how public fisheries management may impact product characteristics and corresponding socioeconomic benefits, a non-linear programming model of the Pacific whiting fishery is developed. The model uses a generalized age-structured representation based on stock-synthesis analysis. This approach uses the temporal variation in the intrinsic attributes of the harvested product to link the biological information with relationships describing the economics of the onshore and offshore sectors. The programming model indicates "optimal" public policies including allocations to the industry sectors and season openings. Results show that socioeconomic benefits are highly dependent on the assumptions regarding the relationships of intraseasonal variation of intrinsic product quality, recovery rates, and regulatory policies. Implications for future whiting management including development of private property rights for the fishery are also discussed.

INTRODUCTION

Traditional analysis of marine resources rarely focus on product quality (Natural Resource Consultants, 1990). In many fisheries, however, seafood quality is related to management of the resource and can impact industry benefits. The Pacific whiting fishery provides a case study for illustrating the relationship between marine resource management, seafood production, and socioeconomic benefits.

The stock of Pacific whiting migrates annually from spawning grounds off Baja California in late winter/early spring to summer feeding grounds off Washington and Oregon in the United States (U.S.) and British Columbia in Canada. The stock has a total biomass estimated at 1.5 to 3.5 million metric tons and the fishery has sustained annual catches of 125 to 300 thousand metric tons (Dorn *et al.*, 1993). It is the largest stock of groundfish found off the continental U.S. and the U.S. annually harvests approximately 80% of the total allowable catch.

The Pacific Fisheries Management Council (PFMC) develops the management plan for the Pacific whiting resource in the U.S. This plan has involved a variety of regulatory options including setting season opening dates and allocating the annual domestic allowable harvest among competing fishing and processing sectors. The opening date (April 15) has been set primarily to accommodate the needs of the offshore fleet to operate between the Alaskan pollock A and B fishing seasons. The allocation decision, which has received the most attention, normally involves a choice among alternatives based on net present values and other social benefits that each sector would generate. These decisions are made to satisfy three broadly defined goals set forth by Amendment 4 (Section 2.1) of the Pacific Coast Groundfish Fishery Management Plan, namely: (1) conservation (monitored by biologists), (2) maximum economic value (calculated by economists), and (3) efficient utilization. Utilization issues have been implicitly considered through the economics of the alternative fleets (for example, costs differences due to externalities such as bycatch, discards, and secondary meal production). Equity issues have also been considered through public testimony. In conducting their studies, however, analysts and policy makers have largely ignored the temporal (intraseason) variation in the characteristics of the raw product. This variation can have significant impacts on product quality and, ultimately, socioeconomic benefits.

As an alternative, efficient resource utilization can be explicitly considered by incorporating observed intraseason variation in the quality of the raw product. Seafood product quality, however, can be defined many ways. In this paper 'quality' is loosely defined in terms of the characteristics of the product. Thus, an analysis of the quality of a product would consider the variation in its attributes, such as size, sex, flesh color, proximate composition (protein, fat, and moisture as a percentage of body weight), and various sensory characteristics (Love, 1988). Additional variation in product attributes may be related to capture and handling techniques. For Pacific whiting, the characteristics of the raw fish, i.e. the *intrinsic* characteristics, are known to affect recovery rates (Peters, 1994), product texture, flesh color, shelf life, and consistency. This suggests that intraseasonal variation in the intrinsic characteristics of the raw product can ultimately affect final product quality and market demand (Sylvia, in press[b]).

To investigate how public fisheries management may impact product quality and corresponding socioeconomic benefits, a non-linear bioeconomic programming model of the Pacific whiting fishery (originally developed by Enriquez, 1992) is employed. The model uses a generalized age-structured representation based on stock-synthesis analysis. This approach uses the temporal variation in the intrinsic attributes of the harvested product to link the biological information with relationships describing the economics of the onshore and offshore sectors. Social welfare, therefore, is determined by the complex interactions between natural forces (biological and environmental) and human forces (resource managers, harvesters, processors, and buyers).

The following sections of this paper include a description of the bioeconomic model and data, definition of alternative public policy options (including allocations to the industry sectors and season openings), and a discussion of the results. The final section of the paper summarizes implications and directions of future work.

BIOECONOMIC MODEL AND DATA

The objective of the programming model is to maximize discounted net industry benefits by incorporating biological, economic, and intraseason product quality variation. Relationships between product characteristics and prices, costs, recovery rates, and production practices are made explicit through equations estimated using intraseasonal data. The most crucial estimations concern intraseasonal changes in product quality characteristics. The use of, and reliance on, undocumented or anecdotal evidence was unavoidable as these are highly contentious issues and actual figures have been well guarded or involve preliminary data. Each model component and the corresponding quantitative data will be discussed in turn. Some explanatory detail is sacrificed given page limitations.

Biology

The biological component of the model uses an estimate of the initial population (by age), and incorporates annual recruitment, migration, natural mortality, and fishing selectivities (by age, country, and harvesting sector) to determine the annual population, spawning biomass, fishing mortality, and sustainable harvest levels. A variable fishing mortality constraint allows harvest to increase at higher spawning biomass levels. The annual allowable domestic (U.S.) harvest is disaggregated (or allocated) into monthly catch.

The model uses the biological data generated by the National Marine Fisheries Service (Dorn *et al.*, 1993). This data was used by the PFMC to determine the 1994-1996 maximum sustained yields for the entire fishery. These parameters were chosen such that results could accurately depict the implications of alternative management schemes. The model, therefore, was calibrated to the December 1993 recommendations.

Economics

Sector (onshore, offshore) and product form (surimi, H&G, meal) economic parameters are incorporated to complete the model specification. The economic component is linear. Product prices and costs were taken from the 1993 cost-benefit analysis (Freese and Squires, 1993) and are assumed constant throughout the season. The authors used the average of figures reported in the 1992 and 1993 Processed Products Surveys administered by the National Marine Fisheries Service (NMFS). Like the biological data, these estimates were chosen because they were used by the decision makers. The (discrete) discount factor uses a 5% real interest rate, the same assumption as NMFS.

Intraseasonal intrinsic quality

Once catch (in numbers) is known by month, information on intraseasonal weight gain and change in proximate composition can be incorporated to identify intrinsic product characteristics. Monthly weight-at-age data was used to predict intraseasonal gain-at-age (Dorn, 1992). The younger year classes gained weight early in the season but peaked in August. A similar pattern held for the older year classes except the peak occurred earlier (June) and the initial gain was much greater. The middle year classes gained weight at an increasing rate throughout the season. The estimations explained over 90% of the weight gain for each age class.

The total gain can also be adjusted to reflect gain in usable product by incorporating intraseason length data. The ratio of weight to length is used as a proxy and is similar to what seafood technologists term the "condition factor" (AFDF, 1991). Intraseasonal changes in the weight/length ratio (which increases at an increasing rate) were hypothesized to be explained by moisture content of the fish based on (1) examination of the observed data and (2) results obtained by International Seafoods (AFDF, 1991). The following linear equation was estimated:

$$\text{weight/length}_m = 74.8 - 0.749*\text{moisture}_m \qquad (R^2 = 0.98) \qquad (1)$$

The index m corresponds to the month, 1 to 7 (April = 1, October = 7). The estimated parameters were both significant at the 99% level.

The Astoria Seafood Laboratory provided information for the quantitative assessment of intrinsic product characteristics (Morrissey, 1991; Peters *et al.*, in press). This consisted of multi-weekly data on proximal content, specifically, protein and moisture composition (Figure 1 and Figure 2, respectively). The observations covered 1992-1993 and samples were derived from harvesters delivering onshore.

Although the Figures depict non-linear data trends when examined on a weekly basis, we were constrained to use monthly aggregates because the weight-at-age data was only available by month; simple linear models were assumed to reflect the monthly changes. The protein and moisture content are estimated as follows:

$$\text{protein}_m = 14.6 + 0.41*\text{month} \qquad (R^2 = 0.71) \qquad (2)$$

$$\text{moisture}_m = 84.0 - 0.42*\text{month} \qquad (R^2 = 0.64) \qquad (3)$$

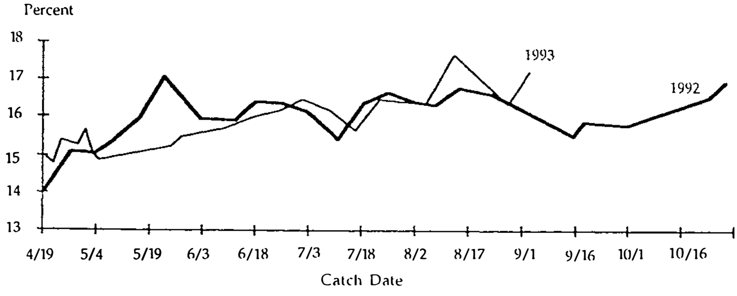

Figure 1. Intraseason and Interseason Protein Content from April-October 1992-1993.

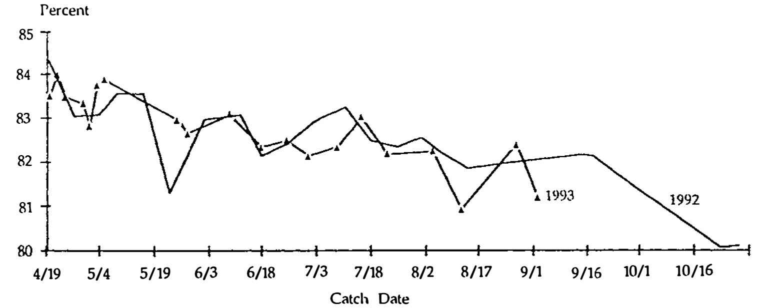

Figure 2. Intraseason and Interseason Moisture Content from April-October 1992-1993.

All the parameters were significant at the 99% level. Using these equations, protein and moisture contents at season opening are 15.01% and 83.58% respectively, and change to 17.47% and 81.06% by the end of the season. These values fall within seasonal ranges reported by Nelson, Barnett, and Kudo (1985) for 1964 - 1966 samples suggesting that interseason proximate composition has remained relatively stable.

Proximate composition can be used to explain the intraseason variation in yields of the various product forms (fillets, surimi, and headed and gutted or H&G; AFDF, 1991). Using data on yields supplied by an offshore processor and several onshore plants and the proximate analysis described above, the following relationship was estimated for surimi,

$$\text{surimi yield}_m = -0.15 + 0.023*\text{weight/length}_m \qquad (R^2 = 0.76) \qquad (4)$$

the parameters are both significant at the 99% level. The meal relationship was assumed based on analysis of similar groundfish species conducted by the AFDF (1991). The following equation was specified,

$$\text{meal yield}_m = 0.15 + 0.0023*\text{protein content}_m \qquad (5)$$

whereby yield increases slightly with higher protein content. This assumption was necessary because intraseasonal meal yield data was not available.

ALLOCATION SCENARIOS AND RESULTS

Various allocation schemes among the alternative harvesting (and thus processing) sectors are specified and results are compared assuming discounted net returns are maximized over a fifteen-year period. These returns are dependent upon the characteristics of the fish at the time of processing. In this manner, intraseason surimi and meal production is linked to multi-year harvest decisions.

To examine the effects of an early season fishery and the effects of a late harvest by the offshore sector, three alternative intraseason harvest patterns are examined. Within each defined intraseason harvest scenario, alternative allocations between harvesting sectors are assumed. This is necessary as (1) the different sectors have historically different intraseason harvest patterns, and (2) previous allocations have been subject to change without notice. The alternative allocations were based on historical harvests and proposed plans. The scenarios also allow for examination of the effects of an Olympic or pulse fishery. In this manner, comparisons can be made between policies using the status quo data (using annual aggregates or averages) and those incorporating known intraseason variation in product quality (assuming time of harvest is important).

The first scenario consists of the offshore sector harvesting its allocation, in equal proportions, in April and May while the onshore sector harvests 10% in April and 15% in each of the remaining months (through October). This is referred to as the "traditional" scenario since it most closely depicts recent harvest patterns. The second scenario depicts the situation where the PFMC designates a 'release' or additional harvest available to the offshore fleet. Under this "late release" scenario the offshore sector harvests 45% in each of the first two months and 10% in October. This pattern has been observed in previous years. The last scenario was developed to reflect an altering of season length, specifically, a delayed opening in which no fishing occurs in April. The offshore fleet is assumed to split its allocation between harvest in May and June while the onshore sector harvests its allocation in equal instalments from May through October. A "base" scenario was also defined for comparison to the traditional case where proximate composition and weight was assumed constant throughout the season; it reflects the current assumptions used by analysts and policy makers. Consequently yields were also constant (surimi yields equalled 14.2% and 13.6% for the offshore and onshore sectors, respectively, and reflect the relative magnitude and relationship of the reported 1993 figures).

The season opening decision was generally considered less important than the allocation issue until 1993. In 1993 onshore production ceased shortly after the April 15 opening, and remained "down" until early May, due to very low recovery rates (resulting from poor proximate composition). In addition, interviews with seafood buyers and preliminary work by food scientists (Figure 1 and Figure 2) suggest there may be other problems associated with an early fishery. Experienced European buyers of Pacific whiting fillet blocks have stated that the quality of product processed from fish harvested early in the season was generally poor as a result of the emaciated condition of the fish (During, 1992). This resulted in fillet blocks of overall poor quality and shelf-life, making them unacceptable for production into secondary products including fish sticks and portions. Consequently, at least one buyer recommended that Pacific whiting should not be harvested until mid-May. Previous application of bioeconomic models to the Pacific whiting fishery (Enriquez, 1992; Sylvia and Enriquez, in press) suggested that early season harvests may forsake up to 15 percent of economic returns and increase industry risks compared to a fishery in which effort was more temporally diversified.

To examine the effect of the allocation decision, five alternative allocations were considered, Cases A-E. Allocations A and E reflect total allocations to either the onshore or offshore sector, respectively. Although unrealistic, they serve to bound the intermediate cases and aid relative comparisons. Case B reflects an equal allocation, Case C a 70/30 split between offshore/onshore, and Case D represents a 90/10 split. Cases C and D were defined to correspond to Alternatives 2 and 3 of the December 1993 assessment (PFMC, 1993). Case C is the most likely outcome and Case D reflects the status quo, or "open access" solutions.

Results

The estimation results are presented in Table 1. Comparison of the "base" and "traditional" management rules suggests that incorporating known information on intraseasonal variation in product quality raises the national (discounted) net benefits measure by as much as $19 million (if only the onshore sector harvests). The average increase, $6 million, also corresponds to the gain under the "historical", or 70% onshore and 30% offshore allocation (Case C). Note also that the shadow value for a 10% increase in allocation to the onshore sector (i.e., the opportunity costs or additional NPV generated by increasing onshore allocation by 10%) increases by over $3 million (from $6.8 to $9.9) under the historical allocation. This reflects the onshore's harvest of product with higher yield given they operate later in the season.

Comparing Scenarios 1 and 2 (the traditional versus the late release to the offshore sector) indicates an average increase in social welfare of over $7 million. The largest increase occurs under Case E, a total offshore allocation (from $56 to $70). Note that the shadow price for onshore allocation increases is reduced by over $1 million. In addition, the reallocation of 10% of the offshore fleet's catch to latter in the season increases the average annual sustainable harvest by approximately two thousand metric tons. This reflects a positive stock effect in terms of conservation issues.

A delayed opening management strategy produced the largest increase in net national benefits, an average increase of $13 million over the traditional scenario. Examining Case C, where NPV would increase from $86 to $100 million, also reveals that not allowing harvest in April also produces a positive, but much larger, stock effect as sustained yield increased by four thousand metric tons (from 154,000 to 158,000 mt).

Comparisons across allocations reveals that, under the current economic assumptions, onshore allocations produce the largest social benefit but leave a lower spawning biomass in the fifteenth year. Comparing cases B, D, and E (realistic outcomes) reveals that there is roughly an $18 million gain to be made by moving away from an open access allocation. This result corresponds to that produced by the delayed opening scenario.

In summary, an early season fishery (traditional scenario) may affect economic returns. These returns may further be reduced if the early season is associated with an Olympic style fishery (Case D). Specifically, a compressed Olympic style fishery can result in heavy fishing pressure on certain year classes and lead to lower stocks and harvests. The economic or social consequences may reflect three related issues: 1) low weight, 2) poor proximal condition, and 3) harvest of a higher proportion of younger fish. The relative importance of these factors, may depend on, and be related to, selection of final product forms to process (Sylvia and Peters, 1991). Of course, these results are sensitive to the specification of recovery rates, product quality information, and biological assumptions.

IMPLICATIONS

In general, the preceding analysis (1) emphasized the potential importance of sector specific data, (2) established a method for incorporating intrinsic product quality information, and (3) indicated that a late release and/or a delayed season opening may increase social welfare. Results also show that socioeconomic benefits are highly dependent on the assumptions regarding the relationships of intraseasonal variation of intrinsic product quality, recovery rates, and regulatory policies.

These results may be considered using capital theory in which the stock of whiting is viewed as an capital asset. Because it is a renewable resource the value of the asset can grow and change over time due to biological factors, regulatory decisions, and market conditions. Thus, the investor (harvester) must decide on the timing, amount, and form of the withdrawal (harvests) in order to maximize benefits from the asset (resource stock) over time (Sylvia, in press[a]). This perspective has particular relevance for Pacific whiting given its variability in temporal and spatial characteristics.

Table 1: Bioeconomic Model Results Under Alternative Allocations

Management Rule [a]		**Allocations**				
		(A) Onshore	(B) Equal	(C) Historical	(D) Open Access	(E) Offshore
Base	NPV	$124	$91	$78	$64	$57
	OSP[b]	$0	$6.7	$6.8	$6.9	$6.9
	MSY	165 mt	157 mt	154 mt	151 mt	149 mt
(1) Traditional	NPV	$153	$105	$86	$66	$56
	OSP	$0	$9.8	$9.9	$10.0	$10.1
	MSY	165 mt	157 mt	154 mt	151 mt	149 mt
(2) Late Release	NPV	$153	$111	$93	$76	$70
	OSP	$0	$8.6	$8.7	$8.8	$8.9
	MSY	165 mt	159 mt	156 mt	153 mt	151 mt
(3) Delayed Opening	NPV	$159	$117	$100	$82	$74
	OSP	$0	$8.5	$8.6	$8.7	$8.8
	MSY	167 mt	160 mt	158 mt	155 mt	153 mt
Spawning Biomass		675 mt	682 mt	684 mt	687 mt	689 mt

[a] Net Present Value (NPV) and the onshore allocation shadow price (OSP) are in millions of U.S. dollars. The average annual sustainable yield (MSY) and last period spawning biomass estimates are in thousands of metric tons (mt).

[b] The OSP (onshore allocation shadow price) is defined as the potential increase in NPV by allocating an additional 10% of the resource to the onshore sector.

As suggested in this preliminary analysis, harvests which are not optimally controlled can result in lower returns to both industry and society. This has implications for future whiting management including development of private property rights for the fishery. For example, individual transferable quotas (ITQs) would allow harvesters to sell their right to capture a specified quantity (which could increase efficiency or promote market power) or provide the incentive to harvest fish with 'desirable' characteristics that could fetch them a higher price and greater volume. Thus, to understand the implications of public policy decisions, resource managers should recognize that captured unprocessed seafood is not delivered as a standardized commodity throughout the season, but can exhibit significant variation; a sharp contrast to the controlled conditions of aquacultured products.

In conclusion, the Pacific whiting fishery is a new and complex industry. Analysis must be comprehensive and forward looking in order to understand the long run implications of management decisions. Because information about the fishery is sparse and property rights for the resource non-existent, any examination of "Net Economic Value" may be misleading. In our opinion it is critical that fisheries biologists, economists, seafood technologists, and other scientists collaborate by sharing information and collecting the data necessary to accurately analyze potential industry costs and benefits. Future research can be designed to expand this analysis by looking at how private and public management plans can impact the ability of industry members to control intrinsic characteristics in order to improve final product quality such as surimi grades.

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DESIGN OF THE WATER-INTAKE WORKS WITH A SUBMERGED MOUND

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ABSTRACT

The Water-intake Works with a Submerged Mound (WWSM) is the facility bringing seawater into a basin using wave energy. WWSM is composed of a breakwater with openings and submerged mound. For improving water quality in a basin, the authors developed it for several years with hydraulic models. WWSM has been constructed at several fishing ports in Japan.

At a few fishing ports, the field survey was carried out to find whether the facility can intake sufficient amount of seawater and whether it is useful for purifying the basin. From the results of the survey, the usefulness of the facility was recognized in the water quality id sea bottom in the basin were improved.

As an example, the results of the field survey at Shikanoshima fishing port is described. Average inflow rate was about 100,000 m^3/day, and the water inflow is mostly saturated with oxygen. DO concentration in the basin was kept more than 60% after the construction of WWSM. At the point near the WWSM, ignition loss of bottom sediment was decreased from 10% to 3.5% by the construction of WWSM.

Comparing the results of the field survey with those of the theory, it is found that the theory for calculating inflow rate is practically applicable.

INTRODUCTION

Japanese people like fish very much, and they prefer high quality fish. Recently, many kinds of live fish, called 'katsugyo' in Japanese, are supplied to Japanese consumers. Most of the basins in fishing ports are used for live fish stock. Moreover, these basins are sometimes requested to be used for nursery culture before seed liberation. So improvement and conservation of water quality in basins are of increased importance.

In order to improve and conserve water quality in basins, it is necessary to construct waste water treatment works and training facilities that bring clean seawater to basins. Training facilities are not always effective. When the fishing port is small or medium size and seawater exchange efficiency is not so high, WWSM is effective. For bringing clean seawater to a basin, it is economical to use natural power such as tide, wind waves, internal waves. Some methods using natural power have been studied up to now, but almost all studies are about using tidal power. Authors have been studying WWSM that is effective to exchange seawater by utilizing wind waves even' if the wave height is relatively small.

In this paper, WWSM's principle and some results of the field survey are described, and a planning and design method of the facility is proposed.

PRINCIPLE OF WWSM

Figure 1 shows a schematic view of WWSM. WWSM is composed of a breakwater with training channels, a seawater pool and a remote submerged mound. Wind wave breaking at the remote submerged mound cause wave-setup at the seawater pool and the mean seawater level at the pool is higher than the one at the basin. Seawater flows from the pool into the basin through the training channels. The layout and scale of a submerged mound, wave force acting on a breakwater, and flow pattern in a basin were investigated experimentally. Conclusions of these studies are as follows:

(1) Quantity of seawater inflow can be estimated by using wave height.

(2) Impermeable submerged mound is more effective than permeable one. Its crown height should be nearly equal to mean tide level. Its slope should be 1/1-1/3.

(3) Training channels should be under seawater level not to increase transmitted wave height.

(4) Plural channels increase mixing of seawater in the basin

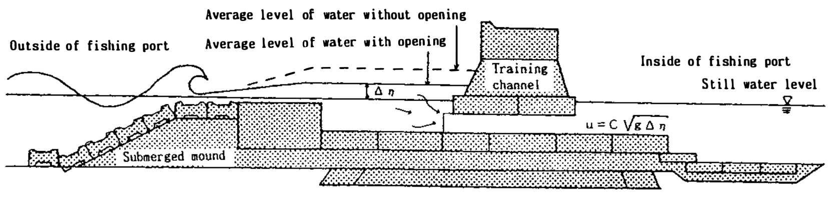

Figure 1. Schematic view of WWSM.

LAYOUT

Position of a submerged mound

The position of a submerged mound should be determined from the following points.

(1) The incident wave height is big enough to get required seawater inflow when seawater quality becomes the worst in the fishing port or the nursery culture ground.
(2) The submerged mound is normal to incident wave direction.
(3) Sediment transportation is little at the submerged mound.
(4) Depth at submerged mound is larger than twice of design wave height that is not for its stability but for its function.
(5) Sea bottom is stable.

Inlets

Outflow from an inlet diffuses at an angle α (tan α 1/4) to flow axis. In case of one inlet, velocity reduction along flow axis is not so large, and outflow reaches relatively long distance. But circulation flow and dead water region is generated. On the other hand, in case of plural inlets, diffusion is large, and velocity reduction along flow axis is relatively large. From the experiments, scale of flow diffusion by two inlets is two times the one by only one inlet.

In planning plural inlets, it is necessary to estimate the extent of flow diffusion and compare it with scale of supposed sea area. In a fishing port, current speed at the quay wall should be less than 1.0m/s. Jet velocity is calculated by equation (1).

$$Um/U0 = 2.5\ (X / b0)^{1/2} \qquad (1)$$

Um: velocity at the supposed point
U0: velocity at an inlet
b0: width of an inlet
X: distance from an inlet to the supposed point

If inflow velocity, or transmitted wave height, exceeds a limit value or a large amount of sand with inflow is brought into the basin, it is necessary to take countermeasures such as a gate.

Outlets

For a fishing port, an outlet of WWSM is just equal to the fishing port entrance. The layout of an outlet is very important to get enough seawater inflow. The layout of an outlet should be decided from considering the following.

An outlet should not be against the wave direction. If the outflow velocity against the wave direction is large, the wave height will become large because of interaction between outflow and wave, and wave breaking may cause wave-setup at the outlet.

SEAWATER INFLOW

Seawater inflow Qin by WWSM depends on wave height, tidal level, cross sectional area of training channels and so on. According to the experiments, maximum seawater inflow by WWSM is about $1/5 \bullet (g \bullet H^3)^{1/2}$. Qin can be calculated by equation (2).

$$Qin = Cin \bullet (g \bullet H^3)^{1/2} \qquad (2)$$

$Cin = 0.2 \bullet \tanh(4.0 \bullet A/BH)$
A: cross sectional area of a training channel
B: length of a submerged mound
H: incident wave height

In this section, we proposed a method of calculating seawater inflow in case of permeable submerged mound. In the experiments, regular waves are used as external forces. So it is necessary to convert irregular wave height to regular wave one. Relationship between regular wave and irregular one is as follows.

$$H0' = 0.66\ Hs \qquad (3)$$

Ks: significant wave height
HO: equivalent deep water wave height

Wave-setup at the seawater pool can be calculated by equations (4),(5).

$$\Delta h = 0.49 \bullet (H0' - hc) \qquad (4)$$

$$\Delta h = 0 \quad H0' < 0.78 \bullet h \ \text{or}\ hc - H0' \qquad (5)$$

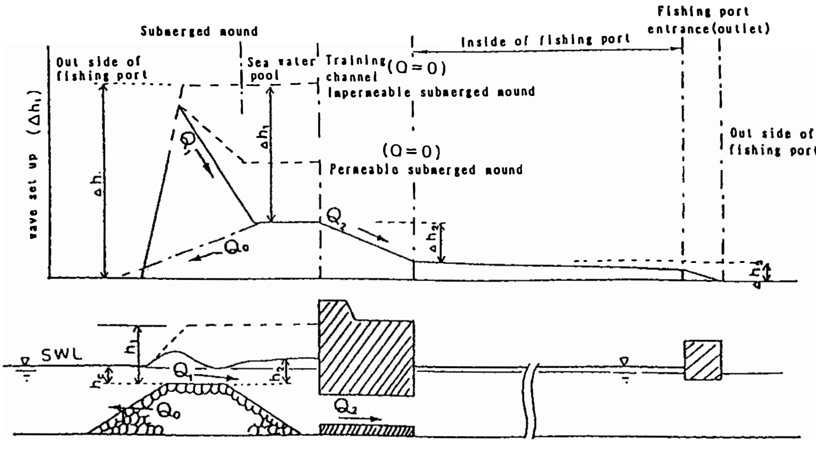

Figure 2. Explanation of the method to calculate the quantity of seawater inflow

WWSM is hydraulically composed of three parts that is the submerged mound, the inlet and the outlet (Figure 2). Wave-setup Δh generated by wave breaking at the submerged mound is expressed in three parts Δh1, Δh2, Δh3, by equation (6). Relationship between inflow Q and Δh1 is expressed as equation (7) using the formula on the submerged sluice gate.

$$\Delta h = \Delta h1 + \Delta h2 + \Delta h3 \tag{6}$$

$$Q = (C1 \bullet h1 \bullet B) \bullet (2 \bullet g \bullet \Delta h1)^{1/2} \tag{7}$$

h1,h2: sea level at front edge and end edge of the submerged mound
C1: coefficient of inflow rate
B: length of submerged mound

From the results of experiments on impermeable submerged mound, the coefficient of inflow rate is calculated by equations (8), (9).

$$C1 = 0.32 \qquad h2 / h1 < 0.71 \tag{8}$$

$$C1 = 0.45 \bullet h2 / h1 \qquad h2 / h1 > 0.71 \tag{9}$$

In case of permeable submerged mound, return flow in the submerged mound exists. It is calculated by equation (10).

$$Q0 = (C0 \bullet hd \bullet B) \bullet (2 \bullet g \bullet \Delta ho)^{1/2} \tag{10}$$

$C0 = (2 \bullet \beta lm)^{-1/2}$
β: $\beta 0\,(1 - \lambda) / (\lambda^3 \bullet d)$
$\beta 0$: 2.2
lm: width of the permeable submerged mound
λ: void ratio (= 0.4)
d: diameter of stone

Relationship between $\Delta h1$ and flow rate $Q1$ is expressed as equation (11).

So relationship between head loss $\Delta h0$ and resistance in the permeable mound is as equation (12). Head loss $\Delta h2$,$\Delta h3$ at the inlet and the outlet are calculated by equations (13), (14).

$$\Delta hl = 1 / [2 \cdot g (C1 \cdot h1 \cdot B)^2] \cdot Q1^2 \quad = R1 \cdot Q1^2 \quad (11)$$
$$\Delta h0 = 1 / (2 \cdot g \cdot (C0 \cdot hd \cdot B)^2) \cdot Q0^2 \quad = R0 \cdot Q0^2 \quad (12)$$
$$\Delta h2 = 1 / (2 \cdot g \cdot (C2 \cdot A)^2) \cdot Q2^2 \quad = R^2 \cdot Q2^2 \quad (13)$$
$$\Delta h3 = \quad = R3 \cdot Q2^2 \quad (14)$$

R0, Rl, R2, R3 ; resistance coefficient

The relationship among $\Delta h1$, $\Delta h2$ and $\Delta h3$ is shown schematically by Figure 2. Also, the inflow Q1 above the submerged mound is divided into effective inflow Q2 and return flow Q0, as equations (15), (16).

$$Ql = Q2 + Q0 \quad (15)$$
$$\Delta h2 + \Delta h3 = (R2 + R3) \cdot Q2^2 \quad = R0 \cdot Q0^2 \quad = R_{2+3,0} \cdot Q1^2 \quad (16)$$

Substituting equation (16) into equation (15), the coupled resistance coefficient is derived as equations (17), (18). And total resistant coefficient R is expressed as equation (19). Substituting equation (19) into equations (8), (9), equation (20) is derived. Equation (22) is derived from equation (6).

$$1/R_{2+3,0}^{1/2} = 1 / (R2 + R3)^{1/2} + 1 / R0^{1/2} \quad (17)$$
$$R_{2+3,0}^{1/2} = (R2 + R3)^{1/2} \cdot R0^{1/2} / [(R2 + R3)^{1/2} + R0^{1/2}] \quad (18)$$
$$R=R1+R_{2+3,0} \quad (19)$$
$$Q1^2 = \Delta h1 / R \quad (20)$$
$$\Delta h1 = R1 \cdot Q1^2 = (R1 / R) \Delta h \ (21)$$
$$\Delta h2 + \Delta h3 = (R_{2+3,0} / R) \cdot \Delta h \quad (22)$$

Finally, seawater inflow can be calculated by equation (23).

$$Q2 = [(R_{2+3,0} \cdot / R) \cdot \Delta h / (R2 + R3)]^{1/2} \quad (23)$$

Using these equations, seawater inflow can be calculated (Figure 3). If the wave is not acting normal to WWSM, the length of the submerged mound should be corrected to its length normal to wave direction.

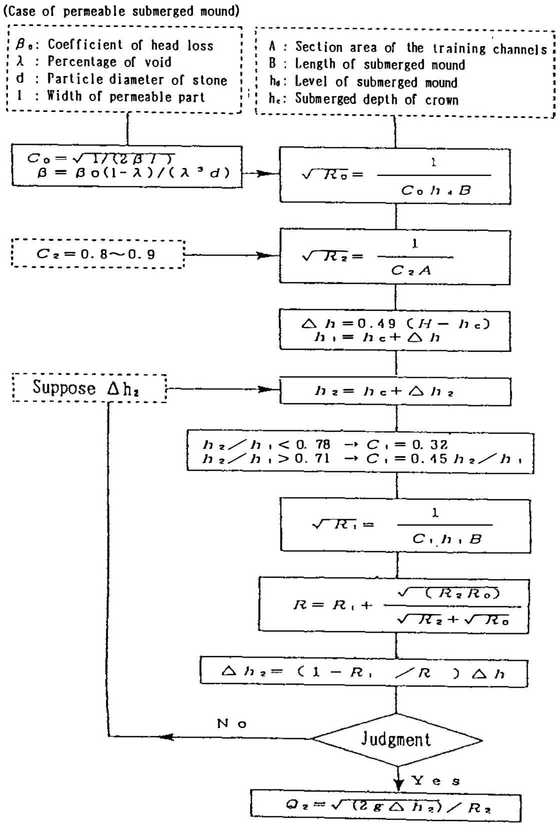

Figure 3 . Flow chart of calculation of seawater inflow

FIELD SURVEY

Background

Recently WWSM was constructed or is under construction at several fishing ports in Japan. For example, Yokata fishing port (in Toyama pref.), Oshima fishing port, Shikanoshima fishing port (both in Fukuoka pref.). Field surveys were carried out at the three fishing ports. In this paper, the results of the field survey at Shikanoshima fishing port are described.

Shikanoshima fishing port is located at the western part of Japan, eastern side of the Hakata bay entrance facing the Genkai sea.(Figure 4) In this area, angling fishing using live fishing bait is one of the major fishing methods. So in this fishing port, live fishing bait and live commercial fish are stocked at its basin. Before constructing WWSM, in every early summer, the live fish died because of the deficiency of dissolved oxygen. This was very serious problem for fishermen. A large amount of seaweeds rushed into the basin in every early summer and sunk in the bottom. These seaweeds polluted seawater in the basin. low seawater exchange efficiency, putrefaction of the seaweeds and wastewater were thought to be the cause of oxygen deficiency. For preventing stocked live fish from dying, WWSM was constructed in 1992.

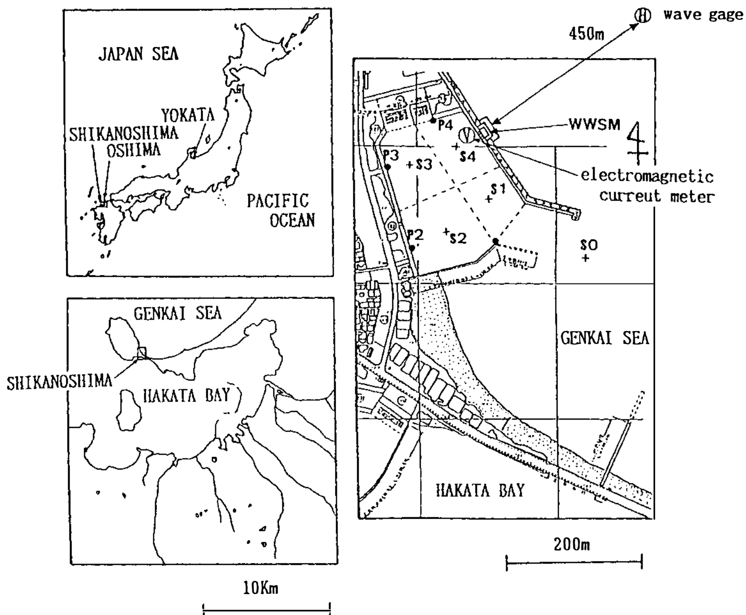

Figure 4. Location of Shikanoshima fishing port

In order to estimate performance of WWSM and investigate current, quality of seawater and bottom sediment in the basin, field survey was carried out from June 7 to 8 in 1990 and from July 14 to August 12 in 1993.

RESULTS

Inflow rate

Figure 5 shows the time series of measured wave height, tide level and inflow velocity at the exit of the training channel. The average of wave height over the observation period was about 60 cm and the average of inflow velocity was about 40 cm/s. The average inflow rate was about 100,000 m^3/day. The seawater interchange rate by a tide was estimated from 40,000 to 90,000 m^3/day. The average exchange rate was doubled by WWSM, increasing flow velocity in the inner region of the fishing port. So inflow by WWSM may greatly contribute to improved seawater quality and bottom sediment in the basin. Moreover, inflow prevents a lot of seaweeds from rushing into the basin.

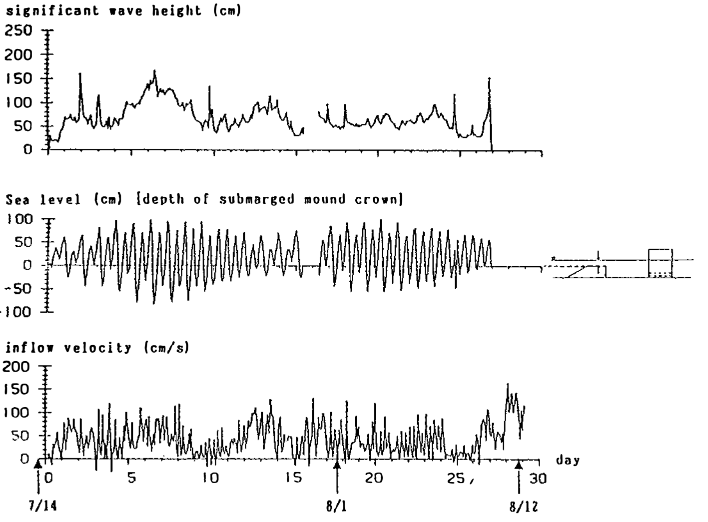

Figure 5. Time series of wave height, tide level and inflow velocity.

Comparison of measured data and calculated one

Figure 6 shows the relationship between wave height, depth at the submerged mound hc and inflow velocity. Curved lines in this figure are calculated by the theory, mentioned above. It is found that inflow velocity depends on wave height. In case of high tide level, wave set-up by wave breaking at the submerged mound is low and inflow velocity is relatively small. In case of low tide level, inflow velocity is also relatively small because wave set-up by over topping is less than the one by wave breaking. Figures 6(b), 6(c) show that the inflow velocity is larger than the one in the case of 6(a), 6(d). From this figure, the crown height of the submerged mound should be set equal to mean sea water level, in order to get inflow by WWSM effectively. Calculated values agree well with measured data, except Figure 6(a). Figure 6(a) is the case of large hc. This case must be investigated further. But in practice, this theory is sufficiently applicable.

As an index of seawater quality, we measured dissolved oxygen change from sunset to sunrise. At the same time, we sampled sediment in the basin and out of the fishing port. Figure 7 shows the time series of DO concentration. From the upper figure, there was little difference between the data before and after the construction of WWSM. In the lower figure, the data in 1990 reached minimum value (about 35%) at 8:00, but the data in 1993 was almost constant about 70 or 80%. DO concentration in the basin was kept more than 60% after the construction of WWSM. When waves break on the submerged mound of WWSM, a lot of air bubbles are entrained in the sea water. So, DO of the inflow is mostly saturated with dissolved oxygen.

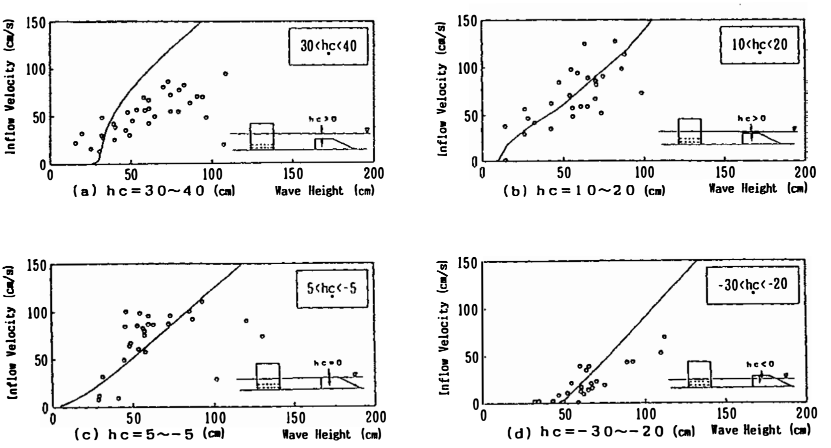

Figure 6. Relationship between wave height and inflow velocity.

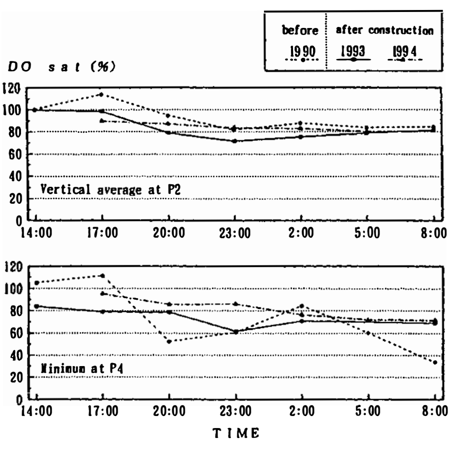

Figure 7. Time series of DO concentration.

Sediment analyses

Table 1 shows the results of the sediment analysis. Especially, at point S4 near the WWSM, the ignition loss decreased from 10% in 1990 to 3.5% in 1993. Sediment in this region was thought to be improved by inflow from WWSM. But at another region, no remarkable change was detected. It may take more time to improve sediment in the whole basin.

Table. 1. Sediment analysis

Point	**Year**	**Median grain size D50 (μm)**	**Particles < 74μm (Mud) %**	**Ignition loss (%)**
S 1	1990	177.4	13.8	10.66
	1993	158.8	4.1	4.50
S 2	1990	198.1	9.6	2.59
	1993	192.9	11.6	2.60
S 3	1990	122.8	31.9	4.40
	1993	120.3	32.8	4.95
S 4	1990	120.1	31.8	10.00
	1993	370.1	6.6	3.46
S 0	1990	163.3	2.9	4.92
	1993	663.4	0.1	0.42

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SUSTAINABLE DEVELOPMENT OF THE WATERFRONT IN HONG KONG

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ABSTRACT

A policy formulated largely from past experiences gained locally over the last two centuries for the sustainable development of the waterfront in Hong Kong is proposed. In this policy, which is based on the concept of building with nature, the coastal waters of Hong Kong is divided into three zones, eastern, central and western. All existing utilization activities are permitted at least in one of the three zones while the desirable natural characteristics in the most unpolluted zone is conserved. In the eastern zone, the naturally clean waters is to be kept free from dredging and marine dumping activities in order to cater for marine parks, protected wetlands, mariculture, inshore fisheries and recreation. In the western zone, because the waters are already strongly influenced by discharges of the Pearl River system, the zone may be used for dredging marine fill and marine dumping. In the central zone, including both Tolo Harbour and Victoria Harbour, the waters are already severely polluted. Because land is reclaimed episodically in this zone to fulfil a long-term need, a cost-effective strategy is to allow effluents from storm drains and sewage outfalls to be discharged and trapped within typhoon shelters in order to minimise their environmental impact over the remainder of the harbour. These typhoon shelters may be reclaimed at intervals of about every 10 to 20 years to create new land for development when the effluents trapped within them may be dealt with in an acceptable manner as part of a long term coastal management plan.

INTRODUCTION

All development of the waterfront or coastal zone are detrimental to the natural environment in different degrees. Because the waterfront is one of the most important of the world's finite resources (Apsimon *et al.*, 1990), it is important to ensure that planning for all development is aimed at a high level of sustainability. When drawing up a future coastal management policy, past experiences are invaluable but are rarely given the attention warranted even when environmental impact assessments are carried out. It is in this area where greater attention is needed to improve the formulation of predictive models. Afterall, it will only be through the passage of time that the true effectiveness of the predictive models formulated could be tested. There is therefore a role for earth scientists with a good understanding of coastal processes, who have investigated the coastal geological records, to contribute towards the establishment of a policy for the sustainable development of the waterfront.

The concept of an integrated coastal policy through building with nature was popularised in the Netherlands by Waterman (1991). It is based largely upon the recognition of the desirable natural characteristics of individual sites, and, to utilize these assets to the best advantage while at the same time, the demand from a wide range of man's activities can be accommodated. The policy for sustainable development should be aimed at conserving the most desirable natural characteristics in carefully selected sites to make effective use of the natural and anthropogenic circumstances. A major goal is the ecologically sustainable development of the waterfront. However, this is difficult to achieve unless planning, management and research is fully integrated (Kelleher, 1994). In the present study, a policy formulated largely from past experiences gained locally over the last two centuries aiming at the sustainable development of the waterfront in Hong Kong is proposed.

PHYSICAL SETTING OF HONG KONG

Hong Kong is a megacity with a population of about 6 million 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). Figure 2 is a map of Hong Kong showing selected coastal features. It has a subtropical climate with hot and wet summers and cool and dry winters, associated with the southwest and northeast monsoon respectively. It is naturally devoid of low-lying land suitable for development while the steep hill slopes are prone to landslides (Brand, 1985). Therefore in order to create low-lying land for development, there has been a history of episodic coastal land reclamations to create land dating back more than 250 years. Figure 3 shows the shifting position of the coastline in Victoria Harbour as the result of past and future land reclamation schemes. Out of its present land area of about 1100 square kilometres, approximately 10 per cent was estimated by Peart and Yim (1992) to have been reclaimed from the sea particularly in Victoria Harbour and Deep Bay. Due to the irregular coastal configuration formed by the drowning of a highland area, there are a number of relatively sheltered bodies of inshore waters including Tolo Harbour (Figure 4) and Victoria Harbour (Figure 5). The former is particularly prone to storm surge damage because of the natural coastal configuration (Yim, 1993a and 1993b).

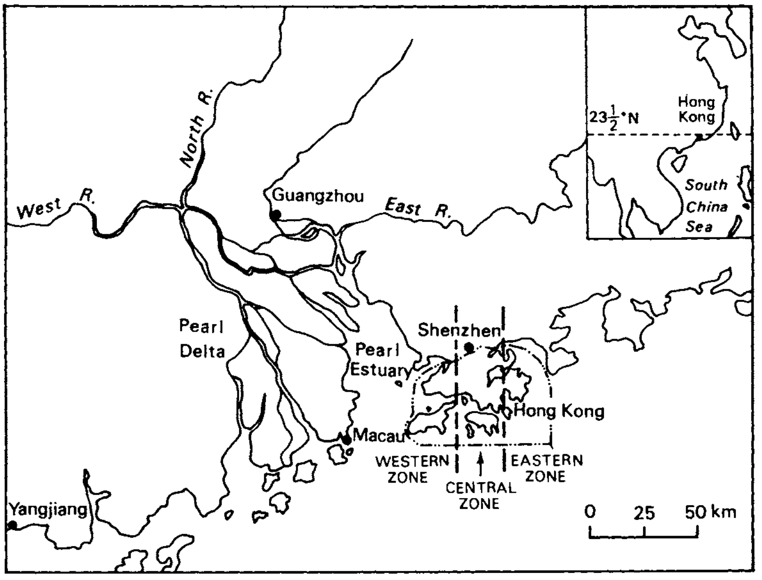

Figure 1. Location map showing the position of Hong Kong, the three hydrographic zones after Morton (1985), the Pearl Delta and the Pearl Estuary.

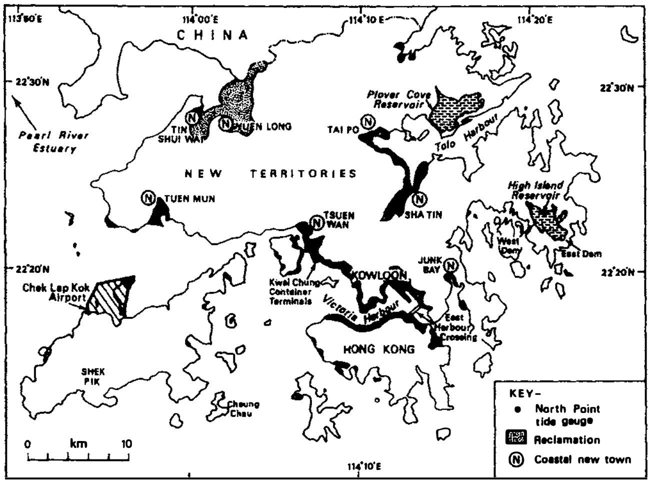

Figure 2. Map of Hong Kong showing coastal land reclamations, coastal new towns, coastal reservoirs and other selected coastal features.

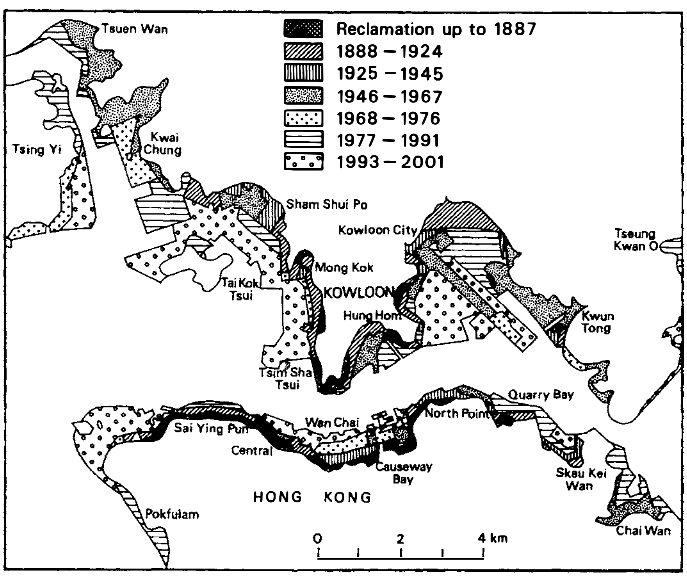

Figure 3. Map showing the shifting position of the coastline in Victoria Harbour as the result of episodic coastal land reclamation schemes. After Kwong and Hacker (1993) with modifications.

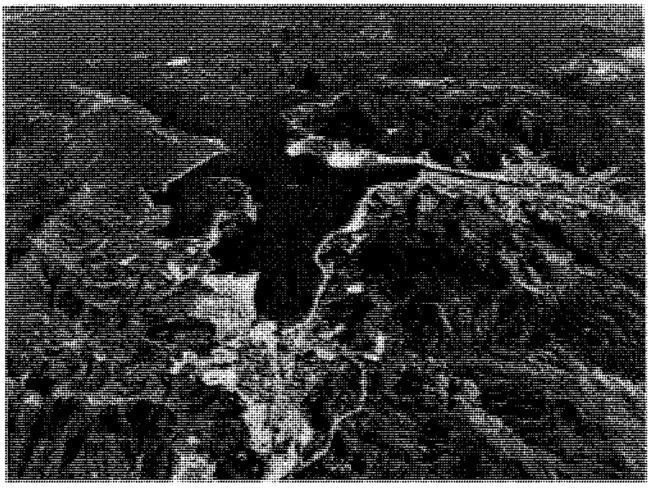

Figure 4. Oblique aerial photograph of Tolo Harbour in a south-easterly direction. The narrow exit into Mirs Bay is Tolo Channel; Plover Cove Reservoir is immediately on the left of the channel. The new towns Tai Po and Sha Tin can be seen on the left and right respectively. Department of Lands © Hong Kong Government.

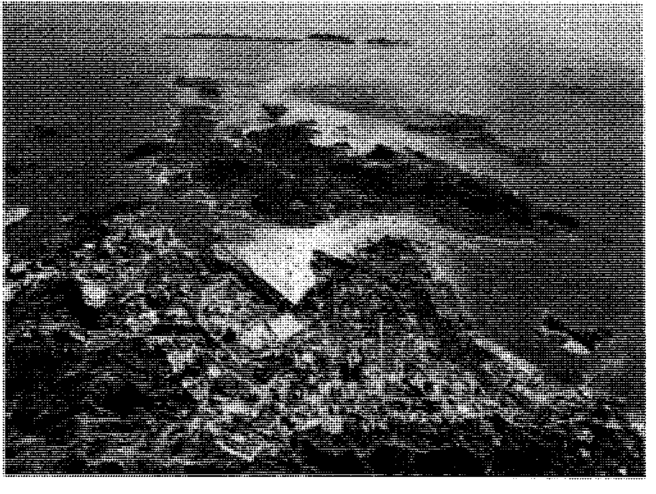

Figure 5. Oblique aerial photograph of Victoria Harbour in a southerly direction along the Central Zone (see Figure 1). Two large typhoon shelters can be seen on the Kowloon Peninsula, to the left in Kowloon Bay adjacent to the Kai Tak International Airport, and, to the right in Yau Ma Tei. Department of Lands © Hong Kong Government.

According to Morton (1985), the present day coastal waters of Hong Kong falls into three hydrographic zones, eastern, central and western (Figure 1). The eastern waters are the nearest to being oceanic, with salinity only marginally below normal seawater and are clear because of the low concentrations of suspended particulates. The western waters are estuarine with low salinity and high turbidity due to discharges of the Pearl River system which shows a net westerly drift. 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 channels on the eastern and western sides, while the latter, having only a narrow eastern exit into to the open sea, is poorly flushed. It is in the central zone where urban and industrial development of the waterfront is the most intense that pollution effects have been the most obvious (Morton, 1976, 1985 and 1989; Yim, 1984; Wu, 1988).

Sea floor sediment surveys by Yim and Fung (1981), Yim (1984) and Yim and Leung (1987) have provided insight into the natural and anthropogenic input of heavy metals into the coastal waters. Victoria Harbour has the highest concentration of heavy metals resulting from the discharge of domestic and industrial effluents. In typhoon shelters, where tidal flushing efficiency is reduced by breakwaters and seawalls, they are able to accumulate. On the other hand, Tolo Harbour has very poor tidal flushing efficiency because of the natural coastal configuration. The latter was verified in a sedimentological and geochemical study of the characteristics of the sea floor sediments by Yim and Leung (1987). The development of two new towns, Sha Tin and Tai Po within the harbour in the 1970s, has created problems associated with a major deterioration of coastal water quality in addition to the destruction of long stretches of the natural coastline occupied by mangroves. This is in spite of the construction of costly sewage treatment facilities at each new town.

UTILIZATION OF THE WATERFRONT

A wide range of activities, some of which are located in Figure 2, utilizes the waterfront in Hong Kong including:

(1) Marine parks - These are at found at Hoi Ha Wan and Cape D'Aquilar. The former possesses the best living coral community within the territory.

(2) Protected wetlands - The Mai Po Nature Reserve is known internationally for its diversity in bird life but is increasingly threatened by upstream sources of pollution via the Shenzhen River and adjacent urban development.

(3) Mariculture - This include fish farming and oyster culture. Fish farming normally requires unpolluted seawater with near average salinity while oyster culture requires unpolluted brackish water.

(4) Inshore fisheries - Local fishermen have over the years been making claims that this industry is severely affected by both marine dumping and marine dredging. The spawning ground of benthic organisms is particularly susceptible to damage.

(5) Recreation - This include water sports such as swimming, scuba diving, wind surfing and yachting.

(6) Extraction of seawater - Seawater is used for lavatory flushing and cooling purpose.

(7) Container terminals and other port-related activities - Currently Hong Kong ranks first in the world in terms of the volume of container traffic ahead of Singapore.

(8) Reservoirs - Two reservoirs, Plover Cove and High Island completed in 1967 and 1979 respectively, are constructed from marine sites from an embayment and a channel respectively (Figure 2).

(9) Landfill sites - Currently two active coastal landfill sites are located in Junk Bay and Nim Wan.
(10) Pulverised fuel ash disposal lagoons - One lagoon is located near Nim Wan and another is being planned for Lamma Island.
(11) Power stations - These are located at Tap Shek Kok, Tsing Yi and Lamma Island.
(12) Typhoon shelters - There are a number of typhoon shelters distributed throughout Hong Kong. In Victoria Harbour, they are noted as pollution balckspots because of their poor tidal flushing efficiency. Currently, the Yau Ma Tei typhoon shelter (Figure 5) is being reclaimed to create land needed for the Port and Airport Development Strategy (Figure 6).
(13) Communication sites - These include airports, cross harbour tunnels, bridges and waterfront highways. The existing Kai Tak International Airport and the Chek Lap Kok Replacement Airport currently under construction both involved the creation of large areas of low-lying land through coastal land reclamations.
(14) Stormwater drains - These are built for stormwater removal to reduce the risk of coastal flooding which may be particularly severe during storm surges and rainstorms. Flooding is a serious problem because over 75 cm of rainfall is possible within a 24-hour period in Hong Kong.
(15) Marine dumping - This include effluents discharged from sewage outfalls, sewage sludge and constructional wastes. Prior to the 1970s, sewage outfalls were almost entirely of the seawall type. These were replaced by submarine outfalls in the 1970s leading to accelerated eutrophication in the deeper inshore waters particularly in Victoria Harbour. Marine dumping grounds are located in Figure 6.
(16) Marine fill dredging - Sand and gravel are dredged to provide construction fill and aggregate. Marine burrow areas are located in Figure 6.
(17) Quarries and burrow areas - These include soil and rock removed from selected headlands for construction fill and aggregate.
(18) New towns - These include Yuen Long, Tin Shui Wai, Tuen Mun, Tseun Wan, Tai Po, Sha Tin and Ma On Shan.
(19) Industrial estates - These are located in both existing developed areas such as Kowloon Bay and Kwun Tong and in new towns such as Tai Po and Sha Tin.

With the exception of marine parks and protected coastal wetland, all above activities leads to either different degrees of destruction of the natural coastline or the increase in pollution loading into the coastal waters. On the other hand, mariculture, inshore fisheries and recreation require uncontaminated natural waters free from domestic, industrial and agricultural effluents. Therefore, there is direct conflict with the other types of utilization. For the remaining types of utilization, natural mangroves in the intertidal zone are often destroyed followed by a shift of the coastline into deeper waters through land reclamation. A case history of coastal pollution due to land formation was documented by Bowler (1985). The new coastline is usually in the form of a seawall or breakwater rising abruptly from the sea floor with the intertidal zone destroyed either completely or almost completely. Due to changes in the coastal configuration and the sea bed profile, the hydraulic regimen of the waves and tidal currents are altered considerably. Often the rate of entrophication of the harbour waters is increased.

Activities such as mariculture and marine dumping invariably result in an increase in pollution loading to the coastal waters. On the other hand, marine dumping, marine fill dredging and shipping activities also increase the turbidity and eutrophication rate of the inshore waters particularly when the area is naturally poorly flushed by tidal currents. This is particularly true in Tolo Harbour where the coastal waters is highly sensitive to anthropogenically-induced changes.

At least over the last 250 years, episodic reclamation have taken place about every 10 to 20 years in

Victoria Harbour (Figure 3). This shift of the coastline seawards have created a combination of problems including flooding (Peart and Yim, 1992) and ground subsidence in the reclamation areas (Yim, 1991 and 1993b). Because such problems are common in the old developed areas, new land reclamations adjacent to these existing areas should provide an opportunity to tackle the problems using engineering solutions during redevelopment. For example, by widening the storm drains, installation of flood pumping stations and the raising of the ground level.

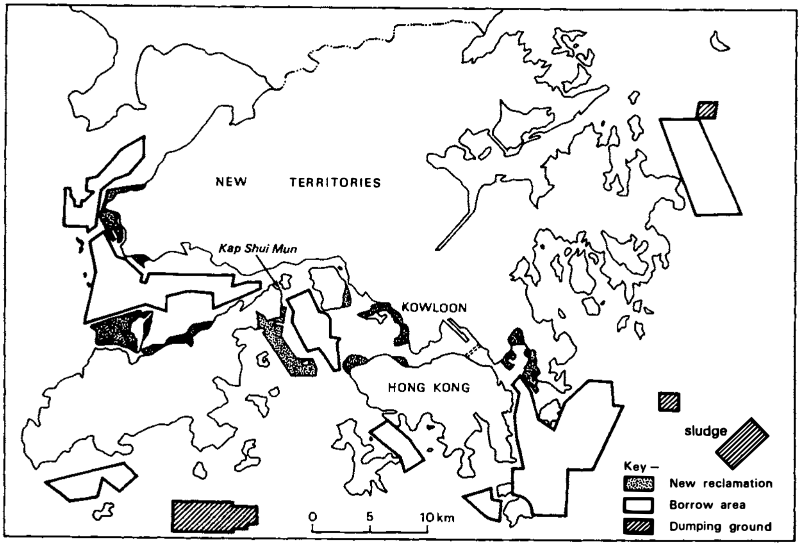

Figure 6. Location map of offshore burrow areas, dumping grounds and the Port and Airport Development Strategy in Hong Kong. After Brand (1992) with modifications.

A POLICY FOR SUSTAINABLE DEVELOPMENT

Table 1 provides a summary of the policy for sustainable development of the waterfront in Hong Kong showing the recommended utilization in each of the three hydrographic zones. This policy is derived from a consideration of the following factors:

(1) The natural conditions of the coastal waters in the three zones.

(2) The existing concentration of developed areas in Victoria Harbour and Tolo Harbour which is likely to persist.

(3) The desirability to cater for all coastal land uses at least in one of the three zones.

(4) The historical record of development recognising the fact that Hong Kong is a rapidly expanding city. For sustainable growth of the city, new land will have to be created by reclamation.

(5) Which is the most ecologically sustainable? - to contain effluents within typhoon shelters, to treat the effluents or to dispose the effluents into the open seas with or without pre-treatment.

Table 1. Summary of the policy for sustainable development of the waterfront in Hong Kong showing the recommended types of coastal utilization in each of the three hydrographic zones.

Western Zone	Central Zone	Eastern Zone
Container terminal and port-related activities	Container terminal and port-related activities	Recreation
Landfill sites	Landfill sites	Mariculture
Reservoirs	Reservoirs	Reservoirs
Pulverized fuel ash disposal sites	Typhoon shelters	Coastal fisheries
Typhoon shelters	Communication sites	Marine Parks
Communication sites	Stormwater drains	Protected wetlands
Stormwater drains	Quarries and burrow areas	Extraction of seawater
Quarries and burrow areas	Industrial estates	
Industrial estates	Extraction of seawater	
Marine dumping Marine fill dredging	New towns	
Power stations		
Extraction of seawater		

Out of the above considerations, (5) is considered the best option. This is based on three important reasons. First, sooner or latter the typhoon shelters will be reclaimed to create more land needed for development. Based on the historical record of development, typhoon shelters will sooner or later be reclaimed. When this takes place, the effluents trapped within them may then be dealt with in an acceptable manner as part of a long term coastal management plan. Second, effluents released into typhoon shelters are largely confined there. Consequently, they will have a smaller environmental impact than to release them into the open sea. Third, it is the most cost-effective option available until technology improves to make the treatment option feasible.

It is inevitable that because some of the demands of coastal utilization by man that the policy cannot be ecologically sustainable throughout Hong Kong. The important advantage of the present policy is that by making use of what nature has provided, sites can be protected to permit desirable ecological activity to continue under favourable natural conditions. This is essential to ensure that such activities would survive and cater for the need for other types of coastal utilization.

SUMMARY AND CONCLUSION

Radical changes to the planning policy will have to be made if sustainable development is the goal of the future development of the waterfront in Hong Kong. This will involve zoning activities aimed at:

(1) Reducing the environmental impact of the anthropogenic activities.
(2) Conserving the most desirable natural characteristic in some sites.
(3) Permitting continued development in sites where land is in demand.
(4) Permitting all activities to continue in at least one of the three zones.

In order for integrated management to take place, I am in agreement with Kelleher (1994) that a single government agency should be responsible. The primary aim should be to achieve ecologically sustainable development of the waterfront.

ACKNOWLEDGEMENTS

I am particularly grateful to I.J. Ayson, M.L. Chalmers, Dr D.J.H. Phillips, Dr G.B. Thompson and R.E. Waterman for their assistance. Research grants for this work were provided by the Croucher Foundation and the University of Hong Kong.

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