Annual Report

1978 79

The Planning and Management of California's Coastal Resources

University of Southern California Sea Grant Institutional Program

UNIVERSITY OF SOUTHERN CALIFORNIA
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CONTENTS

INTRODUCTION

During its nine years of participation in the national Sea Grant Institutional Program, USC has continued its commitment to solving regional problems and adapting to changing needs. The 1978-79 program was no exception. The goals of USC's marine research program have historically paralleled those of the National Sea Grant College and Program Act of 1966. As that program has changed, so has the USC program. The National Sea Grant Program has increasingly sought to stress the involvement of the scientific community as well as the needs of the user community in its selection of projects.

USC's commitment to applied marine research dates back to the early 1900s, and through the years university faculty and staff have worked with representatives of the public and local industry to solve marine and coastal problems of importance to the region.

This is a report of the University of Southern California's ninth year of participation in the Sea Grant program. Subsequent sections contain summaries of the results of projects in marine resource development, socio-economics, environmental quality, coastal engineering, marine advisory services, and marine education and training.

PROGRAM DEVELOPMENT

Donald L. Keach and D. Patrick Hartney

Sea grant projects usually require a lead time of about one year from submission of the proposal to startup. However, there are many times during a given fiscal year when new or urgent research needs emerge which cannot or should not be delayed until the next budget cycle. New oil and tar seeps and fish kills are examples of time-critical research subjects.

Quick-response funding enables the Sea Grant Program to provide:

1. An interim source of funding for initiating short-term research projects during the course of the Sea Grant fiscal year in response to articulated needs from state and federal agencies, as well as private-sector, industry-wide problems with coastal resource management and development

2. Startup funding and background research for longer term research projects

3. Supplementary funds to be used for one-time advisory visits

During 1978-79, program development funds were used to support the following research efforts described subsequently.

The Impacts of Maritime Transportation in Los Angeles-Long Beach Harbors: Pollution, Environmental Regulations, and Economics. Gerald Bakus.

Shipping is of vital economic concern to the state of California. The Los Angeles-Long Beach harbor complex represents the largest shipping port in the western United States. Harbor pollution has only relatively recently become a major issue in California. Ships contribute to harbor pollution by direct effects (e.g., air pollution, oil spills) and by indirect effects (e.g., cannery wastes, dockside debris). Environmental controls result in economic repercussions. A multidisciplinary study is needed to assess the impact of various sources of harbor pollution related to marine transportation in the Los Angeles-Long Beach harbors.

The goals of this Program Development project were: (1) to summarize information on pollutants derived from marine transportation in the Los AngelesLong Beach harbor complex for direct use of local officials as well as providing the data base for analysis of sources, impacts, and consequences of harbor pollution; (2) to assess the effectiveness of the

current efforts for mitigating marine-transport-related harbor pollution and to suggest alternatives if current efforts are less effective than they should be, (3) to assess the cost-effectiveness of current efforts of mitigating or of eliminating marine-related harbor pollution; to suggest more cost-effective methods if the current efforts are more expensive than they need be, (4) to develop an environmental management tool---an annually updated on-line computer program that would be used by local, state, and federal agencies, industries, and institutions for decision-making activities concerned with marine transportation---related to harbor environment, regulations, and economics in the Los Angeles-Long Beach harbors.

This phase of the project involved primarily the collection of data on maritime pollutants in Los Angeles-Long Beach harbors. Included are pollutants from the activities of waterfront establishments, and from advective sources (i.e., ocean outfalls) and storm drains.

This data was collected from federal agencies (EPA, MARAD, Maritime Transportation Research Board, OCZM, BLM, the U. S. Coast Guard, the U.S. Army Corps of Engineers), state agencies (Coastal Commission, Boating and Waterways, OPR, Fish and Game, Regional Water Quality Control Board), and local agencies (Los Angeles County Flood Control District, Port of Los Angeles, Port of Long Beach, San Pedro Division of Industrial Waste, South Coast Air Quality Management District, and SCCWRP).

To date, this data collection on pollutants is about two-thirds completed. In final form, this collection will form the basis for a major study of the effects of maritime transportation in the Los Angeles-Long Beach harbor.

Geologic Hazards Study: Mass Movement in Santa Barbara Basin, California Continental Borderland. Donn Gorsline

Mass movement is the major transport process moving sediment downslope to the basin floor. It occurs as slides, slumps, debris flows, and creep. In the Santa Barbara Basin, mass movement occurs on a large scale and may be hazardous for sea floor construction and pipeline emplacement. Types and sizes of mass movements can be classified and quantified using seismic profiling and coring with associated analysis of bulk sediment properties. Regional studies require the use of a research vessel to do the heavy coring and profiling.

The objectives of this project were to: (1) produce representative maps for a selected area of current resource development interest of the types of mass movement present, the dates of such movements, and rates if they are currently active; (2) grade the selected test areas in terms of their availability for particular kinds of structures and uses, e.g., no construction platforms of particular types, pipelines, etc.; (3) compile these displays from existing data provided from Hancock Foundation files and archives, from agency open file data, and from industrial data provided

that should be determined for specific sites by service industry; and (5) define regional characteristics for use by these companies and by monitoring agencies in planning use and negotiation of use.

During this funding period, we focused our attention on six small, apparently recent submarine slides and one very large, persistent, older submarine slide in the Santa Barbara Basin. The failing substrate in all cases is silty clay or clayey silt, with very little sand. Water contents studied throughout the basin are quite high, with water contents in the center of the basin making this material essentially a slurry at the sediment-water interface. Sedimentary structures examined from available samples from the slide sites should be evidence of mass movement and rapid dewatering of the substrate following movement. Sedimentary structures from areas between slides are predominantly biogenic in origin, in sharp contrast to the structures found in slide areas. A particularly interesting area of mass movement is the area in the northeastern portion of the basin, where thin pockets of silty clay are sliding along discrete glide planes. This pattern of mass movement for this area has persisted for thousands of years, based on the thickness of these deposits inferred from seismic records. Interslide areas may actually be areas which have experienced mass movement in the past but which are now homogenized by bioturbation.

Pollution Flow through the Food Web of Los Angeles-Long Beach Harbors: A Pilot Study David Young, Allan Mearns, Harold Puffer

Harbors often receive high inputs of various pollutants. It is commonly assumed that all or most pollutants move upward through the marine food web, becoming more concentrated with each increase in trophic level. This concept of a "structured" food web is now being challenged by a number of scientists who suggest that the marine food web is "unstructured" and that energy and pollutants also flow down and through it. Young and Mearns have shown that the cesium/potassium (Cs/K) ratio builds up by several factors in the simplified, structured food web of the Salton Sea. There, Cs/K is a pollutant analog which identifies structure in marine food webs that can lead to "food chain amplification" of certain pollutants. We have shown that San Pedro harbor has received relatively high inputs of vessel-related pollutants such as benzo(a)pyrene (crude oil and products), copper-mercury-lead-cadmium-chromium (bottom primers and antifouling paints), zinc (sacrificial anodes), and PCB [(paint (?), hydraulic fluid(?)] However, little is known regarding the bioconcentration of such pollutants by feeding or other processes, and their subsequent transport to coastal waters by migration, or to humans via seafood consumption.

The major goals of ths project are: (1) to determine levels of nonvolatile trace metals (Ag, Cd, Cr, Cu, Ni, Pb, Zn), total and organic mercury, DDT and PCB residues, and benzo (a) pyrene in selected marine animals from four trophic levels within the Los Angeles-Long Beach harbor; (2) to determine Cs/K ratio within the above trophic level steps; and (3) to analyze data for amplification effects within the above trophic levels and identify the amplification as being either structured or unstructured.

To date, diets of four species of marine animals from western Los Angeles harbor, the site of an oil spill, were examined in order to make trophic level assignments for evaluating food web bioaccumulation or biodiminution of inorganic and organic trace contaminants. In addition, muscle tissue of the animals, and blades of giant kelp, a primary producer, were analyzed for the Cs/K ratio which is a chemical index of trophic structure.

There was litle overlap in diets of the clam and fishes. Assignments, based on a conventional scale of I (primary producers) to V (tertiary carnivores) were: giant kelp (I); gaper clam (II-III); Northern anchovy (III); white croaker (III-IV); and California halibut (IV). Median Cs/K values increased with assigned trophic level (0.70, 1.84, 2.10, 2.92 and 3.49 x 10^{-6}, respectively.

Structure suitable for trophic bioaccumulation was confirmed. However, none of nine "non-volatile" trace elements measured (Ag, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) increased with trophic level; in fact, many decreased by as much as an order of magnitude. In contrast, concentrations of total mercury, total DDT, and PCB 1254 did increase with trophic level. However, another organic contaminant, benzo(a)pyrene, decreased with increase in trophic level; a comparison of this finding with previous studies suggests that benzo(a)pyrene may be more efficiently metabolized in the fishes and sea bird than in invertebrates or seaweed, and that the hydroxylase enzyme activity in these organisms should be measured in future studies. Overall, the benthic-based portion of the food web may be more important than the pelagic in terms of bioaccumulation, but at this point needs further investigation.

MARINE EDUCATION AND TRAINING

> When I have been able to transform a group—and here I mean all members of a group, including myself—into a community of learners, then the excitement has been beyond belief. To free curiosity; to permit individuals to go charging off in new directions dictated by their own interests; to unleash the sense of inquiry; to open everything to questioning and exploration; to recognize that everything is in a process of change—here is an experience that I can never forget!
>
> Carl Rogers

Californians have a keen interest in the world of water, as they well should, for it is their main source of recreation and provides substantial amounts of life sustaining resources. However, the educational opportunities to learn about marine resources, both renewable and nonrenewable, have been limited, especially within the public school systems. The Marine Education Program at USC, through its public school program, and the adult education program, is endeavoring to fill some of that need.

To date, the underlying philosophy in the educational world has been generally to categorize marine studies as a "science," with a fairly heavy emphasis in biology. This has been a natural development, since there is an easily demonstrated biological and evolutionary bridge between aquatic and terrestrial life forms. There is no doubt that the tools of science yield important knowledge about the sea, but educators must consider the audience being reached or excluded, as the case may be, if they leave information related to the ocean strictly to a science class. Recent studies indicate the public school system has failed to teach students adequately about science, and as Carl Rogers says, "to transform our young people into a community of learners."

The recent study referred to was conducted for the National Science Foundation by two professors, Stake and Easley, from the University of Illinois. Their findings clearly indicate that public school students have not been "turned on" to science, and as a result they are choosing other fields of interest which to them seem more relevant. The results of the study indicate, that "with the exception of education for a scientifically motivated minority, the situation (referring to science education) was not greatly different from that of the late 1950's. The cry for more stress on "basic" skills such as reading and arithmetic, has largely pushed the teaching of science into the background, if, indeed, it had ever really left."

If the instructional program in science somehow turns the students off, and they decide they can't manage it, they tend, at a very early age, to gravitate to those subject areas which are less scientifically oriented. Recognizing this tendency, and the need for a marine aware society we have chosen a counter-philosophy for marine education. Rather than define the marine environment as a "science" we have chosen to define it as a widely multidisciplinary subject matter, polycultural; with associational roots in the arts, humanities, history, literature, social studies, and most standard curricular categories. In this manner we are able to teach about marine factors in the biosphere from all angles, and at all levels to increase awareness and appreciation on the oceans in the history of man and his civilizations and to contribute to the goals of exploration, development, and conservation of marine resources.

The multidisciplinary marine education materials we have developed are diversified enough to be implemented, with few changes, into a number of non-traditional classroom situations. Complete programs have been developed for magnet schools, summercamps, boy scouts, museums, bilingual programs, visually impaired students, and for international programs. Although the materials have not been published as yet, they are camera ready and being duplicated by xerox until such time as either a publisher picks them up, or monies are granted for their publication.

A real step forward for marine education in California came when Dr. Riles, the California Superintendent of Education, appointed Mr. Rudy Schafer as the state Director of Marine Education. Mr. Schafer accompanied the Sea Grant educators from both the USC and the UC Sea Grant Marine Education Programs to the Workshop in Hawaii sponsored by PASGAP, April of 1979. The California State Team, consisting of curriculum specialists, public school teachers, Sea Grant Educators, and Schafer as the state representative, submitted a proposal for marine education in California to the Workshop. The major goal set down by the Team for the introduction of marine education into the public education system in the next three years was: "Constructive marine education programs for special needs in the schools and translating curriculum materials into Spanish for bilingual programs."

The interest in Latin America for marine education, generated during a visit to Costa Rica and Chile, has been further stimulated by a grant provided by the Tinker Foundation of New York. In January 1980, fifteen professionals, including University professors, curriculum specialists, and directors of marine-related programs from nine Latin American coun tries, will spend 12 days in Los Angeles in an intensive marine education workshop. It is anticipated that the participants in the Workshop will return to their respective countries and initiate a marine education program in their school systems.

Costa Rica has been granted funds by their government to start a marine education program, using the curriculum materials and the expertise of professionals in the USC marine education program. During 1980 USC professionals will conduct workshops in Costa Rica and then begin the implementation of a country-wide marine education program.

We were fortunate to have hired Jacqueline Bailey-Rojas as an Assistant in working with marine education programs. Jackie speaks fluent Spanish and has experience as a bilingual teacher in California. She is considered by her peers to be one of the best bilingual teachers in California and is extremely effective in teaching other bilingual teachers in workshops. Jackie's enthusiasm and ability to work with educators is a real asset to the marine education program in California.

The Graduate Student Trainee Program continues to be both an inspirational and beneficial part of the Sea Grant Program. The experien ce these students receive as they work with other professionals on ocean-related research has provided them practical experience, which in turn makes them more desirable in the job-related world. Their participation in Sea Grant Projects assists the Principal Investigators in obtaining their goals and objectives as described in their proposals. There is always a greater demand for students than we are able to supply, and a greater number of qualified students who apply to the program than we are able to support. It is our desire to increase the number of students as stipends are available.

The opportunities for expanding the marine education programs in California are numerous. We shall continue to meet these challenges and improve those programs already being implemented in order to reach the greatest number of citizens with marine education.

CALIFORNIA AND THE OCEANS

DOROTHY M. BJUR

During the 1978-79 fiscal year this program was able to meet most of the projected goals as specified in the Sea Grant Project, plus numerous other activities which enhanced the overall program.

Our main concern has been the completion of the three curriculum books developed since the inception of this program. Because we have tried to produce a quality project at a minimum cost, the progress has been more time-consuming than we had first anticipated. We are also constrained by the availability of our graphic artist who has, through her devotion to the program and the project, assisted us in producing unique and attractive books for the public school system.

The Multidisciplinary Supplementary Curriculum Guide "Wet and Wild," is ready for publication. The end result is a very attractive 450 pages of graphically illustrated, easy-to-follow format, and a treasure chest of instructive materials for the teacher to use. The information contained in the introductions to each of the six units is written in layman's terms and is comprehensive enough to allow the non-science teacher to present scientific concepts to her/his classroom without feeling intimidated.

In conjunction with the preparation of the Guide for publication, we have had it translated into Spanish and graphically illustrated in exactly the same format as the English version, thus multiplying its potential considerably. The Spanish version of the guide will constitute the most comprehensive bilingual marine education curricula in California.

The Idea Books took a "back seat" to the guide in the revision and preparation for publication. The elementary book will require very little change. It is also graphically illustrated and has recently undergone some revision. The major changes will be in expanding its overall use by eliminating the instructions which relate specifically to the Inner-city Program and modifying the introduction to include any and all classroom situations.

The high school book evolved from a rather modest 100 pages to an "epistle" of considerable size. The problem of securing consent from authors for use of portions of their materials has been the largest hurdle, and is being resolved little by little.

California Marine Education Proposal

One of the most exciting things to happen during this past year was the formalization of a statewide cooperative proposal to assure statewide participation in marine education.

PASGAP sponsored a workshop in Hawaii at which time educators from the West Coast "brain-stormed" ways and means of promoting marine edcuation within each of their states. The State of California was represented by two members of the Marine Education Program at USC, one from the University of California Sea Grant Program, a "hand-picked" curriculum specialist and high school teacher, and the Director of Environmental Education for the State of California.

The California team made the following proposal as their major goal for the introduction of marine education into the public education system in the next three years:

> Constructure marine education programs will be incorporated into all 58 counties of California, which will affect 50% of students in California schools, grades K-12.

The mechanism to accomplish the goals was to concentrate not only on individual classroom presentations but rather use the 14 interagencies of the state, such as the Department of Fish and Game, Water Resources Board, etc.; teaching training centers; school site councils; administrator and teacher state organizations; plus using teachers, school administrators, and the interagency personnel to draft a statewide course of study. One hundred fifty thousand dollars has been appropriated for the task of drafting an environmental education packet of which marine education will become an integral part. The Director of the Sea Grant Marine Education Program was invited to participate on the task force to review and evaluate existing Environmental Education Programs and give recommendations for the environmental packet.

Due to the efforts of the National Sea Grant Marine Education Director, Barbara Spector, each state has been encouraged to select a statewide Marine Education Coordinator. Dr. Wilson Riles, Superintendent of Schools for California, designated Mr. Rudy Schafer, who also serves as Director of Environmental Education for the State of California. Because marine education most certainly falls within this category, Mr. Schafer's appointment was a very wise selection.

One of Mr. Schafer's first endeavors in promoting marine education was to invite the USC office to serve on the task force in drafting an environmental education package. A week-long survey of existing literature demonstrated the tremendous lack of substantive marine education science materials available. The materials developed at USC were enthusiastically received by the task force of approximately 20 classroom teachers curriculum specialists, administrators, and interagency representatives. Mr. Schafer

has pledged his support to marine education as an integral part of environmental education, and, as his time permits, will assist the efforts of Sea Grant in creating a marine-aware California.

The Inner-City Program

In a recent visit to Manual Arts High School in Los Angeles, where an active Marine Studies Program is in progress, I had an opportunity to speak with the principal of the school. He expressed enthusiasm for the program and found only one problem: it was too popular! It seems that when the Marine Studies Program (using the Sea Grant Idea Books) first began, it was difficult to get sufficient students to sign up for the course to justify its existence. After only two years, more than 100 students have applied, and the search for classroom teachers has begun. According to Dr. Gardner, Director of the Joint Education Program (JEP) on the USC campus, the Marine Studies Program in both elementary and high school is the most popular program offered through JEP. During this past year, 45 University Students from USC prepared and presented lesson plans to a minimum of 500 classrooms in the inner-city schools.

To further encourage the inner-city students, we have been working with Community Service Center at USC in the SEA (Science Education in America) program. The program assists minority students of low-income backgrounds, grade 10-11, to achieve success and strive for a college education. One of the most difficult areas for these students is science. Through SEA we endeavor to stimulate the students to excel in science and strive for a career involving scientific skills. Marine-oriented opportunities are especially appealing to these students, and offer an exciting environment in which to study science. Plans are now in progress for a conference in the spring to introduce black scientists as realistic educational and career role models to the students, as well as introducing the students to: (1) the practical tools of science, (2) the history of technological development in America since World War II, and (3) other science education programs and approaches.

Outreach Programs

Summer Camp: Working with Los Angeles Unified Schools, Sea Grant put together a week-long marine education program for summer camps and coordinated its implementation. An identical series of lessons and activities were conducted in three camps with approximately 150-200 students at each camp. The five instructors/counselors of each camp were given a workshop to acquaint them with the materials and activities that could be used in an open-air type environment. The success of the camp depends entirely upon the capabilities and interests of the instructors in communicating the lessons to the children. Few of the instructors had any background in marine education, and thus were learning along with their students. A few of the comments made in the evaluation were:

(1) regarding tides, students attentive and appeared to comprehend; students performed exercises enthusiastically. (2) Seaweed: useful plants of the sea; students highly interested in learning uses of seaweed; students respnded well to questions. (3) Tidepool exploration; highly enthusiastic and wanted to do it again; lesson consumed entire afternoon as students asked intelligent and interesting questions. (4) Limits: incredibly positive; counselor had to ask students to stop; students interested in learning about governmental controls, enterprise pursuits with respect to oceanic resources; students were more conservation-minded by end of week.

The final analysis was there must be more time spent preparing the instructor/counselors. Lots of activities and student involvement must be stressed. It was a successful and rewarding experience.

Boy Scout Packet

Emphasis of the materials developed for the scouts was to help them fulfill the requirements of the "oceanography"merit badge in an exciting and informative manner. Stress was placed on activity-oriented learning experiences and upon use of the imagination as part of the learning process. Activities were multi-disciplinary, providing scouts with insights into such areas as social studies, science, art, drama, literature, and politics.

The scout leaders spent time at USC, using the resource library for additional information. The response was one of excitement, recognizing that this badge requirement could be an exciting experience. It was suggested that the scout guidelines for achieving the "oceanography" badge be revised.

Visually Impaired Students

We became interested in adapting the program to meet the handicapped child's desire to venture out of the coccoon built around them by society, and become acquainted with their marine environment. Working with the Braille Institute of Los Angeles we took a group of visually impaired and sighted children to the beach to visit a tidepool. It was amazing to see the determination of these visually impaired students to participate at the same pace as their sighted peers. They groped along the narrow path leading to the tidepool, screamed at the feel of seaweed and the prickly sea urchin and grinned a lot.

KCET-TV became interested in our program, and as a result filmed a morning at the beach with these children which was later aired in two segments on the "Summer Faire" television program.

As a result of these activities, HEW has approved funding for a program in marine studies for the visually impaired. This program will provide sample boxes, a book in both braille and large letters,

laboratory experiments, classroom activities, and three field trips. Again, the curricula materials produced by Sea Grant will be the main source of information and the Staff at Sea Grant will coordinate the entire program.

Bilingual Program

An article in the Sacramento Bee, May 17, 1979, stated that by 1982 there will be 400,000 students with limited use of English in California schools. Of the 233,000 limited-English-speaking students in California schools today, more than 80 percent are native Spanish speakers of Mexican descent. A serious problem is the knowledge that the longer non-English-speaking students attend California public schools, the more their achievement scores lag behind those of their English-speaking peers.

The possible answer to this problem is a better bilingual program. With the written materials we have developed and the expertise in working with Spanish-speaking people and California bilingual programs, we have begun developing a bilingual program in Marine Science. To date, three of the six units of the Supplementary Guide have been translated and graphically prepared for publication and use in the school system. The other three will be ready before the end of the year. Special care has gone into the translation of these materials assuring their acceptance by most Latin American countries. These materials will later be again edited by professionals from a total of nine Latin American countries. Although a fool-proof method for translating the materials to meet the expectations of all the Latin American countries may be nearly impossible, we will have at least culled out the most offensive word usages. We have already received letters from several of the Latin American countries congratulating us on the translations and assuring us they are acceptable in their present form.

The bilingual program in California is already in progress with workshops in six different schools. To date, there have been six workshops with 24-30 teachers attending each workshop. One entire school district has pledged its support to the program, allocating monies for materials, allowing teachers free time to attend workshops and supplying them with the appropriate materials and services to make the program a success. It is anticipated that within the next year this program will have grown to include as many other schools as the Sea Grant personnel are able to handle. Our intention is to train a core of bilingual teachers who will in turn assist us in the workshops to train other teachers.

International Assistance

After presenting the marine education philosophy in both Costa Rica and Chile, South America, to groups of educators, and experien-

cing their positive reaction, USC Sea Grant began searching out ways of helping the Latin American countries in setting up their own marine education programs.

Our first endeavor was a proposal to the National Sea Grant Office for programs in Costa Rica and Chile to evaluate the effectiveness of the marine education philosophy as implemented in California, for other cultures. This proposal did not receive funding. However, two things happened: First, Costa Rica took that proposal, revised it and translated it into Spanish and received funding from the Costa Rican Government for that portion which pertained to their country. During 1980-81 Sea Grant Marine Education at USC will work with CEMEC, the science education division of the national science department, CONTACYT, in providing written materials, workshops, and methodologies for implementing the marine education program in Costa Rica.

The second thing that happened was the Tinker Foundation in New York granted the USC Marine Education Program funding for a workshop in Los Angeles of twelve days to bring fifteen Latins from eight Latin American countries and Puerto Rico, to acquaint professionals with the marine education philosophy, written materials and methods for implementation in their countries. This workshop will be held in January, 1980, at the University Hilton Hotel, near the campus. Professionals from the School of Education, Geology, Public Administration, Biology, Engineering, etc., will be participating in the program. An Advisory Board that is made up of University professors, public educators, and international experts has been helpful in planning the workshop.

Resource Library

The Resource Library, although limited in number of publications, has been an important asset to the staff within the Sea Grant Education Program, to the University students working with the innercity program, for the bilingual teachers working with our program, and to the teachers at the Magnet schools using marine education materials to fulfill their science obligations. The programs developed for these groups specifically use the materials available in the Resource Library as supplementary activities and sources of information for the lesson plans.

During the past year another 75 - 90 books have been added to the Resource Center, plus a substantial gift of supplementary materials donated to the Center. The microfiche library has been expanded. A bibliography of available materials from the Resource Center was compiled and mailed to interested teachers in the Los Angeles area.

There seems to be some reticence in using the microfiche library, probably due to lack of experience. Teachers seem to feel more comfortable with the available written materials than in taking time

to use the microfiche reader and then printing films of interest. MEMS has endeavored to up-grade the quality of their films and has increased the number of available materials considerably. It is anticipated that teachers will begin recognizing the importance of the microfiche library and use it more often.

The Resource Library was never intended to meet the statewide need of marine educators but certainly fills a specific need among the educators in Southern California using Sea Grant programs. Our goal is to have available those materials that will assist teachers in making the marine education programs more informative, exciting,and stimulating.

Adult Education Program

In past years the Adult Education programs have been well attended. This year, because the cost of conducting these programs has escalated tremendously we tried a different type program which was unsuccessful. The abundance of similar programs through YMCA and other public recreation facilities made our programs overpriced. We will have to look at the adult need of continuing education programs in marine oriented areas and revise our thinking and program format to meet that need.

Extra-Curricular Activities

In conjunction with the many programs already mentioned in this report, the Marine Education Personnel are being invited to participate in a variety of projects which ultimately provide new opportunities and visibility for marine education in California. To mention a few: serving on the Committee of the statewide Marine Education Association in preparing and coordinating a statewide Conference, serving on the Marine Technology Board in the University Student program, consulting with film corporations in developing marine related education films, participating as a member of the Committee for the development of a new science oriented high school near USC, elected to and serving on the USC President's Advisory Board. This position provides an opportunity to influence decisions regarding the governing of the University, plus visibility for the marine education programs now being conducted through Sea Grant.

We are experiencing a natural development of cohesive marine education programs as a direct result of the curriculum materials developed by Sea Grant for the public schools. Interest in the marine environment is being stimulated and educators are making new commitments to the uses of and preservation of the marine environment. The Marine Education Program will continue to be sensitive to the expressed needs of Californians in becoming more intimately acquainted with their marine world.

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GRADUATE STUDENT TRAINEE PROGRAM

Dorothy M. Bjur

The opportunity to fulfill needed research for an advanced degree while working on a marine related project with a professional is an opportunity few graduate students are offered. The USC Sea Grant Trainee Program offers this possiblity to qualified graduate students at USC.

Trainee applicants are selected on the basis of their scholastic qualifications and their interests adaptable to the overall USC Sea Grant theme: "The Planning and Management of California's Coastal Resources." Applications are reviewed by a Selection Committee and selected students are assigned to a Sea Grant Project. The project should be one that will either provide the student with thesis material or provide a training program in their major field.

Selected students are awarded a fixed amount of money to be paid in nine equal payments over nine months. In special cases, a Traineeship may be awarded for a shorter period at proportionately smaller total amounts.

During 1978-79 there were thirteen graduate students participating in the Traineee Program. Their names, degrees sought, and project assignment were as follows:

Robert E. Bowen
Ph.D. in International Relations
The Impact upon California of World Ocean Decisions

Kay L. Brodersen
M.S. in Geological Sciences
Offshore Sand and Gravel Resources in San Pedro and Santa Monica Bays, Southern California

Peter L. Brosnan
M. A. in Broadcast Journalism
Marine Advisory Serives

Julie Chen Hsiao-Li
Masters in Urban and Regional Studies
The Economic Impact of Marine-Related Industries on Southern California

Wen-Li Chiang
Ph.D. in Civil Engineering
Problems of Harbor Modeling

Keith L. Duncan
Ph.D. in Pathology, Medical School
Benzo(a)pyrene Induction of Tumors in Flatfish

William T. Gorham
Ph.D. in Biology
Heterotrophic Metabolism of Marine Dinoflagellates

Blayne A. Hartman
Ph.D. Oceanography
Sediment Accumulation and the History of Pollutant Accumulation in San Francisco Bay

David W. Krempin
Ph.D. in Marine Biology
The Role of Natural Populations of Microheterotrophs in Carbon Cycling in Southern California Coastal Waters

Sarah McGrath
Ph.D. in Biology
The Role of Natural Populations of Microheterotrophs in Carbon Cycling in Southern California Coastal Waters

Richard C. Murphy
Ph.D. in Biology
Marine Education Program and Ecology of a Small Tidal Lagoon Under the Influence of Urban Recreational Use

Marianne Ninos
Ph.D. in Biology
Southern California's Nearshore Marine Environment: A Significant Fish Nursery

Sarah E. Swank
Ph.D. in Biology
Southern California's Nearshore Marine Environment: A Significant Fish Nursery

There have been 15 published articles by the Trainees during this past year, plus four dissertations completed. Several of the Trainees have co-authored books and/or presented papers at conferences.

This program offers a unique opportunity to provide combined research, education experience, and advisory services. Under the direction of faculty members, the graduate student pursues reserach topics which are important to Sea Grant goals and which fulfill degree requirements. Through interaction with other Trainees, they learn more about other disciplines and thus become specialists who can deal effectively with a broad range of social, economic, and scientific problems. Through the Marine Advisory Services staff, the Trainees become famliar with the needs of the ultimate recipient of Sea Grant work and the public. Thus, from the beginning, education, training, research, and public service have been important in order to guarantee Sea Grant's applicability to the citizen user.

By providing a stipend and the opportunity to work with professionals while completing their graduate work, the students are given the incentive needed to complete their degree and become effective professionals in their field. On a very practical level, the burden of providing financial assistance to qualified graduate students in specific Sea Grant research areas can be partially relieved by the Trainee assistance.

This investment brings more than adequate return. With the experience provided in this program, these students are better prepared to fill leadership roles in research and development in marine-related fields. Further, the students bring additional perspectives to each research team and make substantive contributions to research results.

The students have expressed in many ways their appreciation for the opportunity of working with Sea Grant and continuing needed research. As they enter the job world they also find their experience as Trainees has been helpful in making them especially attractive to future employers. Several of their comments were: "The research experience gained during my tenure as a Trainee was a vital asset toward 'landing' my teaching position." "The experiences I have had in the Trainee Program have qualified me to work in marine education, communication, and research, all of which are useful on my new job." "My Sea Grant Training was valuable in securing my present position in several ways, especially when I could offer my employer some geological experiences besides my schoolwork. The computer experience I gained as a Trainee will be invaluable in my future work."

The additional perspective and enthusiasm these graduate students bring to the Sea Grant Program makes a substantive contribution to the entire Program.

MARINE ADVISORY SERVICES

The programs and structure of Marine Advisory Services are designed to achieve the goals of both USC and the national program---to provide liaison between marine resarchers and marine resource users. However, due to USC's location in a major metropolitan area and also to the fact that we share the state with another Sea Grant program, some selectivity in subject matter is possible, i.e., an emphasis on problems more concerned with urban institutions and less concerned with such elements as fisheries and aquaculture.

The three continuing specialist programs, coastal planning, mass communications, and management, deal with these subjects in a manner particularly relevant to our southern California region.

An additional program area, R/AS-1, also deals with a phenomenon which is regional but which has application on a larger scale---that of the management of fragile marine resources in a coastal area that is subject to heavy recreational use.

A/S-1

MARINE ADVISORY SERVICES

Stuart Ross, Director; James A. Fawcett, Coastal Planning Specialist;
Shirley J. Hudgins, Communications Specialist

The goal of Marine Advisory Services is to deliver information and expertise needed to help people solve marine resources management and development problems. It seeks to be the link between on-campus researchers and the communities of California—channeling the ideas and research needs of the community to the researchers and delivering the results of research to the appropriate users of that information.

For 1978/79, three programs were emphasized. One program was in coastal planning: California has more multiple-use problems along the coast and more ambitious attempts to deal with the problems than most other coastal states. An additional program was in mass communications: increasing marine awareness and information generally among the public facilitates appropriate public and private decisions about marine resources, and Los Angeles is a world center for the mass communications industry. A third program, newer than the others, concerns marine policy: with regard to offshore energy and other policy problems, specialist assistance is needed by both public and private groups.

Although the programs are reported separately for purposes of indicating that each person has concentrated primarily on one area, it should be emphasized that the three staff members, in fact, work in close daily contact with one another. Each made substantial contributions in time, energy, and expertise to the work of the others. This cooperation has proceeded very smoothly, and it makes the advisory services staff very flexible and resourceful in responding the the needs of outside groups.

Coastal Planning in California

James Fawcett

During this year, as in previous years, progress was made on four fronts: educating public groups about the coastal planning process, assisting individuals and groups involved in particular planning problems, stimulating research by faculty members, and educating university students.

In early October, a monograph was published detailing the permitting

procedures of the California Coastal Commission. This monograph is intended for persons likely to be very involved in the process, i.e., developers, environmentalists, public officials, and others. More than 1000 copies have been distributed as of January 1980, including response to multiple-copy requests from two of the regional coastal commissions. For these audiences, the monograph represents the first concise but fully accurate summary of the California coastal permitting process ever available. Previously, the only materials available were either journalistic summaries or legal tomes. The months of research and writing which went into this publication are expected to pay large dividends in making this regulatory process comprehensible to the layman. The monograph was written with Barbara Katz of the University of California Marine Advisory Program and published jointly by both universities.

A proceedings of the joint USC/UC marine adivsory conference, Recreational Access to the Coastal Zone, held in March 1979, will be published late in the year. The proceedings is the compilation of the remarks of 25 speakers, who, in the two days of the conference, discussed recreational access to the shoreline from a number of perspectives. The 25 public officials, environmentalists, developers, and journalists who spoke to the audience of 200 addressed problems such as: the limits to access, the costs of access, and the criteria for an adequate access plan. They reviewed legal principles, management practices, planning techniques, and political realities in light of the experiences of cities throughout the country.

Every week requests for information or assistance come in from individuals or private groups who are engaged in some aspect of coastal planning. These requests have been answered as fully as possible in writing or by telephone, although the Advisory Services role precludes becoming directly involved on the side of any applicant. During the past year, the coastal planning specialist has given particular attention to a group of local fishermen in developing materials and techniques for presenting their interests in the development of a new port plan for Los Angeles Harbor. The group he has helped was originally referred to him for special assistance by the UC marine advisor who was located at that time in the USC advisory services office. The specialist has met at times weekly with that planning committee or its individual members.

Three preliminary proposals on coastal management problems have been submitted to the USC Sea Grant program by faculty who have not previously been involved with Sea Grant, and in each case services rendered by the advisory staff have been instrumental in the development of the proposals. The proposals were for studies of state/local political relationships (in which the coastal planning specialist is co-principal investigator), recreational access to the coast for the handicapped, and housing problems in the coastal zone.

Finally, educational assistance has been provided to graduates and undergraduates in planning and public administration. The coastal planning specialist serves as a research resource for graduate students in both schools. He also has been selected by the Dean of the School of Planning as a practitioner-mentor to a group of second-year students in the

School of Urban Planning in teaching them what functions a planner in a position such as his might be expected to perform. In that role, he joins appoximately twenty-five of his professional colleagues in broadening the education of these students to include some appreciation of the role of the planner in practice.

Marine Information and Communications

Shirley Hudgins

The transition reported in the previous annual report, toward heavier involvement with the mass media, has continued. Several advisory programs using the mass media have been completed and several more have been started or are continuing. The Sea Grant publications program has also been strengthened, including greater support from the Institute for Marine and Coastal Studies (IMCS), USC Sea Grant's parent institution.

Major progress has been made in the area of radio communications. Los Angeles radio station KPFK has agreed to air radio programs prepared by the specialist and her staff and to distribute them to other stations in the Pacifica network as well as to university stations. These programs include a half-hour interview on dolphin studies and several shorter programs. Several programs had been finished in preparation for seeking air time and new programs are now being produced as rapidly as possible. Furthermore, a Spanish-language radio station, KLVE, has begun airing materials that the communications staff first prepared as newspaper fillers. Previously established radio programs, including especially the Marine Weather Watch on KNX, continue without interruption.

In teaching newspaper and magazine audiences, previous efforts have continued, and one new venture has been launched. The preparation of Sea Grant news releases and of filler material for local papers, in both Spanish and English, continued throughout the year, and the material is used extensively by the papers. Two articles on Sea Grant programs at USC have been prepared for Sea Grant 70's. At year's end, a new initiative was begun, namely, supplying seafood recipes from other Sea Grant programs to the food editors of the local newspapers. The South Bay Daily Breeze has been particularly interested, and began its use of the recipes with a special story on Sea Grant in its November 14, 1979, issue.

Two projects have been undertaken in film communications. One was a short film done to cover the beach clean-up efforts of the Oceanic Society at Malibu Lagoon. Another was the initiation of planning for a film on coastal management in California. Current plans are for a film of approximately one hour that would cover critical issues in the California coastal zone; the film would be used primarily for school and civic groups but would also be suitable for television use. Outside funding will be sought for the production of the film.

Further progress was made during the year on one potentially major television project. The staff has been working with the Children's Television Workshop (CTW) to include marine science information in its forthcoming science series for children. In August, meetings were arranged between a CTW vice president and the manager of the IMCS Catalina laboratory to discuss filming and possible subject coverage.

The specialist has also been preparing a nationwide resource book for the use of media representatives, giving them access to the expertise available in the nation's Sea Grant programs. As part of her role as West Coast regional representative to the Sea Grant communicators group, she has been compiling and editing the materials submitted by the communicators at other Sea Grant programs. It is hoped that once the format and procedure are established the directory can be updated every year or two, perhaps by various Sea Grant programs in turn.

The Sea Grant publications effort was also strengthened during the year, with the hiring by IMCS of a full-time editor to carry out the tasks of final editing and production on Sea Grant and other Institute documents. IMCS also prepared, for the first time, a publications manual detailing the character of and procedures for its various publications. The advisory services staff, which has always had the central role in Sea Grant publications, retains responsiblity now for coordinating publication. This year six reprints, two dissertations, two advisory services publications, and one research report were published.

In addition, the communications specialist has been called upon to provide advice and assistance to other groups on their communications programs. The specialist participated in the site review for the Maine-New Hampshire Sea Grant Program in September 1979. She also participated in a seminar for USC public relations personnel, gave a class on media usage for KCETTV at the USC Gerontology Center's annual summer workshop and the Los Angeles region section of the Marine Technology Society, and the Los Angeles Chapter of the Oceanic Society in their public relations effort.

Marine Policy

Stuart Ross

In 1978/79 the advisory services staff broadened its expertise in the realm of marine policy by the addition of a social scientist as Director of Advisory Services. This work builds upon and assists the work already underway in coastal planning and communications.

A paper on the organization of federal marine agencies has been contributed to a book on marine policy, intended for students at the early gradaute level. Other contributors include USC faculty from the department of International Relations and the School of Public Administration.

No comparable book exists, yet the need for such texts is growing rapidly. The book will appear in 1980.

Plans have been laid, or work is underway, for contributions to the series of newspaper fillers, for a brochure on the problems associated with oil drilling offshore California, and for teaching a course in the School of Public Administration.

Program Coordination and Management

Stuart Ross

With the arrival of a new Director of Advisory Services in June 1979, after a prolonged vacancy in that post, coordination and support for the advisory services are now considerably stronger. This work has sought to (1) facilitate the work of the existing specialists, (2) provide resources that are generally responsive to the region's marine information needs, and (3) prepare for additional specialist programs in the future.

One principal effort has been to create or renew ties to individuals and groups in marine-related groups in the Los Angeles area. The two incumbent specialists already had substantial connections in their own areas; the director has attempted to broaden and expand contacts at other levels as well.

Another effort has been the maintenance and use of information materials. The MAS library has been made more available to students and faculty; computer literature searches have been done for faculty members; the procedures for the preparation and distribution of Sea Grant publications has been clarified.

Finally, effort has been put into the establishment of program priorities. This has included guiding the incumbent specialists on the selection and implementation of specific projects as well as working with them and others on establishing general directions for the future. As for the latter, it is now informally understood that our next major programs, when budgeting becomes available, will be in the areas of marine recreation and/or marine transportation. USC has had or plans considerable work in both areas, and both of them are very important to southern California.

Until June 1979, much of the administration work was carried out by James Fawcett, in addition to his other duties.

R/AS-1

IMPACT CRITERIA FOR ACCESS MANAGEMENT IN ROCKY COASTAL ECOSYSTEMS

JOSEPH S. DEVINNY

State and local agencies have begun to acquire beaches with diverse and fragile terrain including bluffs, sand dunes, and tidepools. These fragile resources require specific management regimes to ensure that opportunities for enjoyment and exploration by the public will be maintained without destroying the natural resources.

The California State Department of Parks and Recreation funded the present study in which part of an environmental impact study will be prepared for the opening of Topanga Beach for public use. It was anticipated that the number of visitors to the area would rise sharply, but predicting the impact of this development on the intertidal ecosystem was difficult. In many cases, the literature referred to such damage or described it in general terms. But the damage was neither described in detail nor related in a quantitative way to the number of visitors.

When the project began, only one study (Chan, 1974) had provided information describing activity patterns and the degrees of impact associated with various levels of activity. The value of educational programs was established, but information on rates of recovery was still needed to develop a full management plan. No data existed which quantified the impact of people walking through tidepools or picking up rocks to examine organisms and replacing them, perhaps with a different surface exposed. When these activities are concentrated in one area, they can gradually destroy the resource.

It was clear that local officials had little information to work with for management and protection of rocky shore areas. The basis for rational judgment of the proper tradeoffs between public recreational use and ecosystem protection does not exist.

The overall goals of the project are:

1. To determine what levels and types of recreational use will permit the continued reproduction and diversity of marine biota in a rocky coastal ecosystem.

2. To provide guidelines for beach management authorities that will enable them to balance recreational use with ecological preservation by controlling the number of visitors to these fragile environments and providing appropriate interpretive educational programs to minimize damage caused by use of the environment by the public.

3. To demonstrate the recovery rate of a damaged rocky shore ecosystem that is excluded from public use.

Goals established for the first year were:

1. To refine, to establish firmly, and to practice a standard technique for ecosystem assessment at the study sites.

2. To develop and examine methods of measuring the level of public use, selecting the best method for meeting project goals.

3. To complete winter and summer interviews at Abalone Cove and to distribute questionnaires to all users of Abalone Cove on specified days

4. To compile initial data concerning the nature and magnitude of the effect of recreational use on rocky shore ecosystems.

RESULTS

The results of the project in the first year can be summarized in terms of first-year goals:

1. Study sites and survey systems were established, and data was collected. Twenty-eight sites were visited, mostly twice each, for a total of 54 separate surveys. Approximately 100 different species were identified.

2. The degree of public use was measured for three months. Lifeguard observations were compiled and are being computer-analyzed to quantify weekly, seasonal, and long-term variations in the number of visitors to shore areas. Aerial photographs, taken in cooperation with the U.S. Coast Guard, are being analyzed to determine local use patterns and to compare beach areas. Finally, the local distributions of visitors——where they go within each study area——were determined by direct counts from vantage points overlooking the areas.

3. Questionnaires have not yet been prepared and distributed. However, the recently reported work of Joy Zedler (1978) provides some of the information that was to be sought.

4. Considerable amounts of data have been compiled and are being analyzed. Individual species distributions are being correlated with use patterns. Each species list is being entered into a computer file. When this step is completed, elaborate statistical analyses can be performed easily.

The basic goals set for the first year were essentially completed. Two of them were modified: as previously described, the questionnaire part of the study was not done, and some individual experiments, such as the effects of rock-turning and footsteps, were eliminated because Zedler (1978) had already performed these.

A project to erect cages on a heavily used shore and to monitor recovery of the protected areas was also planned. It was to be an independent but closely related experiment funded by the Los Angeles County Fish and Game Commission. Initiation of this work was delayed, but it is likely to begin by January 1980.

The major results of the work will be available only when data analysis is complete. However, two articles based on the project were presented at the Sea Grant conference on coastal access in March 1979. The result was then compared to and combined with the published data of Chan and Zedler. The resulting table was included in the conference proceedings and is presented here as Table 1.

PROJECT COMMUNICATIONS

1. Devinny, J.S., S. Fallaahi, J. Ghazanshahi. 1979. An introduction to the effects of recreational use on rocky intertidal ecosystems. Proc., 1979 California Sea Grant Conf. on Recreational Access to the Coastal Zone. Office of Coastal Zone Management, Washington, D.C.

2. Zedler, J.B. 1978. Public use effects in the Cabrillo National Monument intertidal zone. 1978 project report. Biology Department, San Diego State University, San Diego, California.

TABLE 1

Species Affected by Public Use

Mytilus californianus (common mussel)

Chan	Much lower abundances in high-use area, $2/m^2$ vs $422/m^2$ in low use area
Zedler	Lower abundances in high-use area; decreased abundance when use was increased
Devinny	Much lower abundances in high-use area

Mytilus is taken for food and bait, and may be damaged by trampling or tampering. A major predator, however, is the seastar, which is severely reduced in abundance by even light use. Mytilus is the keystone species of a well-developed intertidal community, and many associated species are no doubt lost with it.

Piaster sp. (seastar)

Chan	Much lower abundances in high- or moderate-use areas; $0.03/m^2$, $0.007/m^2$ vs. $0.9/m^2$ in low use area
Zedler	Found only 2 specimens in a moderate-use area; probably in abundance much lower than natural areas
Devinny	Found no specimens in high- or low-use area, though many were seen on nearby inaccessible pilings

Piaster sp. is a favorite souvenir. It is taken despite the most strenuous efforts to dissuade collecting. Loss of the significant predatory activity of Piaster is likely to alter communities considerably.

Acanthina spirata (rock snail)

Chan	Lower abundances in high-use area; no effect in moderate-use area
Zedler	Data inconclusive for the related species, A. lugubris

Acanthina is an attractive snail and may be collected by casual visitors. It is an important intertidal predator.

TABLE 1 (cont)

Lottia gigantea (giant limpet)

Zedler	Found the size distribution changed in a high-use area; large specimens were absent
Devinny	Specimens over 2 cm totally absent in high-use area; common in low-use area

Lottia is taken as food, so the largest individuals disappear first. Because the large individuals defend large territories, their elimination may result in an increase in the competing populations of limpets or barnacles.

Collisella digitalis (limpet)

Zedler	Lower abundances in high-use area when C. digitalis was generally abundant. Experiments showed C. digitalis easily killed by disturbance. Average size was less in an area of heavy use
Devinny	Found lower abundances in high-use areas

Collisella digitalis is a large attractive limpet and may commonly be taken as a souvenir. If it is dislodged and not carefully replaced, it will die; like all limpets, it cannot right itself. Zedler also showed that just wiggling the shell caused a 12% mortality rate because the anti-dessication seal with the rock was broken.

Pragmatopoma california (sand castle worm)

Zedler	Lower abundance in high-use area

P. californica builds fragile tubes of sand and mucous. Colonies are easily crushed or broken off by a single footstep, and trampling may be the cause of loss.

Spirorbis sp. (calcareous tube worm)

Zedler	Experiments show this worm, which usually grows on the bottoms of rocks, dies within a few weeks if the rock is turned and left.

Table 1 (cont)

Anthopleura sp. (anemone)

Chan	Much reduced abundances in areas of moderate or high use
Zelder	Increased abundance in areas of high use, despite common visitor harassment
Devinny	Reduced abundances in high-use areas

Anthopleura is poked by visitors who wish to see it retract and squirt. It seems likely that this could result in loss of some individuals, and may be the cause of the reductions seen by Chan and Devinny. The contrary results found by Zedler could result from the loss of a locally important competitors or another unknown cause.

Balanus glandula (acorn barnacle)

Zedler	Possible reductions in high-tide, high-use areas
Devinny	Lower abundances in high use areas

Balanus may be crushed by foot traffic

Chthamalis fissus (buckshot barnacle)

Zedler	Experiments showed continuous trampling could cause significant damage. But abundances were higher in high-use areas.
Devinny	Observed bare spots on rocks commonly used as stepping stones. Overall, abundances were higher in high-use areas

Chthamalus can be destroyed by heavy foot traffic, but where the use is not severe, it is benefitted. This may result from elimination of the predator, Piaster, or the competitor, Balanus.

Pollicipes polymerus (gooseneck barnacle)

Devinny	Much lower abundances in high-use areas

Pollicipes is widely recognized as strongly associated with Mytilus. Its loss may be the result of the loss of the mussel. Game hunters also take Pollicipes as food.

TABLE 1 (cont)

Phyllospadix scouleri (surf grass)

Zedler	Abundance increased in area where use was reduced

Phyllospadix is probably damaged by trampling. It is the keystone species for a well-developed marine community, and its loss may cause loss of associated species or increases in populations of competitors.

Centroceras clavulatum (filamentous red alga)

Zedler	Higher abundances in areas of high use

Centroceras is a small alga which rapidly invades areas where the biological community has been disturbed. Zedler (1978) suggests public use may provide it with an opportunity for rapid colonization.

Coralline algae

Zedler	Lower abundances of Corallina spp. in areas of high use. Experiments further showed Corallina spp., Jania crassa, and Lithothrix aspergillum are broken or destroyed by foot traffic
Devinny	Corallines (primarily Bossiella plumosa) exhibited a "cropped" appearance in the high-use area where it occurred on rocks which were convenient stepping stones.

Coralline algae may be particularly susceptible to trampling because they are abundant on horizontal rock surfaces, are brittle, and grow slowly.

Gulls, sea lions

Devinny	Gulls were abundant and sea lions commonly sighted in low-use area. Occurrences were far fewer in the high use area. These are typical of higher species whose feeding or breeding may be interrupted by repeated human distrubance.

SOCIO-ECONOMIC PROGRAMS

Project R/CM-11 had as its aim the measurement of the impact of marine-related industries on the southern California region as a whole and on individual sub-areas.

The importance of measuring this impact stems from the fact that marine trades depend largely on the level of trade through the Los Angeles Harbor and the Port of Long Beach. The objective of this project was the quantification of guidelines for estimating the effects of changes in scale and composition of the trade of the region's ports on the region's economy.

THE ECONOMIC IMPACT OF MARINE-RELATED INDUSTRIES ON SOUTHERN CALIFORNIA

Harry Richardson and Peter Gordon

Marine-related industries are a complex set of activities, some clustered around ports and others (particularly suppliers of inputs to the marine trades) dispersed throughout the region.

There has been no attempt to measure the economic impact of these industries, either over the region as a whole or in individual sub-areas. It is important that this impact be measured, since the marine trades depend directly on the level of trade through the ports (preeminently Los Angeles Harbor and the Port of Long Beach). The ultimate aim of this project is to quantify the economic impact (overall, regional, and sectoral) of marine-related industries on southern California as a guideline for estimating the effects of changes in the scale and composition of the trade of the region's ports on the regional economy.

Within the 12-month period of Sea Grant sponsorship, the scope of the research was to undertake a primary survey of firms associated with marine activities, to develop a data base, and to derive some basic tables showing the scale of intersectoral and interarea transactions. These data will subsequently be used for marine-related impact evaluation.

RESULTS

The major component of the research was the distribution by mail of a questionnaire to a comprehensive list of firms engaged in marine-related industries, asking primarily for information on sales and purchase flows by sector and geographical area of origin and destination. The list of firms was obtained by consulting various company directories, such as Southern California Ports Maritime Directory and Guide, Long Beach Area Chamber of Commerce Membership Directory and similar sources. In total, 2,200 questionnaires were distributed. The number of usable responses was 171, or 7.8 percent of the total. Although this may appear to be a low response rate it is about standard for a mail questionnaire. Also, it must be remembered that the survey was comprehensive, aimed at all identifiable firms rather than based on a highly selective sample.

Some of the major results of the survey are summarized in Tables 1 and 2.

Table 1 summarizes transactions between sampled firms, and is aggregated up to nine sub-regions of the southern California metropolitan area. The table can be read as revenues flowing from establishments in the row areas to firms in the column areas. Alternatively, the flow of goods takes place in the opposite direction.

Table 2 displays similar flows, but the data are in response to a question on purchases made rather than on the past year's sales.

Similar displays for 30 industrial sectors have been computed from our data file.

Beyond the project period, these data will be combined with existing models, either the Southern California Input-Output model or the Southern California Planning Model (developed with the aid of Sea Grant Project R/CM-10), to quantify the impact of marine-related industries on the southern California economy, in the aggregate and by region and sector.

TABLE 1

Sales Flow Between Regions

From	To 1	2	3	4	5	6	7	8	9
1/	258040000	321500	811780	4300	982000	0	0	0	0
2/	765380	2719600	654320	585540	218740	1020000	132500	7537.5	449620
3/	326500	482670	180130000	160390	262600	1433300	3343300	50024000	2550
4/	275000	589500	51145000	1773700	983250	122500	0	100020000	0
5/	659800	350000	318900000	135320	126800	500000	0	50925	0
6/	179560000	319500	4500	0	666700	70000	0	0	0
7/	0	108500	134500	0	0	0	5135000	0	0
8/	119400000	92890	51065000	26520	586900	29300	0	100060000	0
9/	876350000	10255000	155970000	61968000	465560	1000000	10369000	604890	161680000

TABLE 2

Purchase Flows Between Sub-Regions

From	To 1	2	3	4	5	6	7	8	9
1/	16424000	273350000	610670	3535500	193200	26894000	5445	67513000	7395700
2/	289830	314040000	234000	1187000	267030	2369200	38250	0	145390
3/	3933600	788040	813340	1119100	354720	313810	22000	0	232250
4/	2568	85527	8000	3116200	0	73440	0	0	47415
5/	218550	161610000	88619	1685600	278630	671380	3645	7875	17378
6/	36000	41287	0	628290	113150	15750000	405	0	64648
7/	0	0	0	145400	0	1373300	15606	0	27881
8/	37461	0	90000	692720	105880	52500	0	0	0
9/	702980000	71921000	2706600	18345000	330500	2080800	25153	67500000	564820

TABLE 3

List of Sub-Regions

1. Central Los Angeles and International Airport Area
2. Ports area
3. San Fernando Valley and West San Gabriel Valley
4. Orange County
5. East Los Angeles
6. West Los Angeles and South Bay Cities
7. Santa Monica and North Beach cities
8. East San Gabriel Valley and Pomona area
9. Outside the immediate five-county area

R/CD-1

CURRICULUM DEVELOPMENT AND RESEARCH STUDY TO SUPPORT AN ACADEMIC FIELD IN HARBOR/PORT MANAGEMENT

Willard Price and Gilbert Siegel

The study was motivated by the lack of an established academic curriculum in seaport amangement at USC and only limited activity at other universities. At the same time, the principal investigators are currently involved in the academic devellopment in public works/environmental management and view seaports as an important subset of that field. The opportunity to interface with USC's Institute for Marine and Coastal Studies was also a sufficient stimulation to this effort.

To address the field of seaport management, the following projects for 1979-80 were established:

1. Produce a concept of seaport management
2. Develop a curriculum design
3. Prepare initial course syllabi
4. Propose a research agenda

During the first year, this research used several methods of inquiry including interviews with seaport practitioners and university academics concerned with the seaport field, collection of selected data on the magnitude and operation of seaports on the west coast, reviews of literature and computer data bases, and discussions with other USC faculty and researchers.

Specifically, the forthcoming grant report for 1978-79 will include these sections:

1. Introduction to Research Objectives
2. Seaports as Public Enterprises - a conceptual introduction
3. Curriculum Design and Initial Syllabi
    a. Introduction to Port Policy and Management
    b. Port Financial Management
    c. Seaport Planning and the Coastal Zone
    d. Possible other courses:
        i. Environmental Management and Ports
        ii. Port Systems Analysis
        iii. Port Engineering and Development

4. Research Agenda

5. Selected Teaching Materials

   a. Coastal Zone Management and Seaports
   b. Cabrillo Project Development
   c. Federal Port Policy
   d. A Cry for Independence - A Case Study of the Port of Los Angeles
   e. Port Hueneme - A Small California Port
   f. Marine Management

6. Seaport Management - A Bibliography

The most interesting conclusion of this research is the need to understand seaports as public enterprises and to investigate the question of the extent of independence which exists across the seaport industry. Given that the ports of both public and enterprises, there will obviously be a need for some balancing between the independent enterprise or business-like management of the port and the interests of the public for control of the develolpment and impact of the port's activities. This latter isue is initially addressed in the conceptual piece on "Seaports as Public Enterprises" to be included in the grant report.

LIVING MARINE RESOURCES

In the area of living marine resources, environmental quality was the focus, particularly that of the harbor areas. Programs dealt with the question of bioamplification of marine pollutants, particularly in the food chain leading to man, and with the levels and health of marine life in the harbor areas.

One project investigated the nutrient value of organic nutrients to phytoplankton and whether or not all organic effluent other than natural run-off is potentially damaging to the marine ecosystem.

Southern California's potential as a significant fish nursery was investigated, with project goals of providing information on seasonal occurrences and abundances of fish eggs and larvae in nearshore habitats.

A complementary project sought to provide information on the role of natural populations of microheterotrophs in carbo cycling——information which can be used for evaluating the potential for water quality enhancement.

The fourth project investigated the ecology of a small tidal lagoon under the influence of urban recreational use to obtain a better understanding of the role of urban influences on coastal marine waters.

HETEROTROPHIC METABOLISM OF MARINE DINOFLAGELLATES

Bernard C. Abbott and Maria Ross

A series of major oil spills in the ocean (Torrey Canyon off the Cornish coast in 1969, the Platform A Santa Barbara spill in 1969, and Buzzard's Bay in 1976) triggered an awareness of marine pollution dangers. This has led to the generally accepted concept that except for natural rivers, all effluents to the ocean are detrimental, and, indeed, the elimination of effluent waste is a legally binding requirement in some states. However, not all waste materials are harmful, and waste materials discharged under supervised conditions can disturb the system in a manner that will enhance the natural resources. There is an increasing body of evidence which indicates that with suitable control, much of the biological waste can be used as nutrient material with the potential to increase productivity.

Dinoflagellates are a common cause of phytoplankton blooms ("red tides") in organically enriched areas. The occurrence of red tides has been an indicator of uncontrolled levels of high productivity. Though they are primarily autotrophic in their metabolism and derive most of the energy for metabolic processes photosynthetically from sunlight, many are known to be heterotrophic; yet, research concerning causes of blooms has only focused on inorganic nutrients or physical conditions. Consideration of these factors alone has proven insufficient to explain these blooms. We therefore are investigating organic compunds as an additional important factor in the growth of dinoflagellates because these organisms form an important component in the productivity of the ocean. The blooms that occur in Los Angeles and Long Beach harbors are often below the visible discoloration level and are evident only by the taking of cell counts or by measuring the oxygen content of the water. Bloom conditions in coastal waters are essential to the successful survival of fish larvae (Lasker 1975). Our studies have shown that in the presence of the nutrient waste materials from local fisheries, the levels of standing crops of dinoflagellates zooplankton and ichthyoplankton are enriched above the corresponding open coastal waters (Abbott et al. 1976). This appears to be due primarily to heterotrophic metabolism by the dinoflagellate cells of the nutrient organic components of the harbor area. It is probable that much of the organic material as well as dead test detritus is processed through bacteria that are present in the harbor waters. However, nutrients such as amino acids, fatty acids, carbohydrates, and vitamins are by-products of bacterial metabolism excreted into the sea water, thus becoming available as substrates for dinoflagellate species that are capable of heterotrophy. Culture studies indicate strongly that certain vitamins and organic substances must be added to maintain successful axenic cultures of many dinoflagellates (Provasoli 1963, Provasoli & McLaughlin 1963).

It is difficult to assess metabolic activities of the marine dinoflagellates in their natural habitat. The chemistry of the sea is complex, and the occurrence and cycling of organic matter in sea water is still an unsolved puzzle. It is imperative that we study the heterotrophic metabolism of the marine dinoflagellates in the laboratory as axenic cultures and learn of their capabilities to exist under various conditions which may or may not simulate precisely their marine environment. We are testing our hypothesis that some of the nutrient cannery effluent materials are utilized by the organisms that produce blooms. By use of radioactively labeled substrates, we will examine the effectiveness of the dinoflagellate heterotrophic capabilities under conditions of illumination such that photosynthesis is proceeding and also in the dark where incorporation responds to different conditions.

The majority of blooms observed in the Los Angeles and Long Beach harbor area as defined by our criteria have been dominated by some one species of dinoflagellates. Many of these blooms reached the visible state of a "red tide" (Oguri et al. 1974), and all represented states of intensive growth and concentration over that found in regular sea water. From these blooms, the dominant organism has been identified and cultured. The three experimental organisms were isolated as single cells and grown in chemically defined medium of Guillard and Ryther (1962) with F/2 metals and vitamins enrichment. Cultures were established as the cells divided. The unialgal cultures were treated with antibiotics according to the method of Droop (1967). The axenic unialgal cultures used in our experiments are maintained in our laboratory and are continuously monitored for bacterial contamination.

The overall goals of the project are being pursued at present. The study of heterotrophic metabolism and the kinetics of incorporation of amino acids is not in progress with all three experimental species.

RESULTS

Methods and Materials

Cultures were isolated from the Los Angeles and Long Beach harbors as pure unialgal species (Ross, et al., 1978) and then treated with antibiotics (Droop 1967) to obtain axenic unialgal species for the incorporation studies. The incubation temperature is 18°C, which simulates in situ conditions (MoreyGaines, 1976). Sea water enriched with F/2 metals and vitamins is used as the growth medium (Guillard and Rther, 1972). Cultures for the experiments are used 18 hr after innoculation (young culture) and 5 days after innoculation (old culture). Total volume for experimental cultures is 25 ml. Labeled substrates used are 4, 5 ^{3}H-Leuicine and ^{14}C-phenylalanine which are added to the cultures at a final concentration of 2.15 x 10$_{7}$M; 0.1 µci/ml of medium; specific activity 46- µci/umole.

Time of incubation, age of cultures, and illumination conditions are varied for the three species of dinoflagellates.

One-milliliter samples are removed for cell counting with a Coulter counter, Model B-100u window (Richar & Breakell 1959), for protein determination (Lowry et al., 1951) using bovine serum albumin as a standard and for incorporation measurement (Byfield & Scherbaum 1966) as modified by Ross (1970) on Whatman glass fiber (GF/A) filters to be counted in a Beckman scintillation counter, model LS 100, using the external standard ratio method.

Results are expressed as cpm/cell as a function of incubation time in hours or cpm/ug protein versus incubation time in hours.

Gonyaulax Polyedra

Incorporation of amino acids on a per-cell basis (Figures 1 through 6)

^{14}C-phenylalanine incorporation rate is higher for the 18-hr-old cultures than that for the 5-day-old cultures under all conditions of illumination.

The ^{3}H-leucine incorporation, although not significantly higher during the first 6 hr for the two cultures, is again observed to be higher for the young culture at 24 hr of incubation.

Incorporation calculated on a per-microgram protein (Table 1) shows that the incorporation rate of ^{14}C-phenylalanine under all illuminating conditions is approximately 10X greater in the 18-hr-old cultures than in the 5-dayold cultures——with the greatest incorporation occurring in the cultures that were incubated in total darkness where photosynthesis cannot interfere.

When comparing the incorporation of ^{3}H-leucine, the reverse is observed. No significant differences are noted with the variable illumination conditions, and the 5-day-old cultures seem to incorporate ^{3}H-leucine with a slightly higher efficiency for the first 6 hr but at 24-hr, incorporation of the 18hr-old cultures is higher.

These results suggest that G. polyedra is capable of heterotrophically taking up and incorporating the organic compounds (Hellebust 1970, Clark et al., 1972), in this case the amino acids leucine and phenylalanine, under all conditions of illumination. Further support for heterotrophy is the fact that the dark incubated cultures incorporated these amino acids at a much greater rate and concentration.

The difference of the rates of incorporation and the change in preference of amino acids between the young (18 hr old) cultures and old (5 day old) cultures suggests, perhaps, synthesis of different kinds of proteins during the life span of the cultures.

The lower incorporation observed in the older cultures suggests that metabolism may slow down with age, and/or that the by-products of metabolic processes excreted into the growth medium (Fogg & Nalewaijko 1964, Hellebust 1967a, Hellebust 1967b) are inhibitory to the organisms.

Scrippsiella Trochoidea

From the results shown in Table 2, the same pattern of incorporation of the two amino acids is once again observed with respect to young versus old cultures, and phenylalanine versus leucine. One difference noted is that incorporation of both amino acids is greatest in the total light incubation series, thus suggesting that S. trochoidea may combine autotrophic and heterotrophic metabolic pathways efficiently.

Incorporation of the amino acids on a per-cell basis reflects the results of the per-microgram protein basis (Figures 7 through 12).

Gymnodinium Sanguinium

G. Sanguinium (previously known as G. splendens) is the naked experimental dinoflagellate, whereas both G. polyedra and S. trochoidea are the thecate experimental species.

On a per-microgram protein (Table 3) basis, G. sanguinium incorporates leucine approximately 2X more than either of the armored species, irrespective
of the age of the culture and the illuminating conditions. It is as efficient as the two other species in incorporating phenylalanine. Leucine and phenylalanine incorporation rates are both higher under total dark incubation where photosynthesis is not operative. Figures 13 through 18 show the incorporation of amino acids on a per-cell basis between the young and old cultures for incubations ranging from time 0 - 24 hr. The pattern of incorporation seems not to vary among species with respect to the age of the cultures. This is not too surprising since all three species are isolates from the Los Angeles and Long Beach harbors. Refer to Map 1.

From the data obtained in these experiments it is difficult to speculate as to which of the experimental dinoflagellates would prevail in situ if all conditions were equal. Based on our experimental conditions, S. trochoidea appears to be most efficient in the light; on the other hand, G. polyedra and, to a lesser degree, G. sanguinium seem more efficient in the dark.

One conclusion which can be made is that these data support the hypothesis which we have proposed, i.e., that marine dinoflagellates can take up dissolved organic nutrients (Williams 1961; Andrews & Williams 1971; Clark et al. 1972; North 1975) from the sea water and incorporate these into cellular constituents necessary for growth and reproduction (Provasoli & McLaughlin 1963; North & Stephens 1967; Williams et al. 1976; Wheeler et al. 1977).

Experiments are now in progress with incorporation studies using other studies using other substrates (organic acids, carbohydrates, amino acids, and fatty acids).

Specific benefits derived from this project are numerous. The disposal of biological waste material both from food processing plants and from sewage plants presents a major problem for all cities and for all developing countries. Alternative methods of handling the waste materials must be studied intensively and extensively. As a country, we have, with minimal evidence, opted to dictate that all organic waste material be recovered as solid waste and dumped as land fill. Even for the wealthier countries in the world this may eventually prove to be a herculean task, and for developing countries it will be virtually impossible.

It is imperative that other systems of was the disposal be studied. We believe that controlled discharge of organic wastes can be handled by the receiving ocean waters to bioenhance and to increase the regional productivity. In our local situation, the value of nutrient waste from the fish canneries is a specific target for evaluation.

PROJECT COMMUNICATIONS

1. Paper entitled Heterotrophic metabolism of the marine red tide dinoflagellates: accepted for presentation at Am. Soc. Of Limn. & Ocean. mtg., Feb. 1980, Los Angeles, Ca.; submitted for publication to J. Limn. & Ocean.
2. Sea Grant Report, 1978: Isolation of marine dinoflagellates in pure cultures.
3. Paper entitled Growth and reproduction of Scrippsiella trochoidea cultures supplemented with amino acids: presented at conference of Committee for Advanced Science Training (CAST), by Laurence Ng, a high school student. The CAST program is a National Science Foundation funded high school student program. Larry Ng is once again in our funded high school student program. Larry Ng is once again in our laboratory and continuing his project with S. trochoidea: protein content of S. Trochoidea over the cell cycle.
4. Gorham, William Thomas (Sea Grant trainee). Factors controlling feeding in bivalves. Research proposal for Ph.D. oral examination.
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6. Andrasi, Alexander. Molecular biology of the marine dinoflagellates. Ph.D. dissertation, University of Southern California, Los Angeles, Ca. (in progress).

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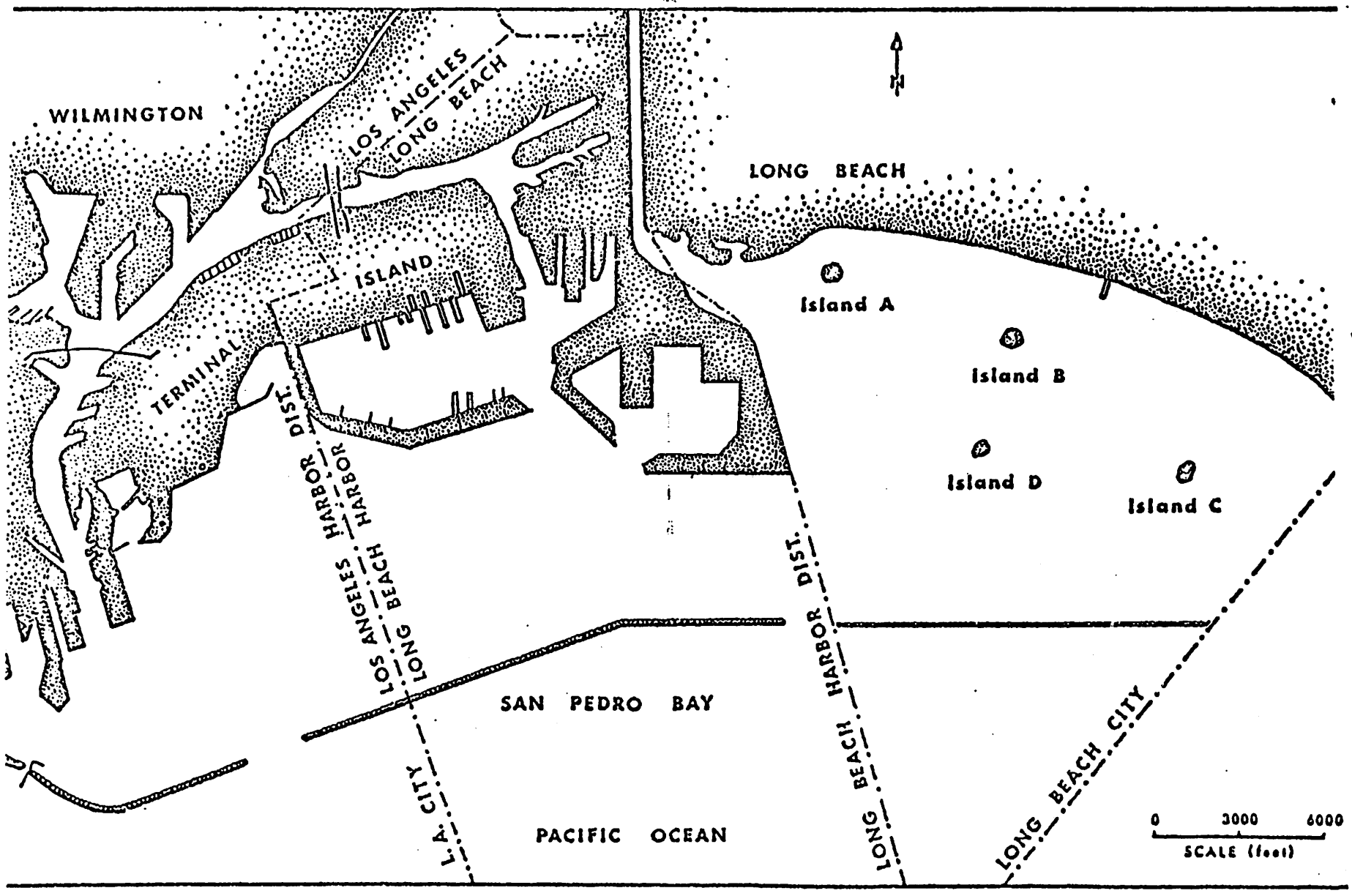
Map 1. LOS ANGELES - LONG BEACH HARBOR



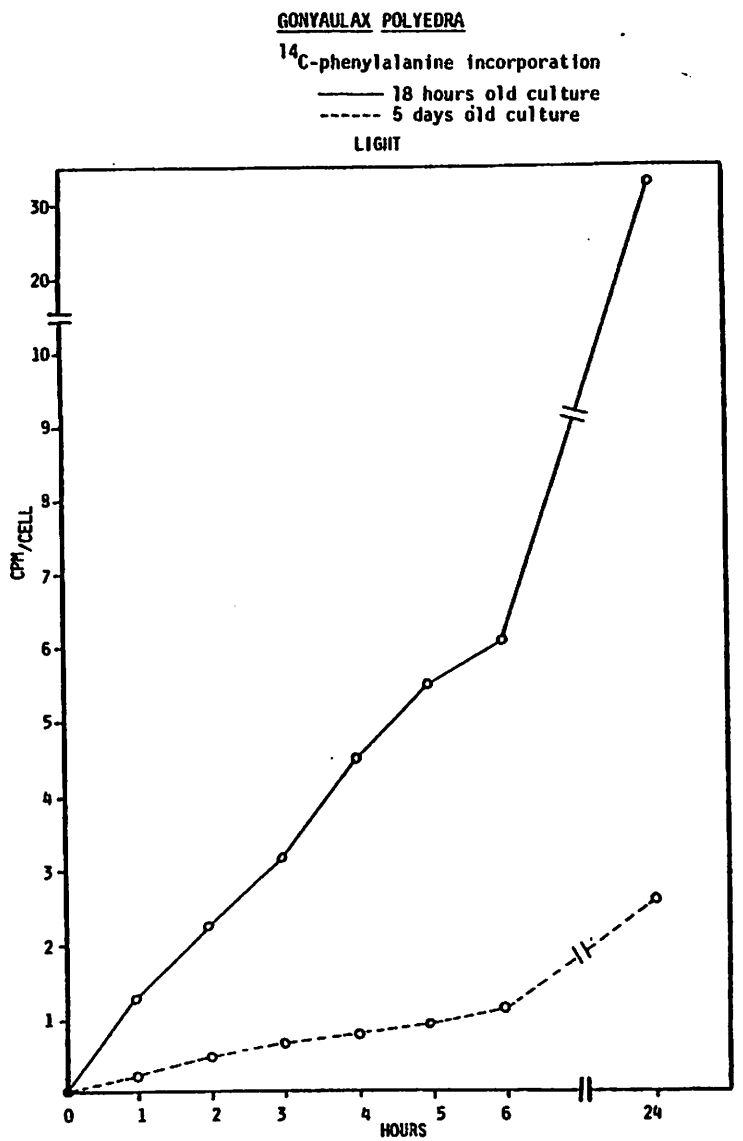


Figure 1 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

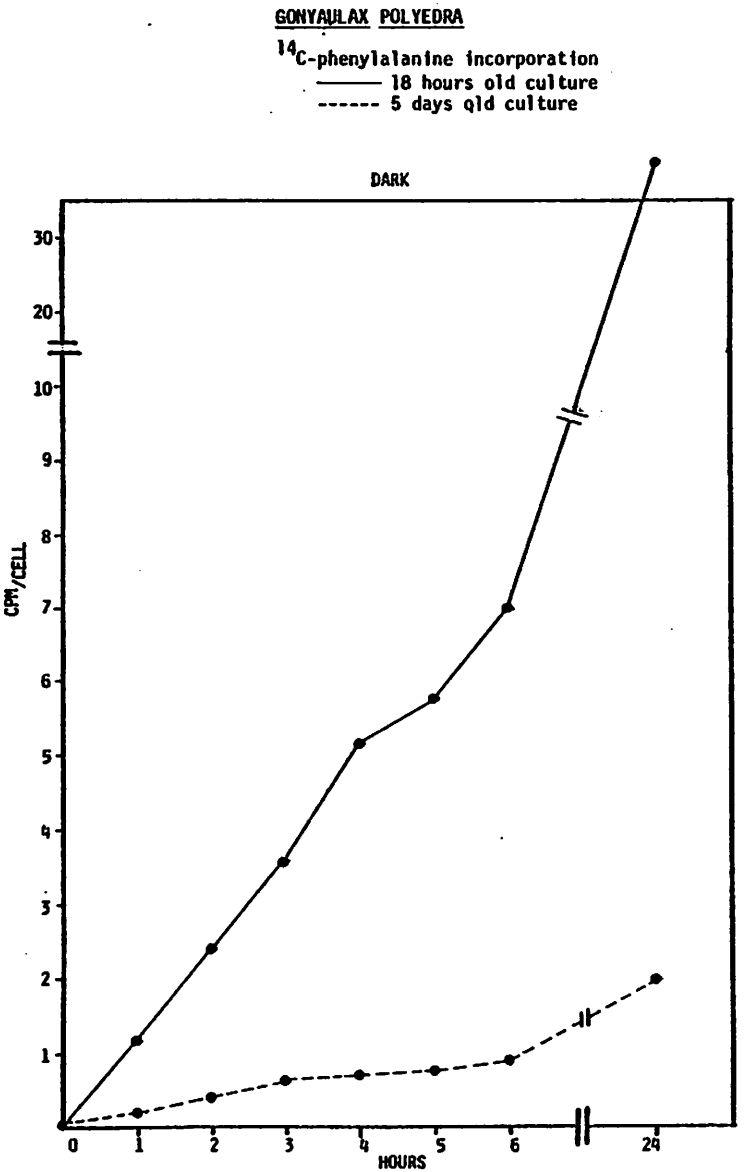


Figure 2 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

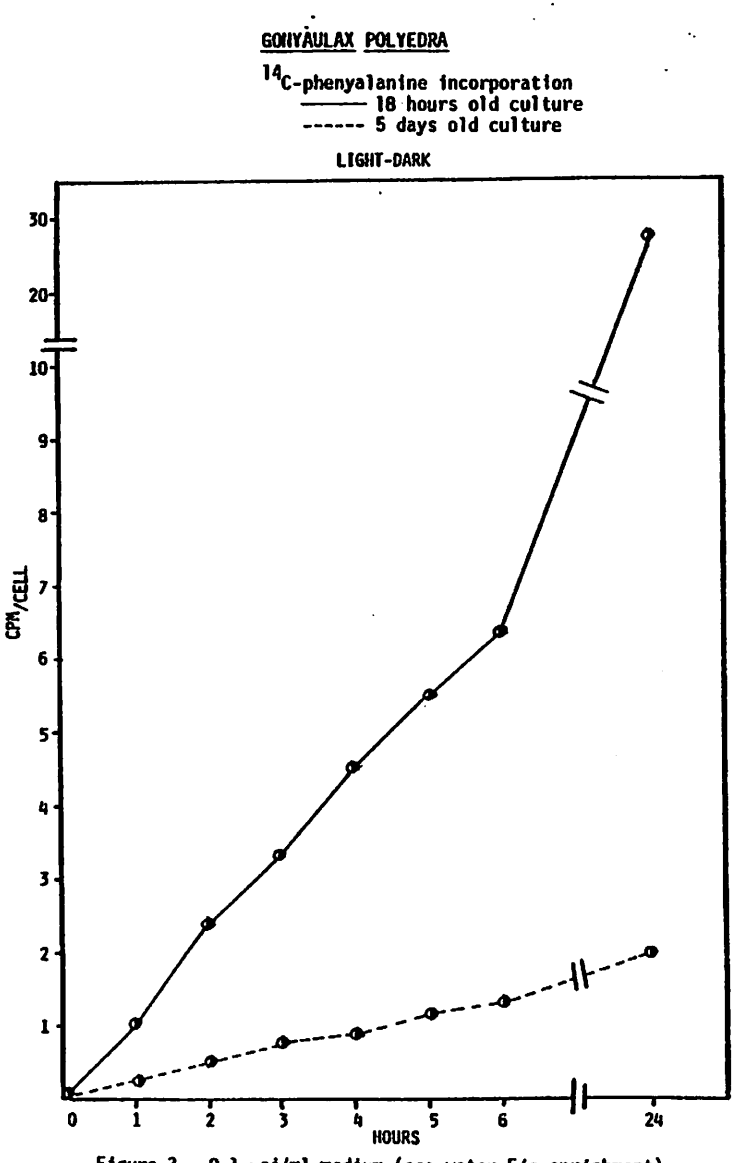


Figure 3 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

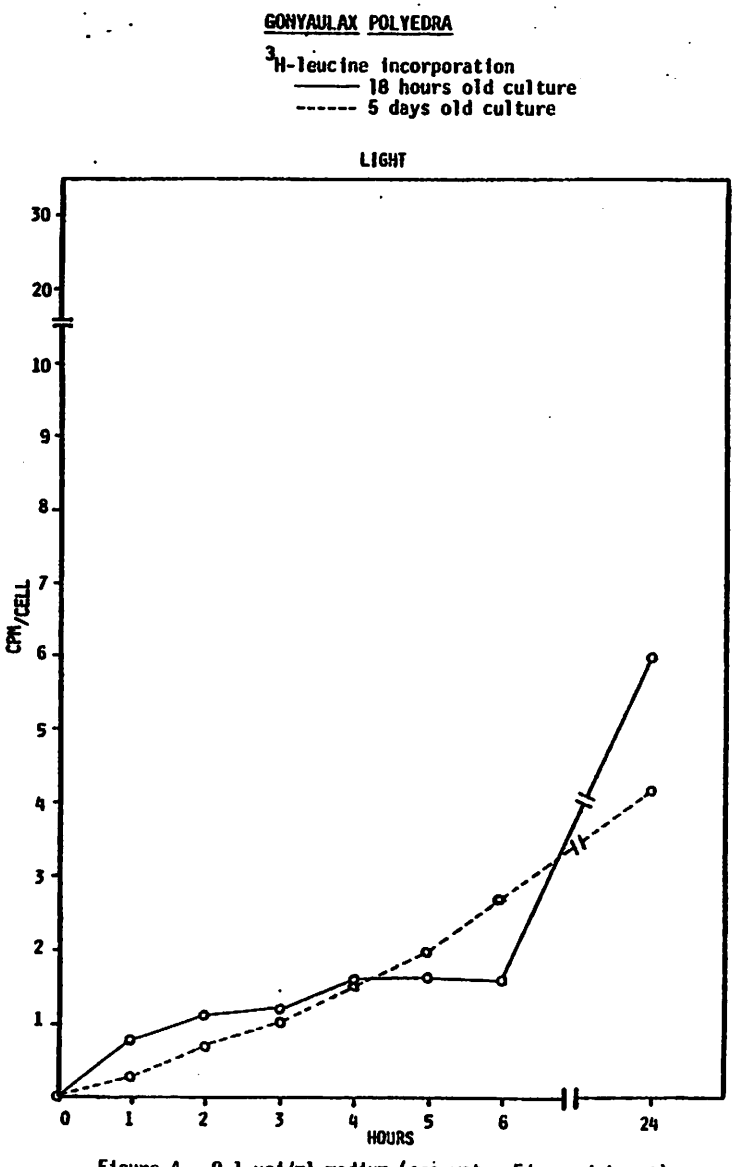


Figure 4 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

GONYAULAX POLYEDRA

^{3}H-leucine incorporation
——— 18 hours old culture
------ 5 days old culture

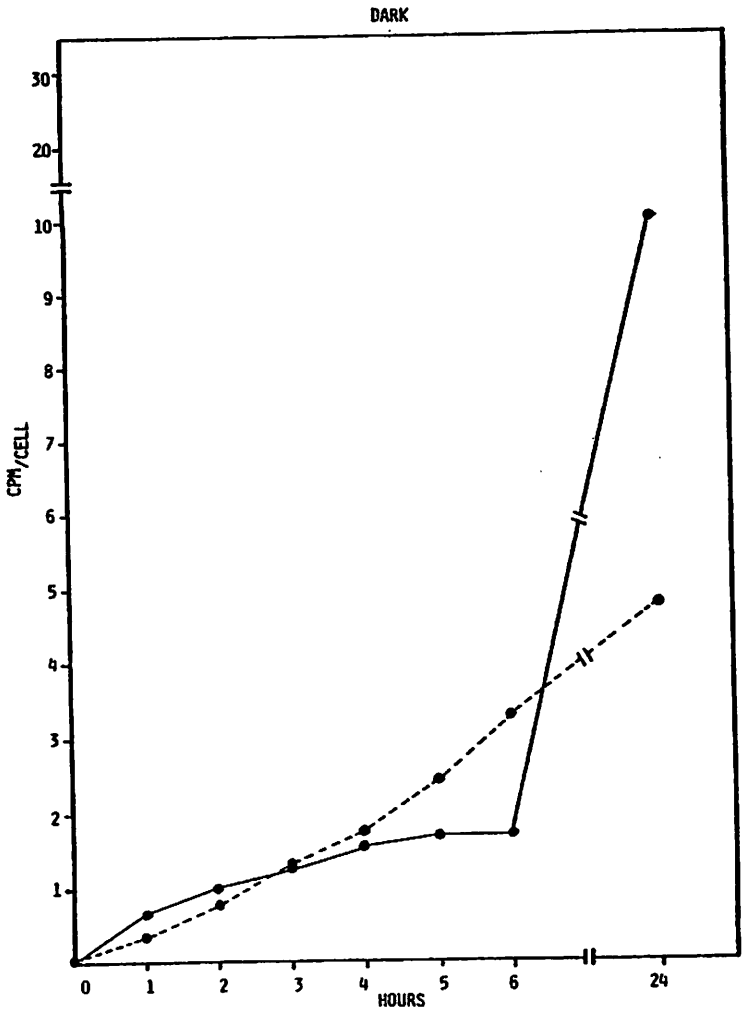


Figure 5 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

GONYAULAX POLYEDRA

^{3}H-leucine incorporation
——— 18 hours old culture
------ 5 days old culture

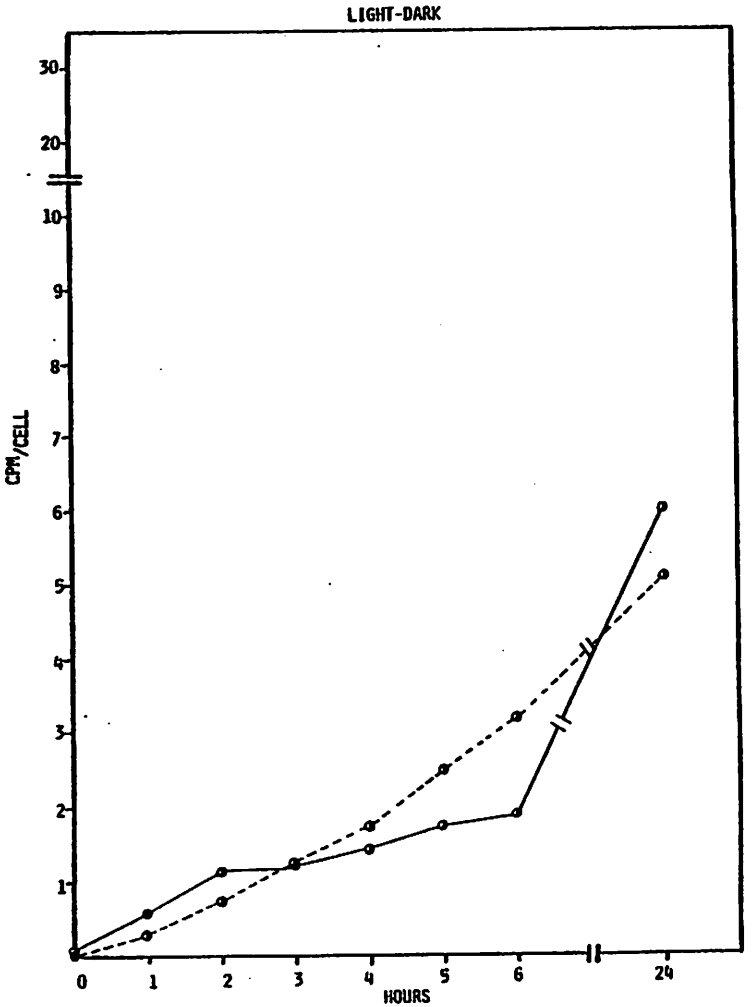
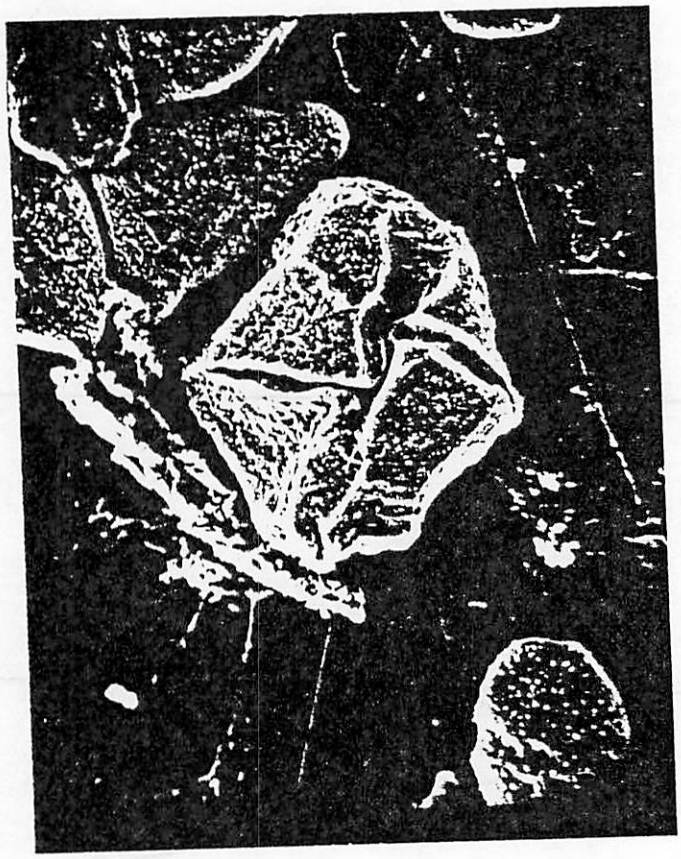


Figure 6 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M



GONYAULAX POLYEDRA

MAG. 1400X

GONYAULAX POLYEDRA

^{14}C-PHENYLALANINE INCORPORATION

CPM/µG PROTEIN

	18 HOURS OLD CULTURE								5 DAYS OLD CULTURE							
HOURS	0	1	2	3	4	5	6	24	0	1	2	3	4	5	6	24
LIGHT	18	293	520	725	1027	1260	1396	7482	2	52	117	156	193	215	262	574
DARK	15	307	606	903	1296	1446	1758	9985	5	59	122	162	182	210	241	537
LIGHT-DARK	15	247	550	769	1026	1265	1456	6382	11	60	129	185	216	265	313	455

^{3}H-LEUCINE INCORPORATION

CPM/µG PROTEIN

	18 HOURS OLD CULTURE								5 DAYS OLD CULTURE							
HOURS	0	1	2	3	4	5	6	24	0	1	2	3	4	5	6	24
LIGHT	18	178	255	280	377	380	371	1366	0	68	168	247	360	450	625	945
DARK	14	171	249	312	386	423	422	2507	0	91	203	331	443	608	832	1200
LIGHT-DARK	14	133	267	282	333	400	439	1371	0	84	177	294	399	557	749	1166

Table 1 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

SCRIPPSIELLA TROCHOIDEA

^{14}C-phenylalanine incorporation

——— 18 hours old culture

------ 5 days old culture

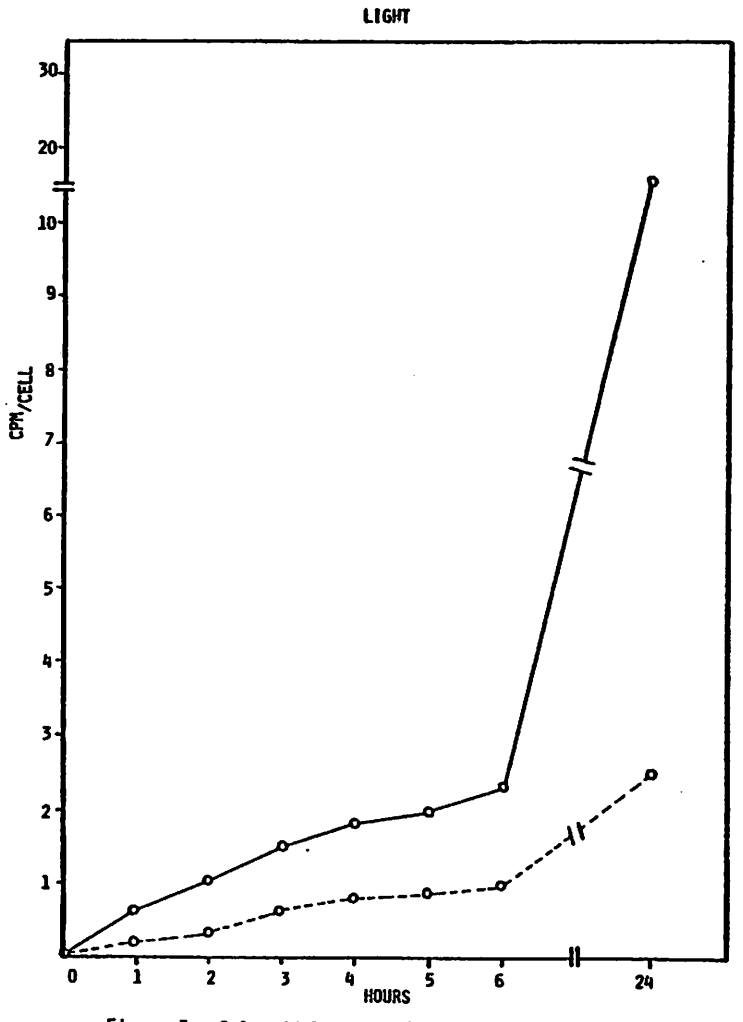


Figure 7 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

SCRIPPSIELLA TROCHOIDEA

^{14}C-phenylalanine incorporation

——— 18 hours old culture

------ 5 days old culture

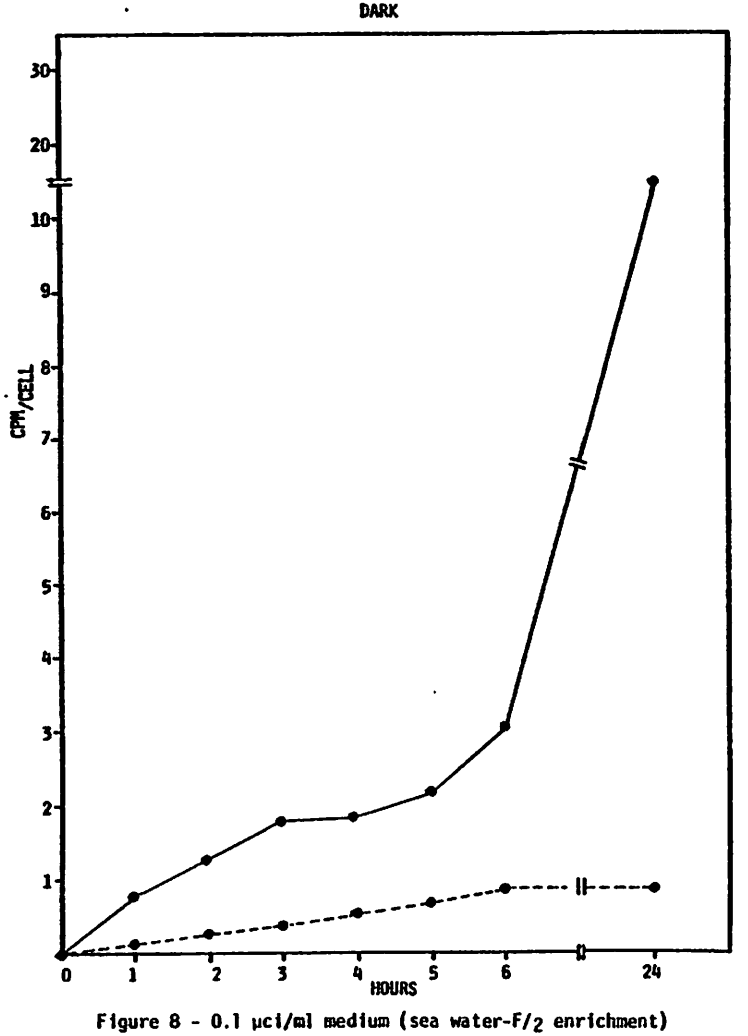


Figure 8 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

SCRIPPSIELLA TROCHOIDEA

^{14}C-phenylalanine incorporation
——— 18 hours old culture
------ 5 days old culture

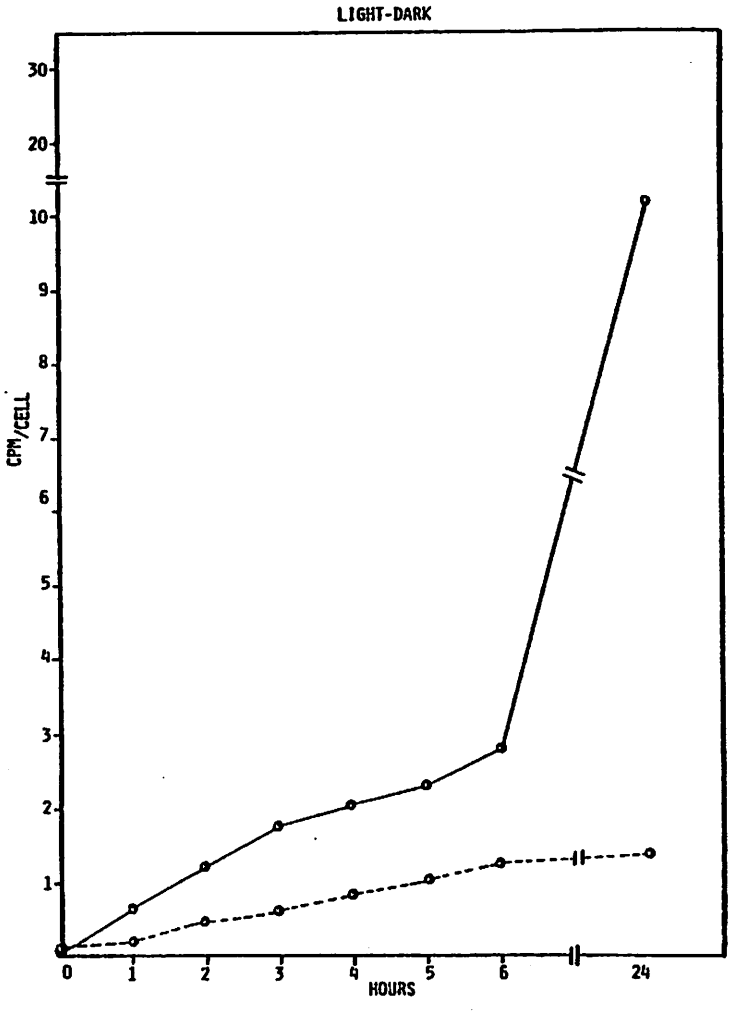


Figure 9 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

SCRIPPSIELLA TROCHOIDEA

^{3}H-leucine incorporation
——— 18 hours old culture
------ 5 days old culture
LIGHT

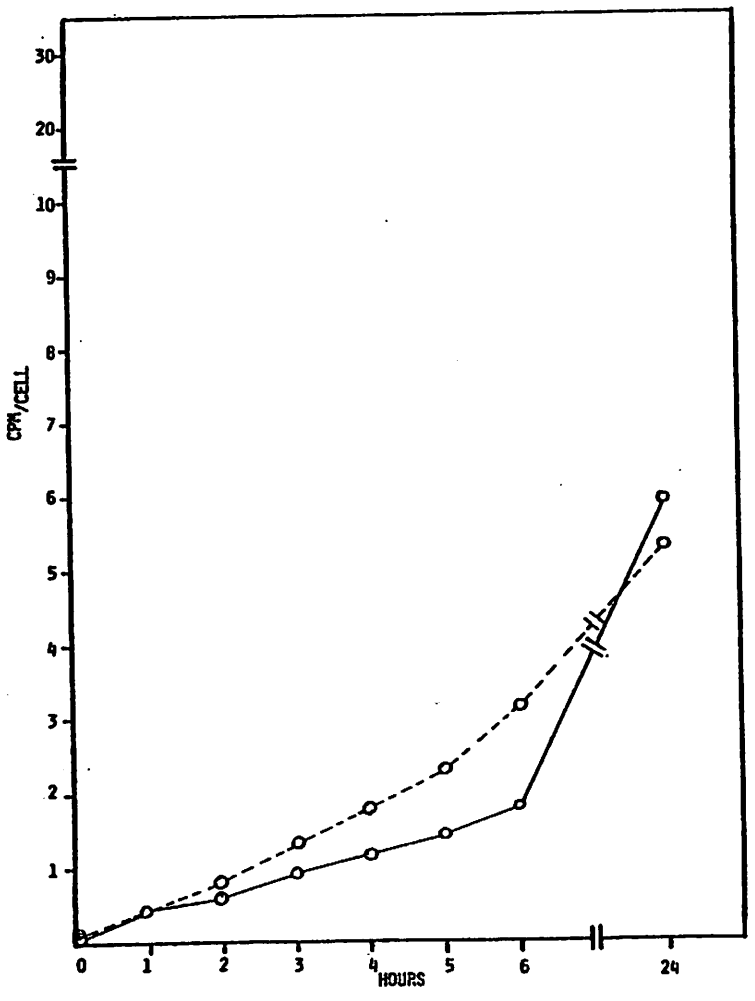


Figure 10 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

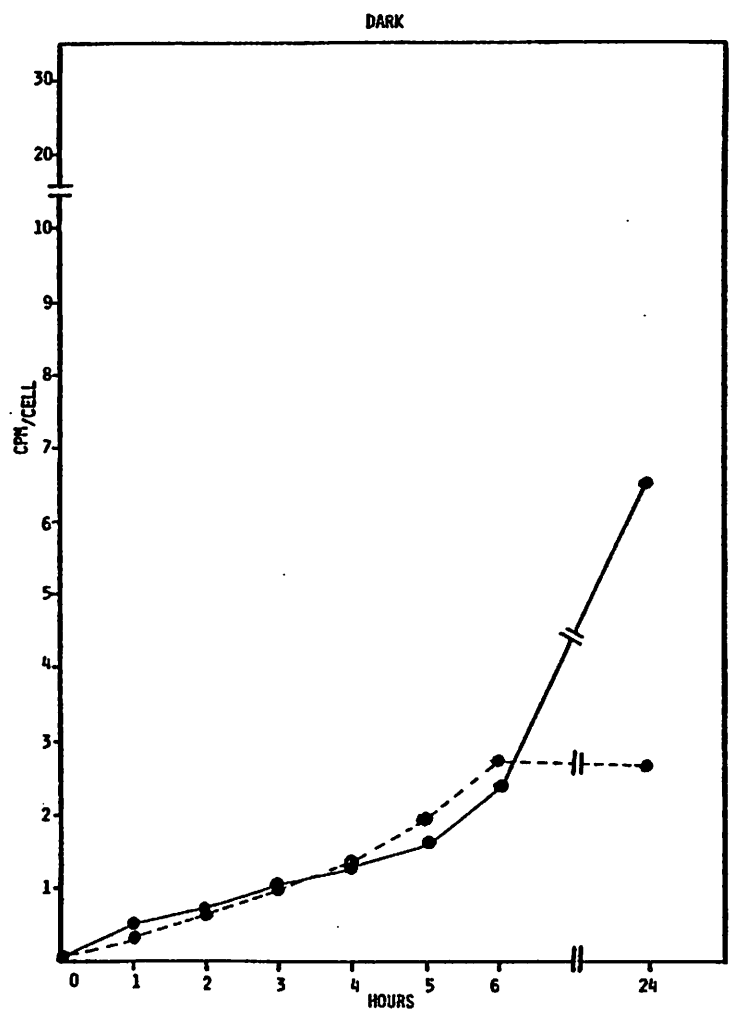


Figure 11 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

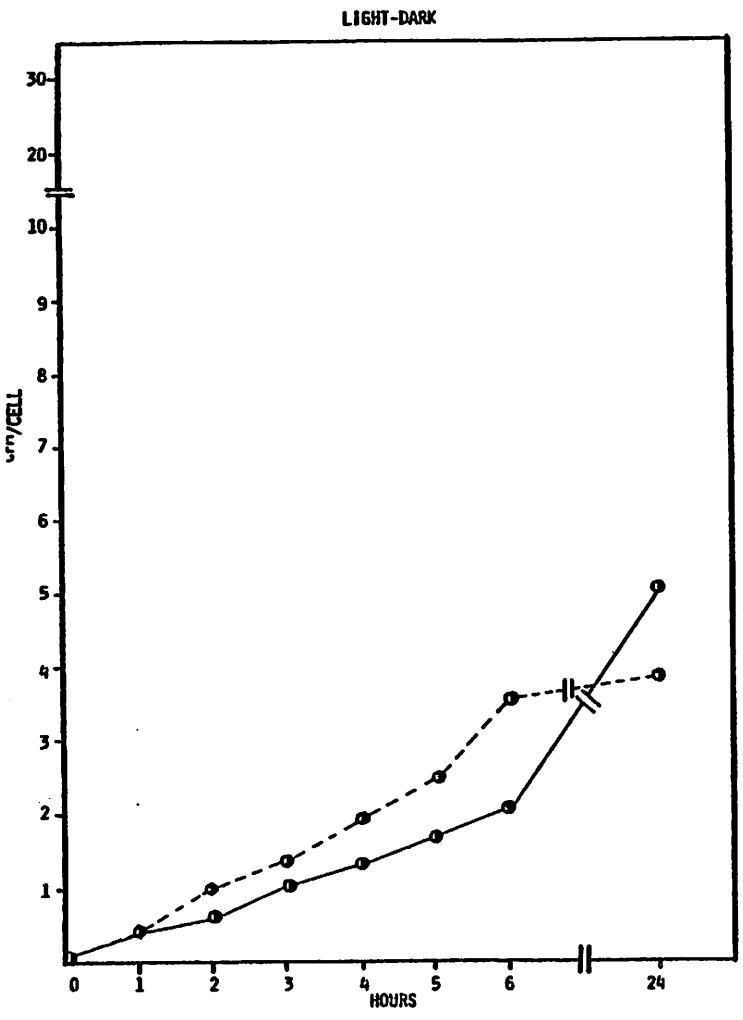
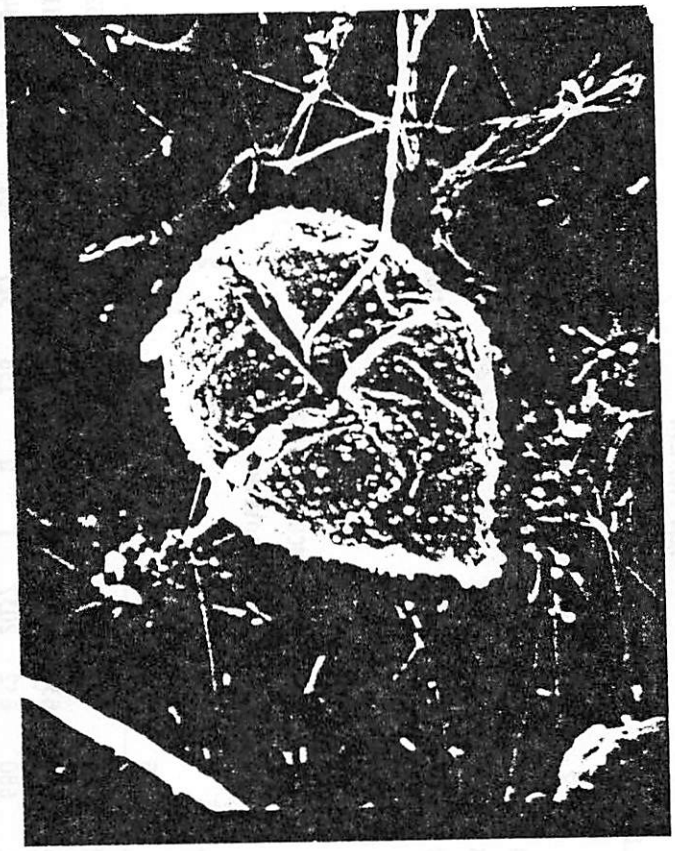


Figure 12 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M



SCRIPPSIELLA TROCHOIDEA

MAG. 2800X

SCRIPPSIELLA TROCHOIDEA

^{14}C-PHENYLALANINE INCORPORATION

CPM/µG PROTEIN

	18 HOURS OLD CULTURE								5 DAYS OLD CULTURE							
HOURS	0	1	2	3	4	5	6	24	0	1	2	3	4	5	6	24
LIGHT	18	298	475	697	820	891	1028	7326	5	108	202	300	367	444	560	848
DARK	9	222	345	489	513	597	836	4098	4	82	153	221	286	355	450	689
LIGHT-DARK	15	266	483	708	813	945	1124	4747	4	76	148	211	284	330	422	676

^{3}H-LEUCINE INCORPORATION

CPM/µG PROTEIN

	18 HOURS OLD CULTURE								5 DAYS OLD CULTURE							
HOURS	0	1	2	3	4	5	6	24	0	1	2	3	4	5	6	24
LIGHT	20	188	258	402	522	629	791	2645	1	222	408	668	904	1152	1587	1749
DARK	8	138	193	288	346	435	631	1743	1	149	307	502	691	981	1382	2014
LIGHT-DARK	11	161	265	408	541	680	832	2037	0	138	327	462	657	834	1188	1927

Table 2 - 0.1 µci/ml medium (sea water-F/$_2$ enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

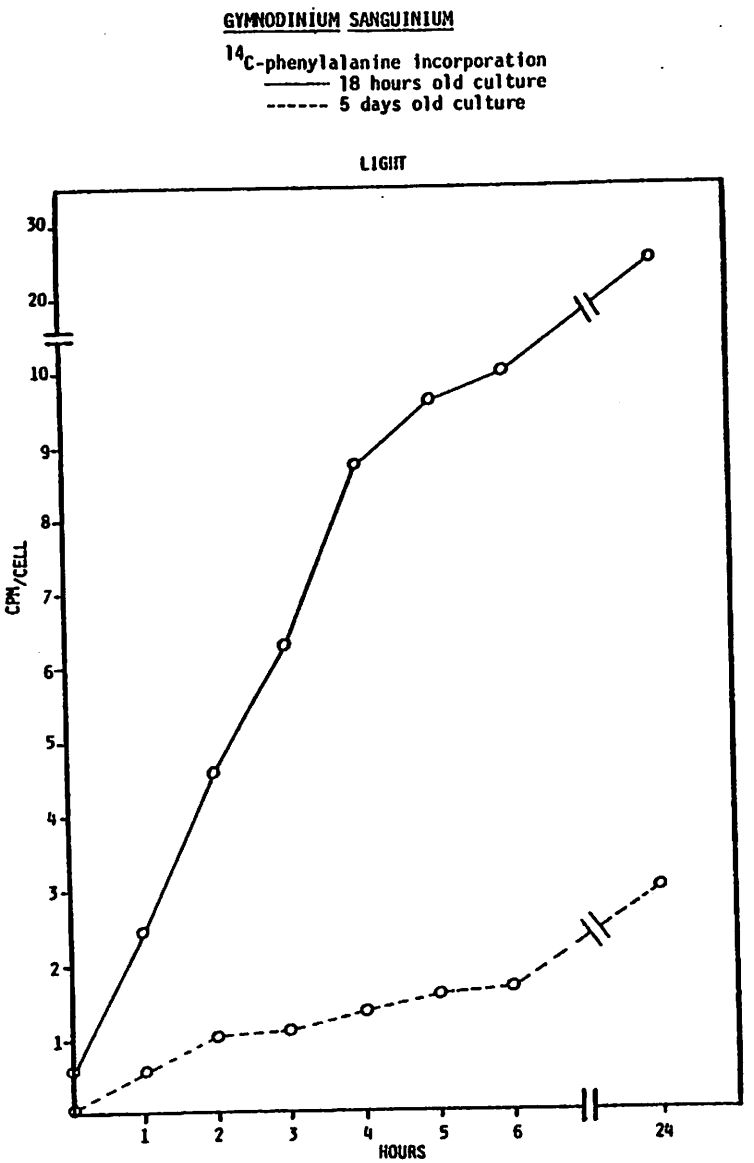


Figure 13 - 0.1 µci/ml medium (sea water-F/$_2$ enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

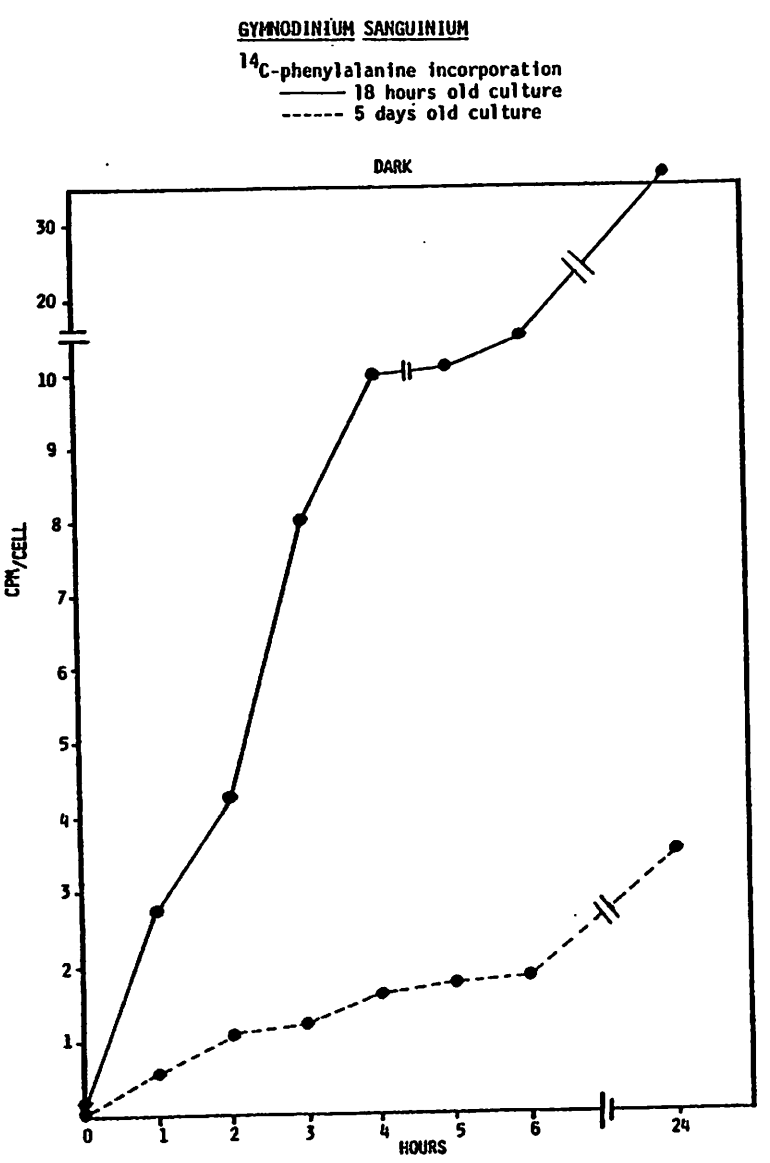


Figure 14 - 0.1 uci/ml medium (sea water-F/$_2$ enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

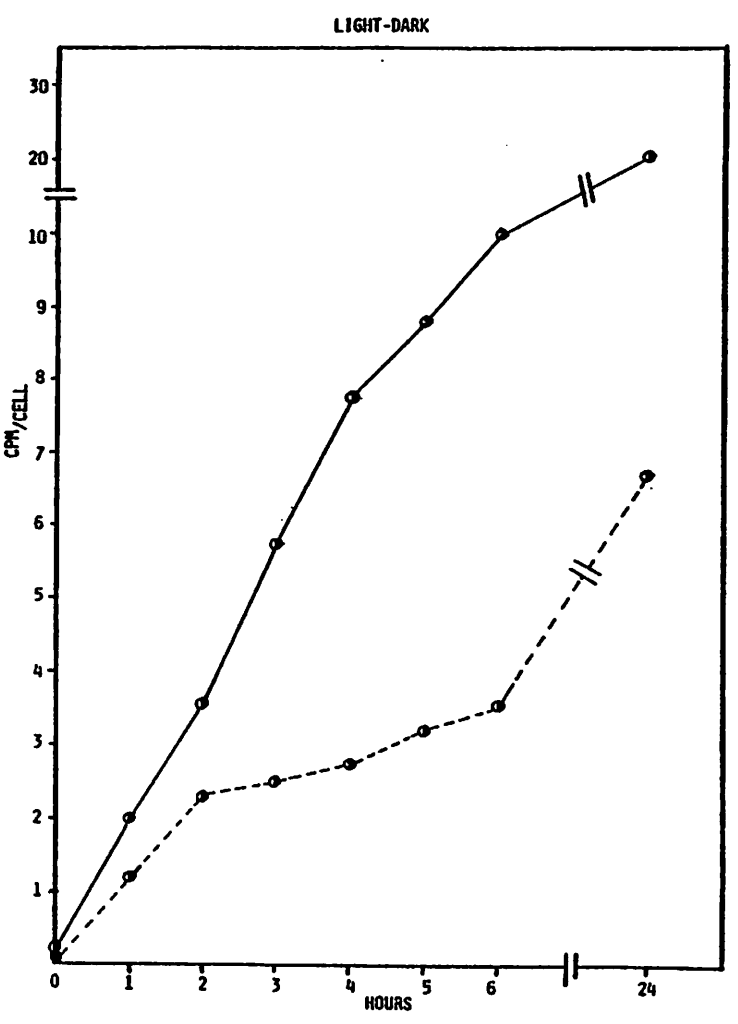


Figure 15 - 0.1 µci/ml medium (sea water-F/$_2$ enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

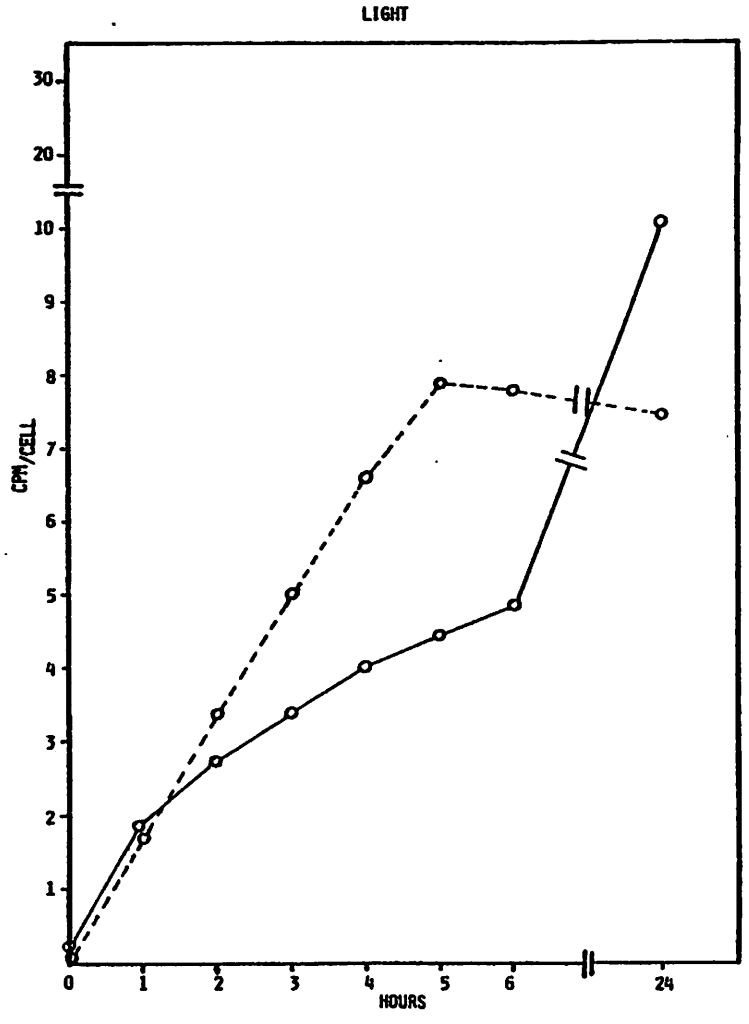


Figure 16 - 0.1 µci/ml medium (sea water-F/$_2$ enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

GYMNODINIUM SANGUINIUM

^{3}H-leucine incorporation
——— 18 hours old culture
------ 5 days old culture

DARK

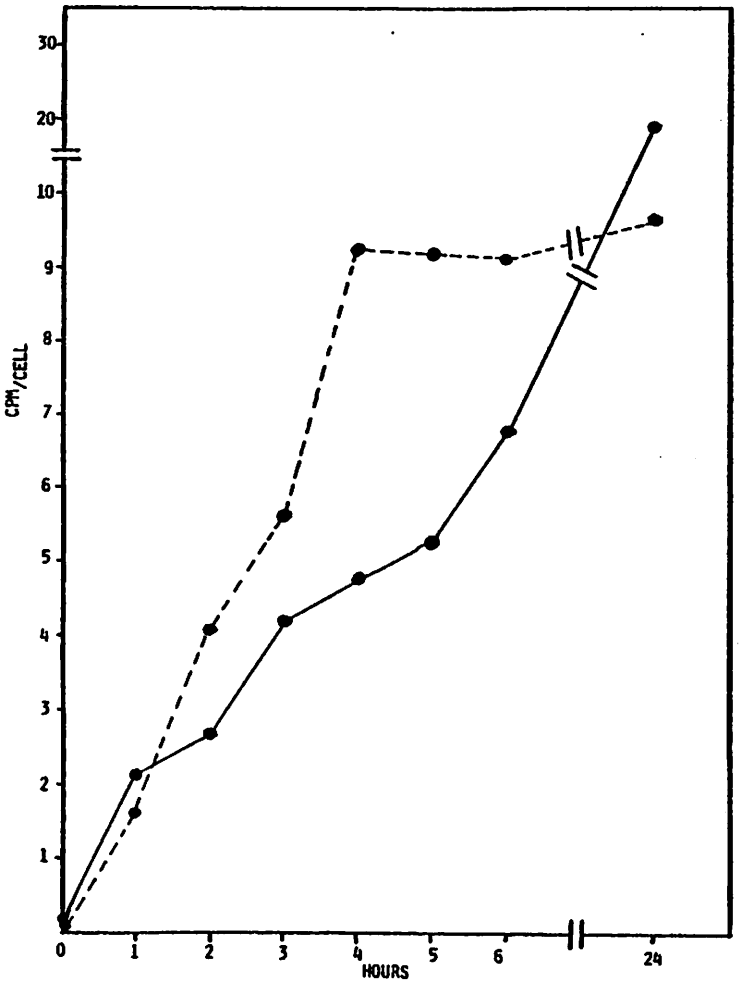


Figure 17 - 0.1 µci/ml medium (sea water-F/$_2$ enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

GYMNODINIUM SANGUINIUM

^{3}H-leucine incorporation
——— 18 hours old culture
------ 5 days old culture

LIGHT-DARK

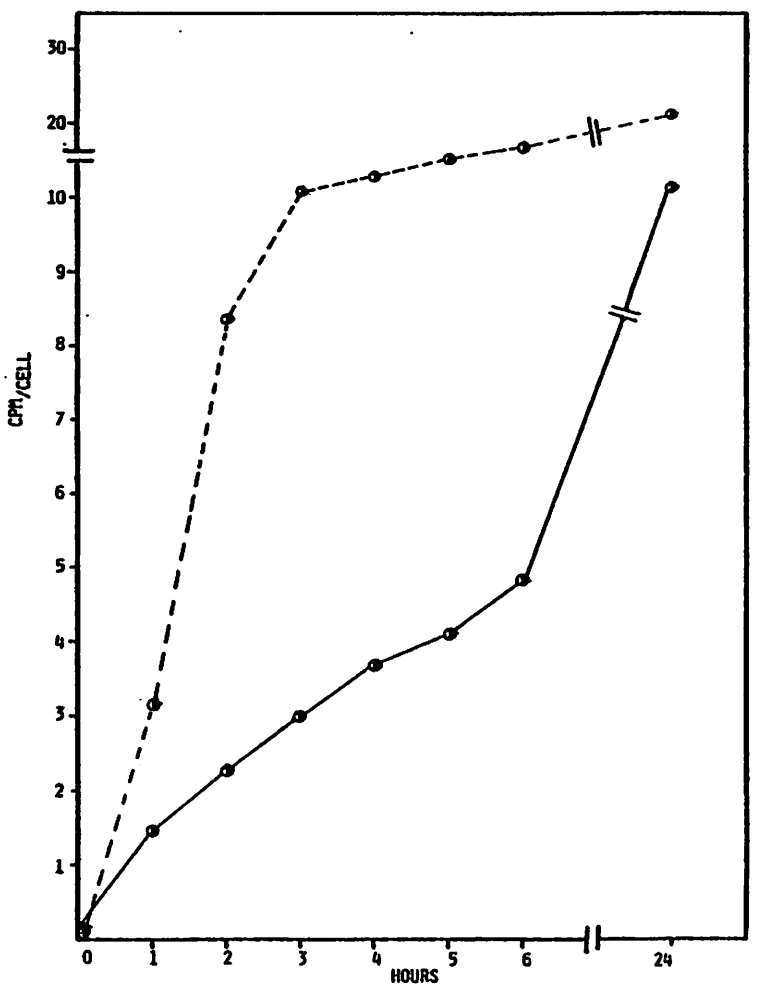
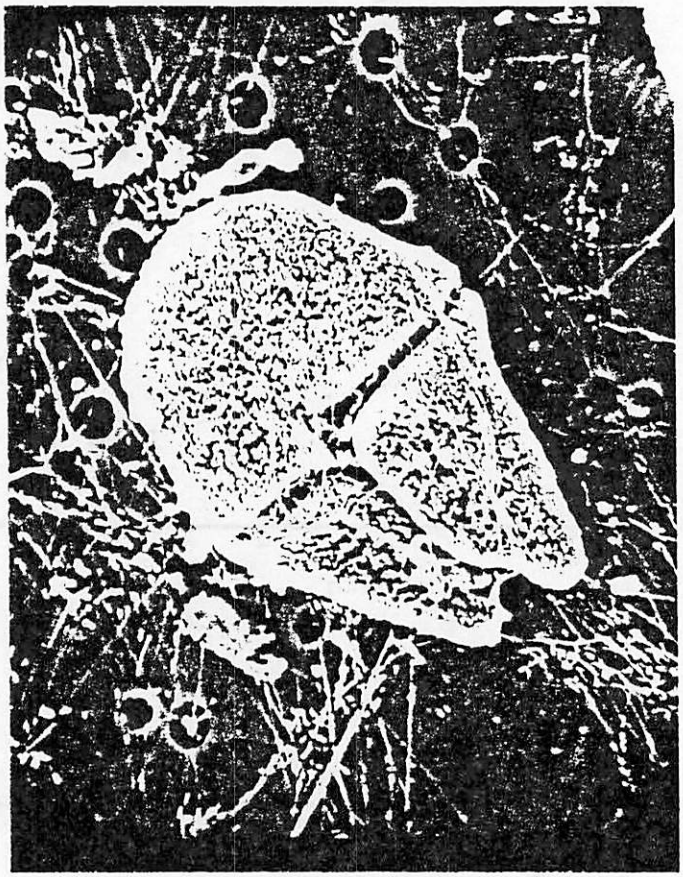


Figure 18 - 0.1 µci/ml medium (sea water-F/$_2$ enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M



GYMNODINIUM SANGUINIUM

MAG. 1400X

GYMNODINIUM SANGUINIUM

^{14}C-PHENYLALANINE INCORPORATION

CPM/µG PROTEIN

	18 HOURS OLD CULTURE								5 DAYS OLD CULTURE							
HOURS	0	1	2	3	4	5	6	24	0	1	2	3	4	5	6	24
LIGHT	176	715	1351	1839	2579	2802	3134	6076	4	135	229	242	297	341	357	536
DARK	56	680	1056	1951	2446	2816	3704	7215	4	114	208	239	319	336	357	844
LIGHT-DARK	70	473	872	1398	1886	2158	2521	4429	5	153	293	313	349	400	447	804

^{3}H-LEUCINE INCORPORATION

CPM/µG PROTEIN

	18 HOURS OLD CULTURE								5 DAYS OLD CULTURE							
HOURS	0	1	2	3	4	5	6	24	0	1	2	3	4	5	6	24
LIGHT	58	563	798	999	1182	1293	1410	2712	1	346	714	1044	1398	1659	1640	1340
DARK	33	519	647	1023	1157	1270	1626	3795	2	319	799	1096	1781	1781	1763	2372
LIGHT-DARK	32	361	554	739	900	1016	1177	2603	3	402	1056	1395	1671	1941	2133	2553

Table 3 - 0.1 µci/ml medium (sea water-F/2 enrichment)
Specific activity 460 µci/µmole
Concentration 2.15×10^{-7} M

R/EG-19

THE ROLE OF NATURAL POPULATIONS OF MICROHETEROTROPHS IN CARBON CYCLING

Cornelius Sullivan

The basic problems of the cycling of carbon in marine ecosystems is considered by many to be a major theme of marine microbiology——a special case of biogeochemical cycles. Fortunately, in studies of organic cycling, the major questions being asked in applied research are similar if not identical to those asked in basic research; thus, the work outlined serves both ends admirably.

With respect to applied research, microbiological studies have been identified by two agencies as essential (and previously lacking) components of Environmental Impact Reports (EIR) for projects which the Environmental Protection Agency (EPA) and State Water Resource Control Board (SWRCB) evaluated for the potential for water quality enhancement. The two projects of greatest concern to the study area are the Terminal Island Effluent Proposal, Project No. C-06-1202 and the Tuna Canneries Association disposal problems.

In correspondence forwarded by Raymond Hertel of the Regional Water Quality Control Board, the Environmental Analysis Section (EAS) Critique, through Raymond Walsh, has stated:

> In the marine environment, the utlization of dissolved organics by microorganisms, through consumer heterotrophic pathways, could be important to nutrient recycling and detrital food webs. (Appendix E, part II)

and, in reference to proteins and amino acids in effluent:

> Work is necessary to determine how much of this total protein is actually available to marine organisms and after determining how much is available, work is necessary to determine how much of the available protein, if any, is actually utilized. (Appendix C, part III)

The current investigation is in agreement with both statements, and addresses both of these ideas and several others.

A significant portion of the project involves the study of the role of microheterotrophs in carbon cycling in California coastal waters, and is directed at understanding the dynamic aspects of the natural microbial population of the outer Los Angeles harbor and adjacent coastal waters under in situ and simulated in situ conditions.

The project is also an integral component of a much broader study of the bioenhancement of receiving waters in outer Los Angeles harbor. A question of major concern in these studies has been whether the discharge of organically

rich waste such as cannery and sewage effluent into the receiving waters of the outer Los Angeles harbor and contiguous coastal waters results in bioenhancement of those waters. I interpret the word bioenhancement to mean: an increase in the standing stock of marine microheterotrophs and maintenance of biomass levels of these organisms which increase the carrying capacity of the waters for organic enrichment but which do not result in episodic degeneration of water conditions such as anaerobiosis.

Objectives of this study are to test these hypotheses that discharge of nutrient-rich effluent in the waters of the outer Los Angeles harbor results in elevated standing stocks and activities of microheterotrophs. The study further hypothesizes that the microheterotrophs provide a potential food source for organisms at the higher trophic levels and thereby constitute the initial links of the secondary marine food web (also called detrital food web). To test these hypotheses, a field program has been set up which is designed to yield estimates of microheterotrophic biomass, rate of substrate metabolism, and substrate turnover time, as well as the population growth rate or turnover times of the microheterotrophic community. Experimental studies using microcosms are designed to obtain estimates of rates of utilization of ^{14}C-labeled bacteria by a variety of suspected bacteriovorous grazers at higher trophic levels. The grazers will be collected from extant natural population in the study area.

The major question posed in this study reflects the problem stated above. If the addition of dissolved and particulate organic nutrients results in bioenhancement of receiving waters, then these nutrients must enter marine food webs so that organisms at the higher trophic levels can benefit from their presence. Therefore, we ask the question, is a detrital food web operative in these waters? Since our preliminary studies (Sullivan et al., 1978) in this area indicate that it is operative, it is incumbent on us to demonstrate and quantify the putative coupling of: dissolved and particulate organic compounds, microheterotrophs, higher trophic organisms.

The following three hypotheses are being tested: (1) that organic enrichment of coastal waters results in elevated standing stocks of microheterotrophs: (2) that the carrying capacity of coastal waters is directly related to standing stocks of microheterotrophs and their metabolic activity; (3) that the microheterotrophs provide a potential food source for organisms at higher levels.

Several basic questions must be answered to test these hypotheses:

1. What is the standing stock or biomass of marine microheterotrophs in coastal waters?

2. At what rates do microheterotrophs cycle the available organic nutrients?

3. Which organic compounds are being utilized by the natural microbial populations?

4. What is the turnover time of the nutrients?

5. What is the turnover time of the microbial community?

6. Are marine microheterotrophs potential or real food sources for organisms at higher trophic levels and if so, at what rates are they utilized?

RESULTS

We have determined total microbial biomass by the ATP method at monthly intervals for four stations in the Los Angeles harbor and one station outside the breakwater and upcurrent of the harbor outflow at A0. In order to distinguish the phytoplankton from the bacterioplankton components we used two techniques: one was to analyze ATP in the size fraction 203um 0.2um (total) and the fraction < lum > 0.2 (bacterioplankton) by subtraction (total - bacterioplankton) we estimated phytoplankton. Phytoplankton biomass was also independently estimated by chlorophyll a and by direct microscopic counting and floristic analysis. Counts of bacterioplankton with the acridine orange direct counting technique (AODC) using epifluorescent microscopy also gave independent estimates of bacterioplankton including autofluorescent cyanobacteria. Phytoplankton communities flucutate seasonally; during early spring there is a diatom-dominated bloom, followed by one or two dinoflagellate-dominated blooms in July and September.

By contrast, bacterioplankton standing stock remains low during the period November through April, but climbs in May through September to reach later summer levels which are tenfold greater than those of winter and spring. An estimation of microzooplankton by direct microscopic counting has also been carried out, but data analysis is not complete at this time.

We have investigated the kinetics of uptake and size fractionation of a variety of radiolabeled organic and inorganic nutrients by the natural microbial communities. Among the substrates tested were (organic) glucose, amino acid hydrolysate, arginine, glutamate, leucine, glycine, thymidine, uridine, and adenosine monophosphate; (inorganic) $^{14}CO_2$, $^{33}PO_4$ and ^{66}Ge-Si $(OH)_4$. The kinetics were linear during short incubation times, but often were exponential during 24-hr incubations. The turnover times were generally less than 24 hr, but for some substrates turnover times of 10 to 40 days were observed. Similar results were found for inorganic nutrients.

It was noted that rapid uptake rates and short turnover times appeared to be more closely correlated with bacterioplankton biomass than to ambient substrate concentration or temperature. This supports the hypothesis that assimilation capacity is a function of microbial standing stock and its activity. Naturally, this assumes nonlimiting oxygen, and our studies have shown that oxygen is not limiting at our sampling times.

A major generalization derived from the nutrient uptake studies was that 50 - 94% of all nutrients tested, except $^{14}CO_2$ and ^{66}Ge-$Si(OH)_4$, were taken up by organisms which passed through a 1-um pore size membrane filter. These data suggest a major role of ultraplankton in nutrient cycles. The functional dominance of this size fraction of the microbial community is even more impressive when one realizes (as noted earlier) that their biomass is only 0.1 to 0.02 that of the fraction < 203μm > 1.0 μm which is composed largely of phytoplankton. That the < 203μm > 1μm size fraction is composed of phytoplankton

was demonstrated by this fraction containing at least 80% of chlorophyll a, 90% of $^{14}CO_2$-fixed, and 90% of the ^{68}Ge-$Si(OH)_4$ taken up had incorporated, presumably by diatoms. By contrast, 90% of the bacterioplankton were found to pass the 1-μm pore size filters using the AODC technique.

Estimates of the turnover time of the microbial plankton community itself are not yet available. This will be, in large part, the focus of our work during the next year.

We have, however, made excellent progress on the question of microheterotrophs as a food source for organisms at higher trophic levels. These studies have shown that a culture ciliate rapidly takes up, incorporates, and respires bacterial carbon when both prey and predator are present at environmentally realistic conditions. Similar results were obtained for natural populations of bactivorous plankton from the Los Angeles harbor. Finally, three benthic invertebrates indigenous to the harbor ecosystem Neathes arenacenondentata, Macoma nasuta, and Mytilus edulis were able to remove significant quantities of bacteria from sea water suspensions.

Now to answer the questions posed earlier, specific details of the data collected and its analysis are given here:

1. What is the standing stock or biomass of marine microheterotrophs in coastal waters?

   Seasonal trends in total Chlorophyll a and Chlorophyll a distribution among size classes of particles in Los Angeles Harbor: October 1977 - December 1978.

Water samples from five stations in Los Angeles harbor were analyzed for Chlorophyll a. Samples were collected once a month for 14 months from October 1977 through December 1978. The particles in the water were subjected to differential filtration, and the amount of Chlorophyll a found in each of the following size classes was determined: $0.2 < x < 0.6$ μm, $0.6 < x < 1$ μm, 1 μm $< x < 5$ μm and $x > 5$μm. For one month a 37-μm filter was added; for two additional months, a 10-μm filter was added.

Seasonal patterns indicate a spring burst in Chlorophyll a concentration at two of the three stations (A2 and A7) sampled in early 1978. A strong peak in Chlorophyll a occurred at all five stations in July of 1978. Values for Chlorophyll a reached 18 - 20 $\mu g \cdot l^{-1}$ at all stations during July.

Size fractionation data indicate that greater than 50% of the Chlorophyll a is found in particles greater than 5 μm. A brief attempt at correlating Chlorophyll a data with floristic analysis is made.

a. Monthly microbial standing stock measurements

The concentration of live bacterial (cells L^{-1}) determined by the acridine orange direct count (AODC) method and a biomass estimate ($ugC \cdot L^{-1}$) of the bacterial standing stock are presented monthly for 1978 for water samples taken 1 m below the surface at four stations (A2, A7, A12, B9) in the outer Los Angeles Harbor, and one station (A0) in the coastal waters outside the harbor breakwater. The range over the year for stations in the harbor is

1.6×10^8 cells$\cdot L^{-1}$ (1.3 ugC L^{-1}) to 55×10^8 cells L^{-1} (42.8 $\mu gC \cdot L^{-1}$), while the annual range in standing stock outside the breakwater is only 1.6×10^8 cells L^{-1} (1.3 $\mu gC \cdot L^{-1}$) to 18×10^8 cells L^{-1} (14.0 $\mu gC \cdot L^{-1}$). The monthly bacterial standing stock in harbor waters averages 2.5 times that found in coastal waters. All stations show two seasonal blooms of bacteria—one in late spring and another in early fall.

Phytoplankton biomass was estimated monthly by three independent methods: (1) Chlorophyll a measurement, (2) ATP content of particles 1, and (3) direct count of phytoplankton and microzooplankton. Collectively, these data show elevated phytoplankton biomass levels for various stations from April through September with maxima occurring at different stations in June (A7), July (A2, A12, B9), August (AO), and September (A2, A12, B9). The average annual range is 100 to 700 gC L^{-1} for harbor stations and 100 to 1,000 gC L^{-1} for station AO. The phytoplankton in late spring coincides with the bacterial bloom at this time. The late summer phytoplankton bloom is followed by an early fall bacterial bloom. The bacterial blooms are correlated with times of increased levels of dissolved and particulate organic materials resulting from (1) the high phytoplankton standing stock, (2) excretion by phytoplankton, and (3) grazing and excretion by zooplankton.

The natural microbial population was size-fractioned each month by passing water samples through Nuclepore membrane filters of varying porosities. The harbor water populations are composed of smaller percentage of small cells [averaging 112% $\pm$ 27 (1 S.D.) < 5μ, 90% $\pm$21 (1 S.D.) < 1μ, and 69% + 15 (1 S.D.) < 0.6μ when compared with the coastal waters averaging 103% $\pm$13 (1 S.D.) < 5μ, 94% $\pm$ 39 (1 S.D.) < 1μ, 77% $\pm$40 (1 S.D.) < 0.6μ]. Conversely, the cells in the harbor environment are generally larger than those found in coastal waters.

The biomass of particles between 0.2 and 1.0μ in size has also been estimated for many of these water samples by measuring the ATP content of this size fraction. ATP biomass estimates averaged 20 times the AODC bacterial biomass estimates. Among other explanations for this difference are (1) nonbacterial ATP in this size fraction (in detritus or small pliable eucaryotes capable of passing a 1-μm porosity filter), and (2) errors involved in converting to ugC with either technique.

A vertical profile in August 1978, at station A2 in the harbor indicates the presence of a subsurface (3m depth) maximum in bacterial standing stock (18.9×10^8 cells$\cdot L^{-1}$ or 14.8 $\mu gC \cdot L^{-1}$). The water at this depth contains 13% more bacteria than is found 1 m below the surface and 51% more bacteria than is found 1 m off the bottom (10 m depth).

If one considers a 10-km^2 area containing the four harbor stations, and assumes an average water column depth of 10 m and an average bacterial concentration at all depths equal to 80% of those values found at 1-m depth, the total bacterial biomass for this part of the harbor can be estimated. This estimate ranges over the year from 110 to 3,610 kgC for the volume of water defined.

Orange autofluoescent particles were observed in water samples throughout the year, and were quantified in August, October, November, and December 1978. Little is known about these cells that are thought to be cyanobacteria. A 1-μm porosity filter allows 82% of these cells to pass, while none are able to

pass a 0.6-um porosity filter. Their standing stock ranges from 0.2 x 10^7 cell$\cdot L^{-1}$ (0.09 µgC L^{-1}) to 6.3 x 10^7 cells$\cdot L^{-1}$ (2.87 µgC L^{-1}) for the four months they were counted. They are of equal concentration in harbor and coastal waters. However, due to the increased bacterial standing stock in the harbor when compared with coastal waters, the biomass of these autofluorescent particles represents 7.0% and 24.8%, respectively, of the bacterial biomass in these two water masses.

b. Floristic analysis of phytoplankton blooms

Two distinctly different bloom patterns appeared among the five stations sampled between October 1977 and December 1979. At station AO outside the harbor breakwater, only one bloom occurred in July when the phytoplankton reached 6.0 x 10^6 cells$\cdot L^{-1}$ (363 µgC$\cdot L^{-1}$ and 16 µg Chlorophyll$\cdot$a L^{-1}). The community was dominated by Nitzschia serratia and unidentified (5 µm) flagellates of the phytoplankton carbon, respectively.

Within the harbor, two or three blooms occurred. During April and July at station A7, two blooms occurred which were dominated by Gonylaulax polyhedra, Chaetocerous socialis, and Cochlodinium cantenatum: 25%, 18%, and 15% of phytoplankton carbon, respectively. Phytoplankton standing stocks reached 1 x 10^6 and 8.6 x 10^6 cells$\cdot L^{-1}$ or 10 and 22 µg Chlorophyll a$\cdot^{-1}$ during these blooms. At each of the other three harbor stations, A2, A12, and B9, three blooms occurred in April, July, and September. The phytoplankton communities were dominated by Gonyaulax polyhedra (20-51%), by Chaetocerous socialis (18 32%) and by Chaetocerous affinis (10-14%) in April; Nitzschia serratia (33-79%) and by Proporcentrum micans (3-19%) in July; Gymnodinium splendens (25-71%), by Gonyaulax polyhedra (19-58%) and unidentfied flagellates, 5 um, (10-15%) in September. During these blooms Chlorophyll a levels were 13-22 µg$\cdot L^{-1}$: phyoplankton carbon was generally 500 to 1,500 g carbon L^{-1} and cell density was 3-15 x 10^6 cells$\cdot L^{-1}$.

c. Scanning electron microscopy of harbor microflora

The purpose of this study is to examine the morphology of natural populations of microorganisms. As laboratory culturing of marine microorganisms may lead to severe morphological changes, it is critical to preserve and examine fresh seawater samples to describe microbial morphology accurately.

Fractionation through membrane filters (Nuclepore) has been employed throughout our studies of microbial activity. Microscopic studies of size fractions using SEM enables one to determine what kinds of microbial populations comprise the different size classes. Information on the structure and activity of the populations may, then, be coordinated.

Several important generalizations may be drawn from the SEM of seawater size fractions. First, the microorganisms less than 1.0 and greater than 0.2 which have been shown to exhibit the greatest heterotrophic activity, are typically small bacteria of a rod, coccoid, or spirillum morphology. Second, the fraction greater than 1.0 is characterized by diatoms, dinoflagellates, large detrital particles, and some relatively large bacteria (possibly blue-green bacteria and microflagellates).

In general, bacteria do not appear to be associated with detrital particles. It is possible, however, that cells may have become dislodged from detritus.

Estimates of bacterial concentration have been made, based on randomly selected SEM fields. These estimates assume that loss during processing is negligible. The actual loss due to processing of the sample has not, however, been determined. The SEM studies also asume an unbiased representation of microfloral composition, that is, it is assumed that any loss during processing is not selective.

The SEM studies allow the direct correlation of the structure and composition of microbial populations with their activities. Further studies might examine the cellular ultrastructure of representatives of natural populations by studying TEMs of thin sectioned material. This would allow the differentiation of blue-green bacteria from eubacteria as well as from microflagellates. Such a study would also allow the comparison of the ultrastructure of microorganisms from natural populations with those from laboratory cultures.

2. <u>At what rates to microheterotrophs cycle the available organic nutrients? What is the turnover time of the nutrients?</u>

a. Microbial uptake of organic and inorganic nutrients

The uptake of various radio-labelled substrates was investigated in September 1977, and from August through December 1978. This microbial activity has been size-fractionated for four different substrates: ^{3}H-thymidine, ^{3}H-uridine, ^{3}H-AMP, and ^{51}Cr. The heterotrophic uptake of reduced organics (^{3}H-thymidine, ^{3}H-uridine, and ^{3}H-AMP) on the average are size-fractionated as follows: 96 + 4% (1 S.D.), < 5 u 82 $\pm$ 10% (1 S.D.) < 1 u 62 $\pm$ 14% (1 S.D.) < 0.6 μ < 5μ, 33 $\pm$ 27% (1 S.D.) 1u, 22 $\pm$ 18% (1 S.D) < 0.6μ. The reduced organics are taken up in the size fractions corresponding to those in which the marine bacteria in the samples are fractionated. This direct correlation is not observed in the uptake of ^{51}Cr.

The kinetics of ^{3}H-thymidine uptake at station A2 on August 2, 1978, showed that a linear period of uptake occurs during the first 6 hr.: 4.0 pmole$\cdot$L^{-1} for particles > 0.2μ, and 0.8 pmole$\cdot$L^{-1} hr^{-1} for particles 1.0u. The concentration of substrate added in this experiment was 258 pmol$\cdot$L^{-1}. Kinetics over a 24-hour period show an 8-hr period of low uptake rate, followed by a 12-hr period of accelerated uptake rate and a levelling off to near-zero uptake rate at 24 hr we compared uptake at stations A0 and A2 when 110 pmole$\cdot$L^{-1} ^{3}H-thymidine was added and found similar uptake kinetics when 1,127 pmole$\cdot$L^{-1} was added (10 times the concentration). The rate of uptake of thymidine by particles > 1μ is 20 % of the uptake rate of particles>0.2u.

The kinetics of ^{3}H-uridine uptake were also examined. At station A0 on October 3, 1978, a linear period of uptake occurs during the first 8 hr: 13.3 pmole$\cdot$L$^{-1}\cdot$hr^{-1} for particles > 0.2μ, and 4.0 pmole$\cdot$L$^{-1}\cdot$hr^{-1} for particles >1μ. The concentration of uridine added in this experiment was 1,590 pmole$\cdot$L^{-1} On November 2, 1978, only 14 pmole$\cdot$L^{-1} uridine was added to station A2 water. The rate of uptake of ^{3}H uridine was only 0.3 pmole$\cdot$L^{-1} for the first 8 hr.

Generally, the 24-hr uptake pattern for uridine is similar to thymidine uptake kinetics with a period of accelerated uptake from 8 to 16 hr between two periods (0.8 hr, 16-24 hr) of low uptake rates. Again, the rate of uptake for uridine by particles > 1μ is 20% of the uptake rate of particles > 0.2μ.

The kinetics of ^{51}Cr uptake at station AO on September 6, 1978, is nonlinear for the first few minutes, but then appears to become linear for the first 3 hrs.

The turnover time of added substrate was calculated for each experiment; the range of values were 8.2 to 1128 hr.

The uptake size fractionation and turnover time of orthophosphate by bacterioplankton and phytoplankton in the Los Angeles Harbor and coastal waters.

Uptake of orthophosphate by natural microbial populations in 4 size fractions was studied by incubation of seawater with carrier-free $H_3{}^{32}PO_4$ or $H_3{}^{33}PO_4$. The relationship between uptake (nmole PO_4^{-2}·liter^{-1}) and incubation time was linear in 12 of 13 experiments, with a correlation coefficient of 0.98 or higher. Uptake rate varies independently of orthophosphate concentration, but has a high correlation with bacterial numbers. Turnover times for phosphate in the Los Angeles harbor are high; the lowest recorded here was 24 hours in July. Phosphate uptake by bacterioplankton per unit C proceeds at a rate 2 to 1000 times greater than that by phytoplankton, making the smaller cells predominate in phosphate assimilation. However, a 2-fold or greater increase in phytoplankton uptake rates allows them to compete for a larger percent of the dissolved phosphate at the beginning of a bloom.

3. Are marine microheterotrophs potential or real food sources for organisms at higher trophic levels; if so, at what rates are they utilized?

The ingestion and utilization of labeled marine bacteria by higher trophic organisms from Los Angeles Harbor and California coastal waters.

I. Ingestion and utilization of bacteria by a cultured ciliate, Euplotes sp; invertebrates; Neanthes arenaceodentata, Macoma nasuta and Mytilus edulis and by natural populations of bactivorous plankton.

A quantitative radioassay method to determine the rates of ingestion, excretion, and respiration of bacterial carbon by organisms from higher trophic levels was investigated. The techniques were developed by employing a marine species of Euplotes (Protozoa, Ciliata) and a marine bacterium, both isolated and cultured from Los Angeles Harbor water samples. The test species were fed uniformly ^{14}C-labeled bacteria and the control-corrected particulate ^{14}C, $^{14}CO_2$, and dissolved organic ^{14}C levels were assayed. The organisms tested were demonstrated to ingest and utilize bacterial carbon with varying levels of efficiency.

In experiments with Euplotes sp., bacterial ingestion rates were shown to accurately reflect grazer density, if prey density was held constant (1.3×10^6 bacteria · ml^{-1}) and grazer density was varied (20, 51, 102, 250 ciliates·ml^{-1}). Euplotes sp. was found to consume 25-48 bacteria·ciliate^{-1} min^{-1}. Ingestion respiration and excretion rates of Euplotes sp. varied

inversely with grazer density. In a related experiment, grazer density was held constant (10^6 ciliates·ml^{-1}) and prey density was varied (1.30, 1.85, 4.05, 7.85 x 10^6 bacteria·ml^{-1}). The ingestion rate versus bacterial density plot suggests a Langumier isotherm.

The method was also employed to determine the feeding and bacterial utilization rates of Neanthes arenaceodentata, Macoma nasuta, and Mytilus edulis on bacteria suspended in sea water. Neanthes arenaceodentata was able to take up 1.7-2.1x10^7 bacteria·day^{-1} from fine sand and 1.5-2.8x10^9 bacteria·day^{-1} from sea water only, apparently by means of a mucus net.

We also estimated the feeding activity of natural populations of bactivorous plankton in Los Angeles Harbor. Bacterial ingestion and utilization was measured for the 5-203 um size fraction of surface (1m) samples from five stations. Bacterial consumption was found to vary directly with in situ bacterial density, independently measured at each of the five stations. Linear regression analysis of a plot of bacterial ingestion vs. bacterial density demonstrated a correlation coefficient of 0.945. Bacterial ingestion rates ranged from 9x10^5 bacteria·L^{-1} min^{-1} at station A0 with 6x10^8 bacteria ·L^{-1} to 31x10^5 bacteria·L^{-1}·min^{-1} at station A7 with 2.9x10^2 bacteria·L^{-1}. At this rate, the bacterioplankton standing stock could be turned over by planktonic grazing in 12-19 hr.

These results demonstrate that bacterioplankton can serve as a source of carbon (incorporation) and energy (respiration) for higher trophic organisms as well as the natural plankton in the marine food web of the Los Angeles Harbor and California coastal waters.

PROJECT COMMUNICATIONS

1. Taylor, G. and C. W. sullivan. 1979. The ingestion and utlization of ^{14}C-labeled marine bacteria by bactivorous plankton from Los Angeles Harbor and Southern California coastal waters. American Society of Limnology and Oceanography, 42nd Annual Meeting, Stony Brook, N.Y. 18-21 June.

2. McGrath, S. and C. W. Sullivan. 1980. Community metabolism of total adenylates by the microorganisms of the Los Angeles Harbor and Southern California coastal waters. American Society of Limnology and Oceanography, 42nd Annual Meeting, Stony Brook, N.Y. 18-21 June.

3. Herold, L. and C.W. Sullivan. 1980. The uptake of vitamin B_{12} by natural marine plankton populations. American Society of Limnology and Oceanography. Winter Meeting. Los Angeles, California. Jan. 31-Feb. 4.

4. Krempin and C.W. Sullivan. 1980. The assimilation of phosphate by microplankton of Southern California coastal waters. American Society of Limnology and Oceanography. Winter Meeting, Los Angeles, Calif. Jan. 31-Feb 4.

5. Palmisano, A.C. and C.W. Sullivan. 1980. The fate of ^{51}Cr (III) in sea water: Uptake by microorganisms and molecular filtration of the dissolved fraction. American Society of Limnology and Oceanography. Winter Meeting.

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R/EQ-20

ECOLOGY OF A SMALL TIDAL LAGOON UNDER THE INFLUENCE OF URBAN RECREATIONAL USE

James N. Kremer and Patricia Kremer

An increasing number of coastal embayments are heavily influenced by various types of urban impact. Colorado Lagoon in Long Beach is subject to heavy recreational use, and receives a substantial land and street runoff. In many marine systems, size and complexity make it difficult to study the influence of the urban environment. However, the small size and relatively simple hydrography of Colorado Lagoon make it an ideal location for investigating some general questions about the coupling between marine biota and their urban surroundings. The average depth of about 4 m is sufficient to support an abundant plankton, nekton, and benthos. Tidal flushing is modified by two power gates that periodically isolate the lagoon from the Marine Stadium and Alamitos Bay.

Part of the motivation for this project emerges from its relationship to one of the identified thrusts of the USC Sea Grant Program: a better understanding of the role of urban influences on coastal marine waters. This study represents a well-defined case of this general topic. Specific characteristics of the Colorado Lagoon allow us to employ approaches not applicable in other local regions. Yet, our results should have general implications that can complement other studies in contributing to the broader question.

Colorado Lagoon is situated in suburban Long Beach, and is constantly under direct human influence. Several storm drains deliver street runoff, and seasonal recreation use is intensive. The lagoon seems to be vigorous ecologically, but it is unclear whether this is in spite of or because of the urban influence. Enhanced primary productivity of the phytoplankton under the influence of external nutrient inputs and controlled tidal exchange may be important, but previous to this study there have been no measurements of critical ecological rates such as primary production, nutrient cycling, or ingesting by the benthos. A knowledge of these rates is essential to an understanding of the vitality of this urban marine recreational resource.

In addition, the success of the hard clam Mercenaria mercenaria in Colorado Lagoon is a question of basic scientific interest. Reportedly introduced elsewhere in the Long Beach system of canals and causeways, M. mercenaria has appeared and flourished only in the lagoon. This may suggest that some specific feature there is favorable to this species. Alternatively, negative effects of recreational use, runoff, or controlled tidal flushing may be excluding competitors and thereby allowing the clams to survive. Although they are of no economic importance on the Pacific Coast, it is pertinent to note that hard clams are of great commercial value on the East Coast, so that information on the biology of the species is potentially useful.

Our goal is to identify and quantify important interactions between the lagoon biota and the urban environmental influences. Of specific interest are the reasons for the apparently unique success of the hard clam. To these ends, we have measured primary production and community respiration for the total system and, in particular, for the plankton and for the benthos. In addition, since nutrients are potentially an important key to interpreting these rates, we have been determining the major storages and fluxes of the dissolved and particular organic and inorganic fractions of nutrients. These objectives require careful definition of the physical characteristics of the lagoon, including the flushing rates as controlled by the tide gates.

RESULTS

During the first year of this project, our work has focused on intensive sampling during two days of each month. From these outings we have been able to observe diurnal and seasonal patterns for several environmentally important parameters. There is a marked seasonal pattern in dissolved nutrients (Figures 1 - 3). The concentrations of nitrate/nitrite, phosphate, and ammonium were all lower in spring and summer and higher in winter. The seasonal pattern for phosphate was not nearly as dramatic as for nitrate and ammonium. Except for periods when the lagoon was affected by freshwater runoff containing high levels of phosphate, the concentrations were generally between 1 - 2 g-at/liter. It is probable that phosphate is not a limiting nutrient in the lagoon, since concentrations rarely drop below 1µg-at/l nitrate. Nitrite is generally about one tenth the nitrate concentration.

In contrast to both the patterns for phosphate and nitrate, ammonium levels increased through the fall and showed a less pronounced effect of runoff. In general, ammonium concentrations were greater in bottom water than at the surface, demonstrating the effect of ammonium regeneration by the benthos. Direct measurements of benthic production, respiration, and nutrient release were made, using light and dark domes (Figure 4). Results of these studies have shown that in the spring and fall, the benthic algae are photosynthetically active, demonstrated by positive oxygen changes in the light domes. In the winter and summer, the algae are much less active, and the light domes showed negative oxygen changes. The dark domes measure the respiratory requirements of the intact benthos. For most of the year, the respiratory rate was about 2 - 3 grams of oxygen per square meter per day, but during the warmest temperatures in September, these rates were nearly doubled. These rates are comparable to other measurements made in eutrophic waters. Measurement of the ammonium release by the benthos is complicated by the seasonable presence of algae which can take up ammonium even in the dark, although at reduced efficiency. Although the dark domes generally demonstrated greater ammonium increases than the light domes, there is a strong seasonal pattern which is the inverse of the pattern of primary production (oxygen production) by the bentbos. Because of this algal uptake, the atomic ratio of oxygen consumed to nitrogen released is often greater than 20:1, and in the spring was measured at about 100:1. Only during periods of low benthic algal production in the late fall and summer are more reasonable metabolic O:N ratios of about 24 observed.

Both phytoplankton standing stock (measured by chlorophyll) and productivity (measured by a change in oxygen) exhibit a summer maximum. Only during periods of low benthic algal production in the late fall and summer are more reasonable metabolic O:N ratios of about 14:1 observed.

Both phytoplankton standing stock (measured by chlorophyll) and productivity (measured by change in oxygen) exhibit a summer maximum. During the winter, there was a low chlorophyll standing stock of less than 3 mg Chl. A m^{-3} and net production was generally negative, that is, the respiration requirement of the water column exceeded the photosynthesis of the phyotplankton. During the spring, net production during the midday period was approximately 0.2 to 0.3 mg O_2 l^{-1} hr^{-1}. As part of our monthly sampling, we determined the profile of production vertically in the water column at two stations in the lagoon during morning, midday, and afternoon periods. These profiles typically exhibit subsurface production maxima at depths of 0.5 to 1.0 m and conform to production profiles observed in many productive coastal waters. In the water column, the large proportion of production is in the top two meters, presumably as a result of the high summer extinction coefficient (K = 0.8).

During the summer, the tide gates connecting the lagoon with the Long Beach Marine Stadium and eventually with Alamitos Bay are closed the majority of the time to maximize the lagoon as a recreational swimming site. When the tide gates are open, tidal circulation thoroughly mixes the water column, but when the gates are closed the water column quickly becomes stratified. During the summer in 1979, lagoon stratification was documented over a 4-day period when the gates remained closed. Although the temperature profiles show physical stratification, the most dramatic effect was seen in the oxygen profiles (Figure 5). The combination of high primary production by phytoplankton near the water surface, and high oxygen consumption by the benthos resulted in supersaturated oxygen values near the surface and nearly anoxic water near the bottom.

Periodic anoxia may have a profound effect on the nature of the benthic flora and fauna in Colorado Lagoon. The appearance and success of the hard clam Mercenaria mercenaria in the lagoon may be linked to the physical characteristics of the lagoon, in particular the intermittent anoxia. In this second year of our study, we hope to understand and quantify the important processes which determine the oxygen concentr tion, and to evaluate the importance of low oxygen event to the ecology of the lagoon. Oxygen depletion is a common problem in warm eutrophic waters, and our evaluation of the situation in the Colorado Lagoon should help contribute to a general understanding of oxygen dynamics in small shallow bays and estuaries. In addition, we should be able to make specific recommendations to the Long Beach Parks Department concerning modifying tide gate schedules to avoid serious anoxia.

One of our goals this year is a predictive oxygen model for the lagoon. To achieve this goal, we must have a knowledge of the bathymetry and hydrography. Bathymetic surveys have been completed, and work on the hydrography (i.e., flushing characteristics) is planned for this winter, in conjunction with our quantitative investigation of runoff. In order to have a real understanding of the oxygen dynamics in a stratified system, it is necessary also to have estimates for physical processes such as vertical diffusive and turbulent mixing and oxygen diffusion across the air-water interface. This past year we have investigated the air-water diffusion question in some detail, and we hope to be able to continue this work in more detail. Although we hope to get some reliable empirical measurement of vertical mixing, for this we will undoubtedly rely on the mathematical model developed by Dr. T. D. Dickey here at USC.

Data from last year's monthly surveys have given us quantitative information on total system metabolism as well as the planktonic and benthic components. This year we hope to construct a metabolic budget for the lagoon to determine the relative importance of the major biotic and physical components to the system as a whole. A quantitative breakdown and examination of how the resources are apportioned seasonally should allow us to understand what are the major driving functions for the lagoon and the importance of its urban setting to the distribution of energy and materials in this system.

PROJECT COMMUNICATIONS

1. Summer 1979: Two seminars were given at the University of Rhode Island concerning the project at the Colorado Lagoon.

2. Winter 1980: Two oral presentations will be given at the winter meeting of the American Sciety of Limnology and Oceanography.

3. One doctoral dissertation and one master's project are in progress associated with this work.

4. The investigators plan at least three journal articles and at least two technical or popularized articles resulting from this work. However, completion of results of this year's work are essential prior to publication.

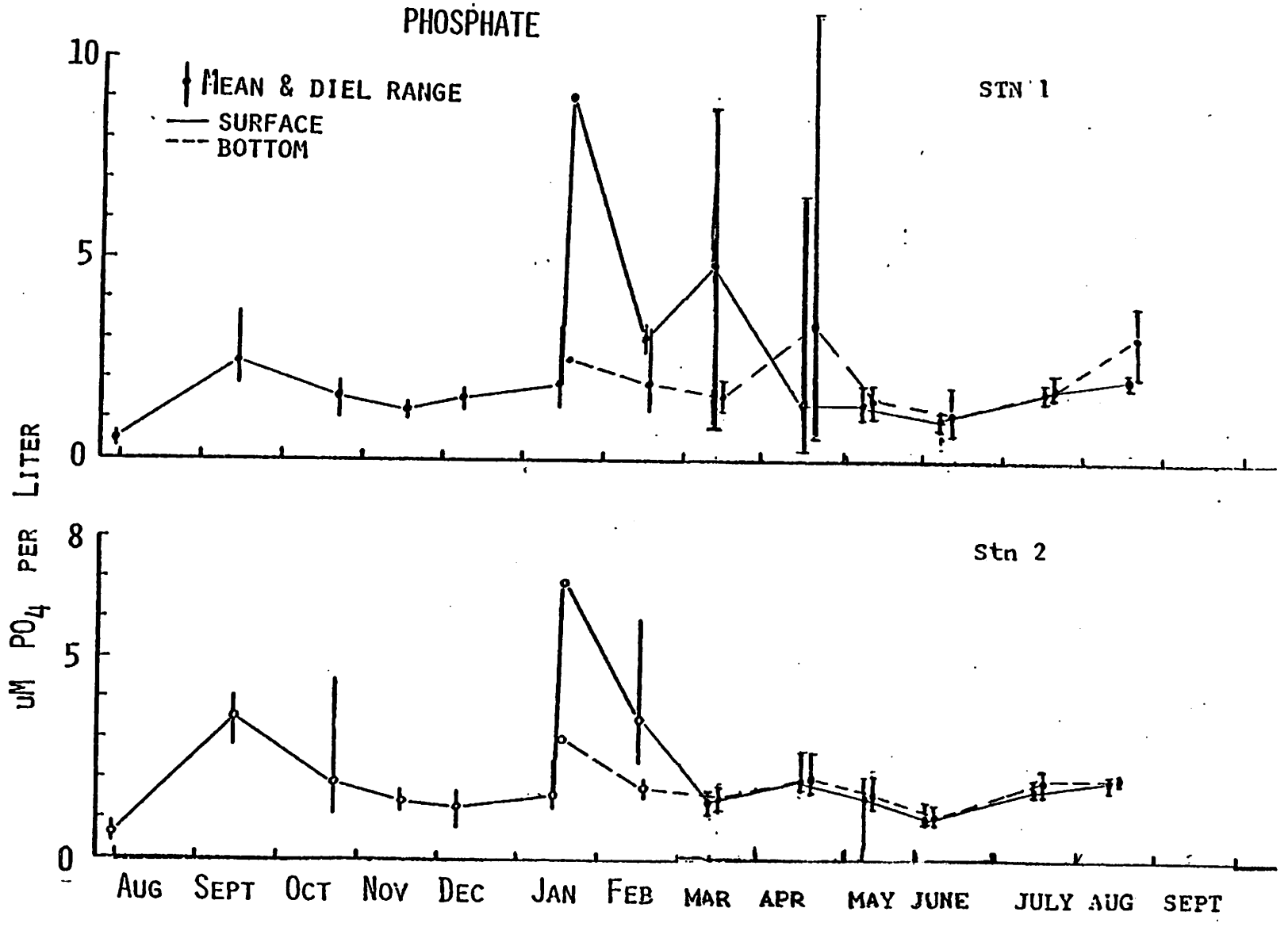

Figure 1. The annual cycle of reactive phosphorus at two stations of the Colorado Lagoon

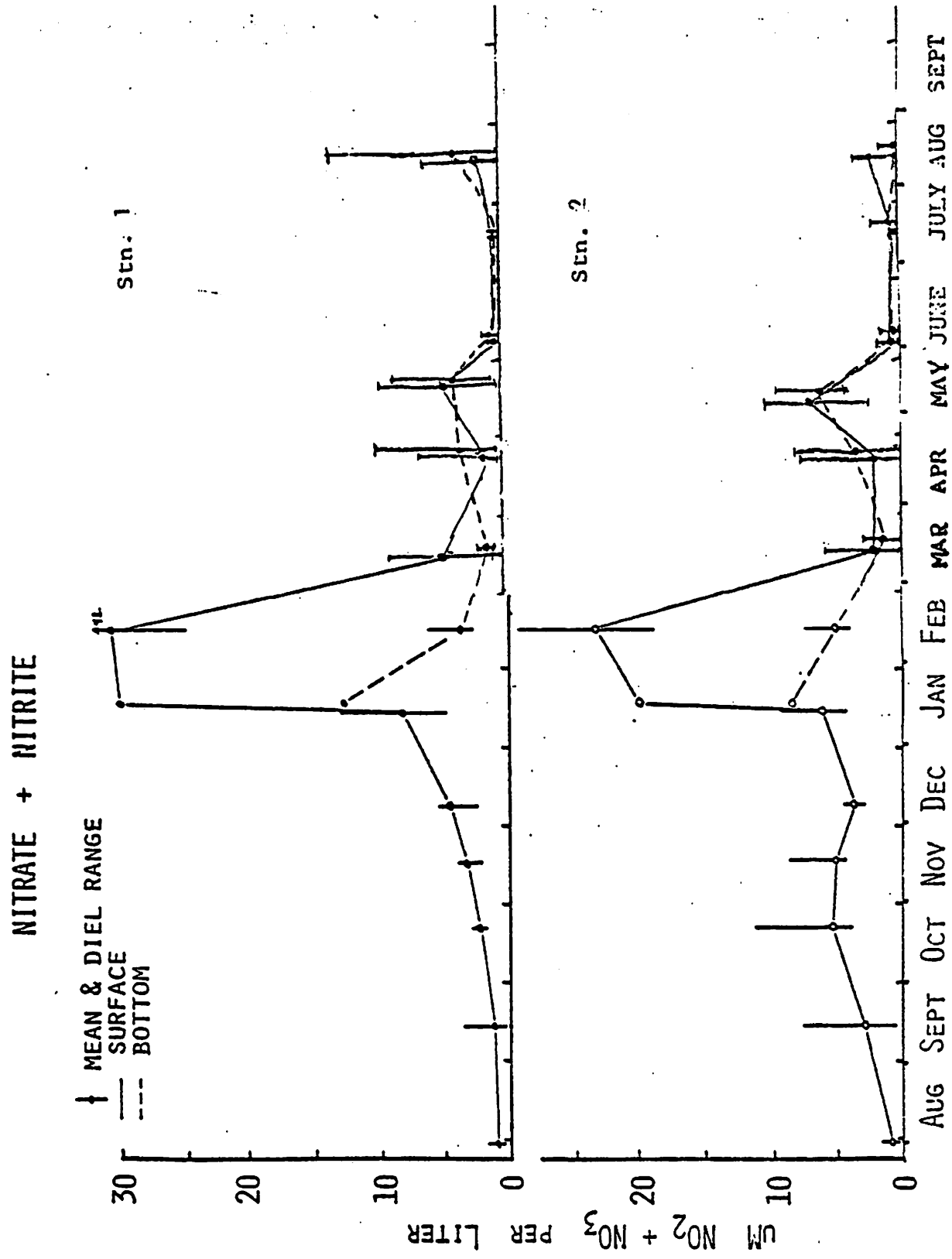

Figure 2. The annual cycle of nitrate plus nitrite at two stations in the Colorado Lagoon

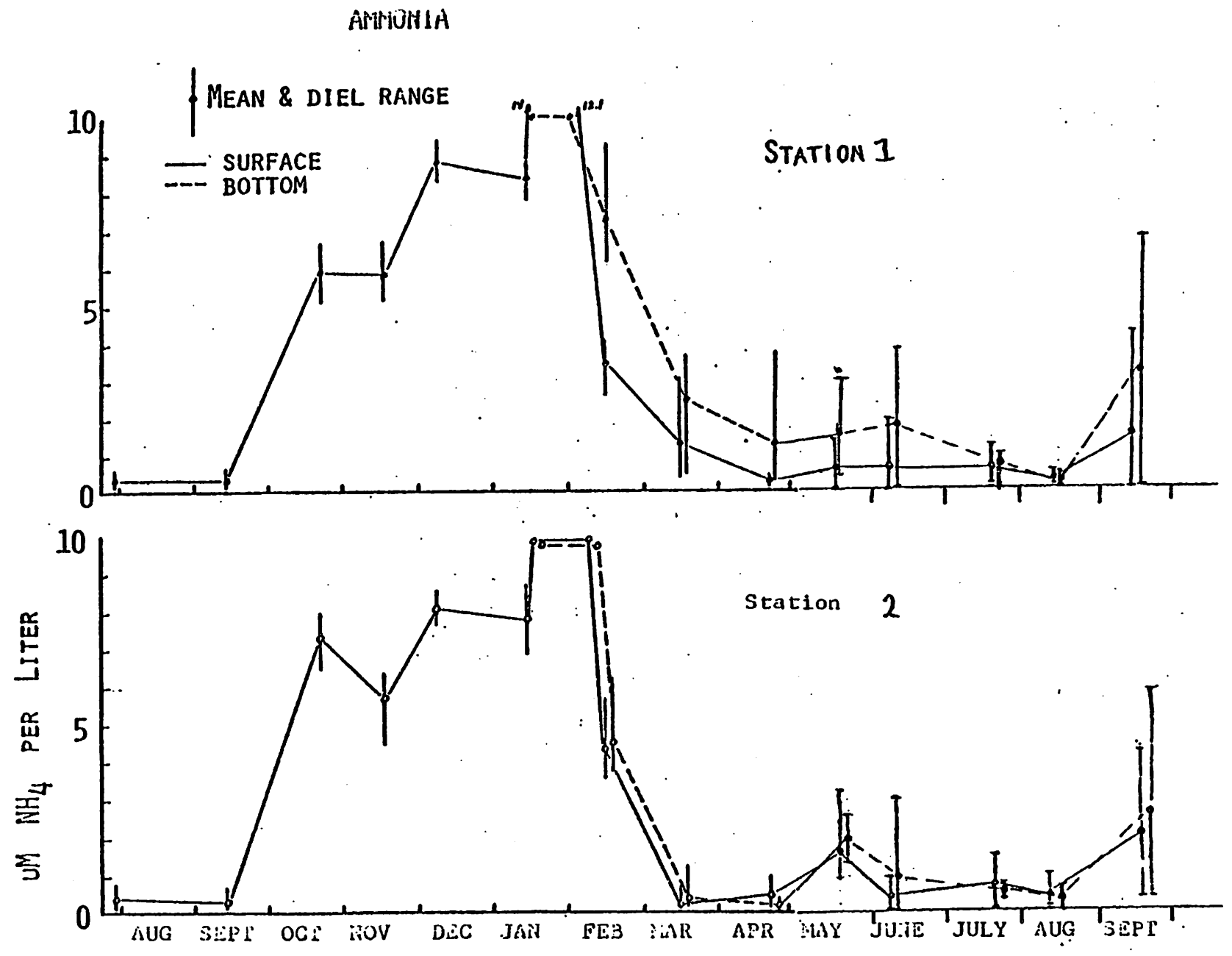

Figure 3. The annual cycle of ammonium at two stations in Colorado Lagoon

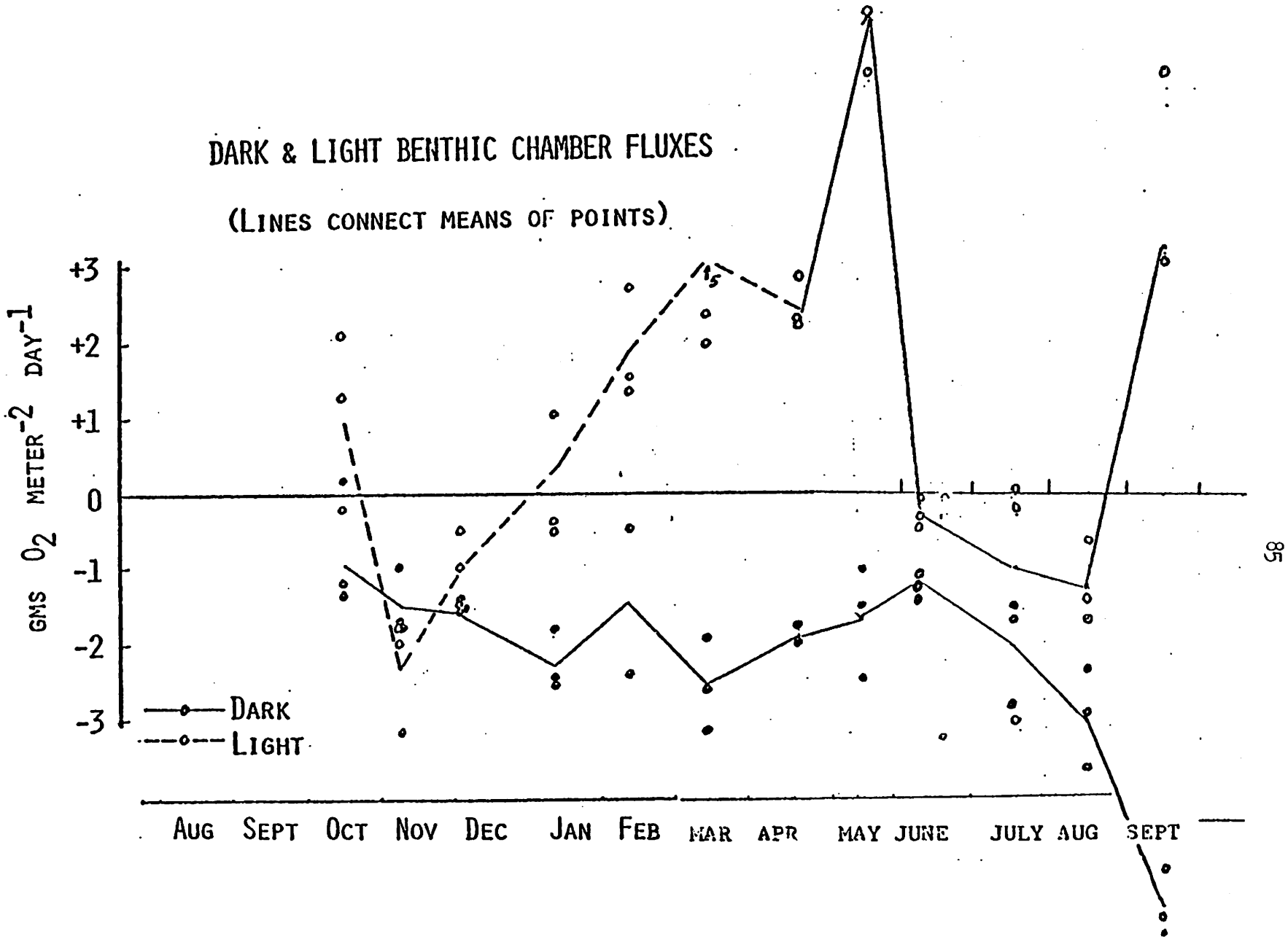

Figure 4a. Net primary production (open circles) and community respiration (closed circles) for the intact benthic community

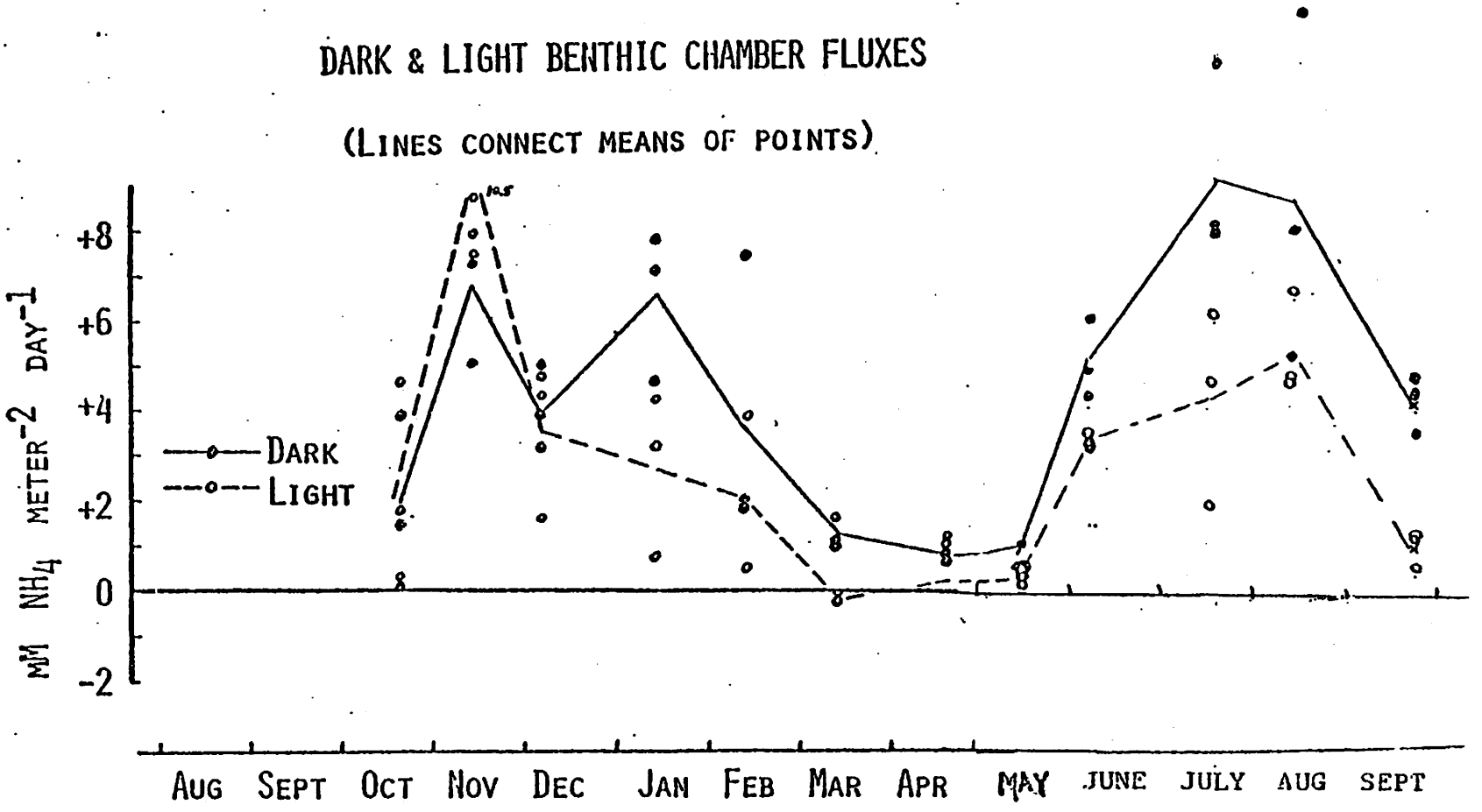

Figure 4b. Net ammonium release by the intact benthic community

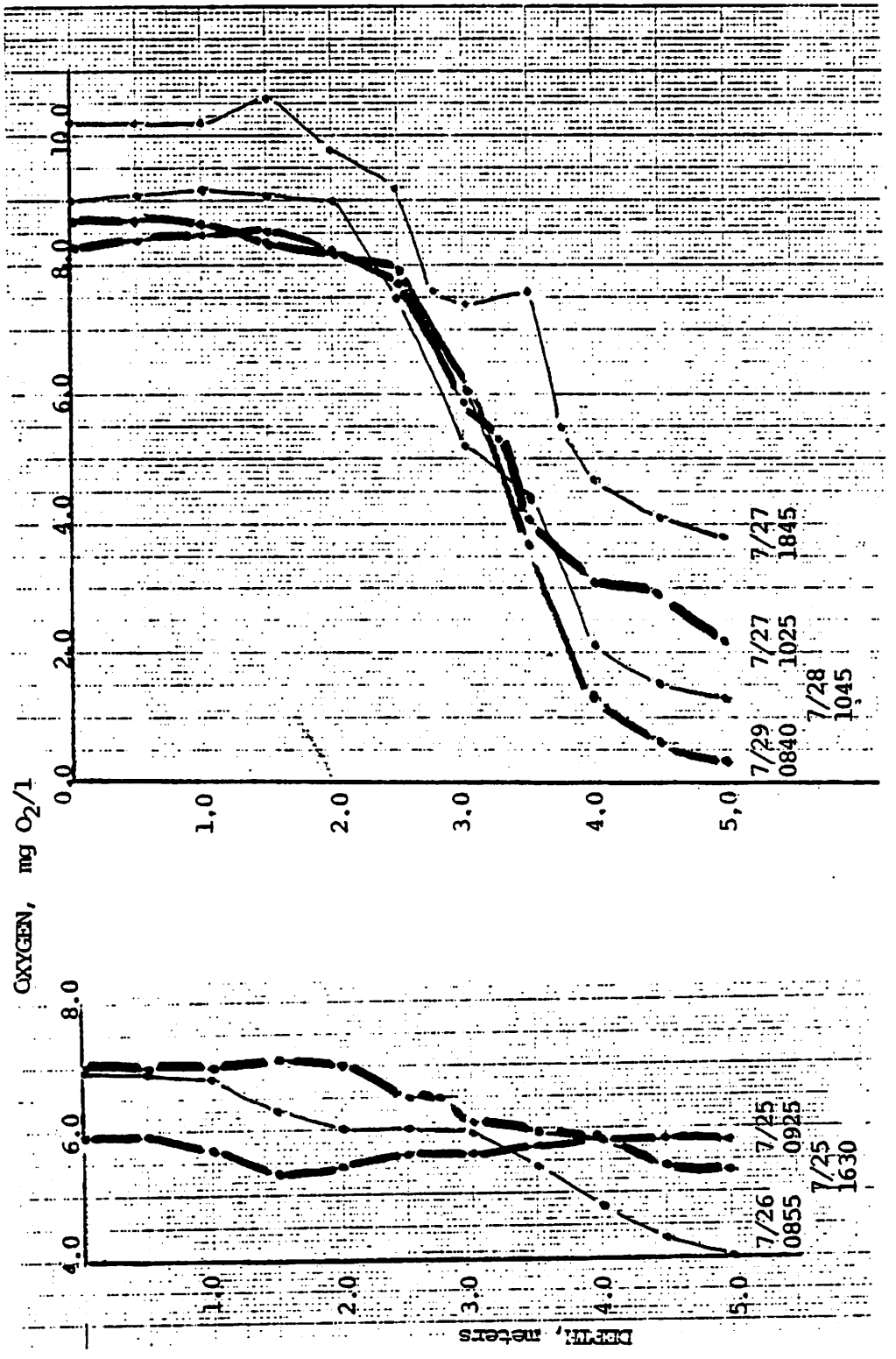

Figure 5 - Oxygen profiles over time with the tide gates closed in July 1979 showed strong stratification with increasing oxygen concentrations near the surface and decreasing levels near the bottom.

R/RD-6

SOUTHERN CALIFORNIA'S NEARSHORE ENVIRONMENT: A SIGNIFICANT FISH NURSERY?

Gary D. Brewer and Robert J. Lavenberg

The distribution of fish eggs and larvae in the shallow coastal zone off southern California is controlled by the interaction of both biological and physical processes. The presence or absence of particular ichthyoplankter at a given point in space and time is governed by several factors, including:

1. The spatial and temporal distribution of spawning adults
2. Passive orientation by currents that may dilute or concentrate spawning products
3. Active orientation by larvae in response to environmental cues such as temperature, depth, currents, light, prey, and predators
4. Mortality of eggs and larvae caused by starvation, predation, or stressful environments (i.e., high or low temperatures)

These factors operate independently of one another, and hence, those conditions that favor gonad maturation, spawning, and fertilization may not be the same conditions that favor feeding, growth, and survival of larvae. In other words, areas where spawning is most intense may not coincide with favorable nursery areas.

Understanding the dynamics of the planktonic stages of coastal zone fish populations is crucial to fisheries managers and to those assessing the impacts of coastal power plants and other artificially induced environmental perturbations. As a specific example, under the Environmental Protection Agency's 316(b) regulations, Southern California Edison is responsible for estimating the loss of fish eggs and larvae in areas adjacent to coastal power plants and assessing the impacts of these losses on local fishery stocks. These tasks can be accomplished only by knowing ichthyoplankton productivity rates and natural mortality rates within the areas influenced by power plant operations. These factors are not easily determined.

The Ichthyoplankton Coastal and Harbor Studies (ICHS) program began sampling the nearshore southern California Bight during June 1978. The ICHS sampling strategy was adopted after consultation with National Marine Fisheries Service, Southwest Fisheries Laboratory, and the Marine Research Committee of the California Cooperative Ocean Fisheries (MRS-CalCOFI) as well as the Research and Development Division of Southern California Edison. The methodology was designed to collect baseline information on nearshore fish eggs and larvae as it relates to the impact of coastal power plants and to complement and supplement the offshore surveys conducted by CalCOFI (Smith and Richardson, 1977); see Figure 1.

The ICHS program was designed to determine: (1) the kinds, abundance, and seasonal occurrence of ichthyoplankton that occur over the continental shelf in water depths less than 36 meters; (2) the relative importance of shallow water versus deep (CalCOFI) region water as spawning and nursery grounds; (3) horizontal and vertical distribution patterns of ichthyoplankters that occur in the nearshore zone; and (4) general life histories and ecological data for the dominant species.

To these ends, an objective of the ICHS during this past year was to sample 47 sites in southern California each month with a Bongo net, towed obliquely, and to sample 39 sites each month with a Manta (neuston) net. We recognized that given the projected funding level it would be impossible to sort and identify all 164 monthly samples. The rationale behind this sampling strategy was to take full advantage of the ship-time expenses (10 days/month) by sampling as intensively as possible. The cost of collecting and preserving additional samples was small relative to ship costs.

The ICHS strategy for data processing has been to first sort and identify samples taken by oblique tows and then sort and identify representative samples taken by discrete-depth samplers. Data from the oblique tows were scaled to provide monthly estimates of ichthyoplankton abundance by region. The discrete-depth samplers supplemented the oblique tows by providing data on vertical distribution. Instead of processing samples in strict sequence from the monthly cruises, we planned to assess seasonal trends according to the plan below.

1978							1979				
Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
x	x		x	x		x	x		x	x	

Hence, the plan was to look at data from oblique tows during eight monthly surveys. In addition, all discrete-depth samples from October would be processed.

It was recognized from the inception of this project that huge quantities of data would be compiled each month. Therefore, a major goal during this past year was to develop a system of data entry and retrieval (using computer facilities at the Southern California Edison Co.) compatible with CalCOFI's data management system. The capability

of a direct information exchange between ICHS-Edison and CalCOFI was an important objective of our efforts.

RESULTS

ICHS has successfully completed 16 monthly cruises, preserved more than 2,200 plankton samples, recorded more than 6,000 water temperatures, oxygen concentrations, and salinities, and computed more than 400 chlorophyll a profiles. Currently, data on ichthyoplankton sampled by Bongo nets towed obliquely from four monthly surveys has been analyzed. Samples from five additional months have been processed but have not yet been analyzed.

Our consultant, T. J. Mueller, in association with Southern California Edison, is working directly with the CalCOFI data management team to fulfill our objective of data compatibility and information exchange between our nearshore surveys and the offshore CalCOFI studies.

Based on data from four seasonal periods, larvae of the northern anchovy (Engraulis mordax) dominated the samples, representing 59% of all larvae captured by oblique tow. Larvae of Pacific mackeral (Scomber japonicus), white croaker (Genyonemus lineatus), queenfish (Seriphus politus), blennies (Hypsoblennius spp.), gobbies (Gobiidae), clinids (Clinidae) were relatively abundant.

The mean number of larvae of all species through the bight based on numbers of 1000 m^3 and 10 m^2 (in parentheses) for the summer and fall of 1978 and the winter and spring of 1979 were: 2,076 (432), 1,088 (265), 2,695 (544), 3,447 (670), respectively. The mean number of fish eggs of all species throughout the bight based on numbers per 1000 m^3 and 10 m^2 (in parentheses) for the same period were 6,288 (1,335), 15,827 (5,401), 7,989 (1,584), and 10,687 (2,400), respectively.

Data were highly variable, but overall, large numbers of larvae were captured at stations in San Diego Bay and off Santa Monica; relatively fewer larvae were captured at stations near Point Conception. Larvae were most abundant at the 22-m depth stations, and eggs were most abundant at 36-m stations relative to the 8- and 15-m stations (Figures 4a, b, and c). Larvae of every major taxa except northern anchovy and rockfish (Sebastes spp.) were more abundant (per 1000 m^3 of water filtered) at the 8-, 15-, or 22-m stations relative to the 36-m stations. These taxa include several species of great interest to sports fishermen and commercial fishermen.

More than 53% of the larvae collected by the discrete-depth samplers were captured in the epibenthic net; similarly, 61% of the eggs were captured in the neuston. The degree of horizontal and vertical stratification of larvae was extreme. As an example, more than 81% of the queenfish larvae captured by the discrete-depth samplers were taken in the epibenthic net at the 8-m station. These data reflect the importance of sampling the near-bottom and near-surface

water strata if one's goal is to estimate ichthyoplankton abundance (Figures 5 - 8).

The depth distribution of larvae of those species that spawn planktonic eggs in the nearshore ranged from predominately epibenthic (queenfish and northern anchovy) to predominately mid-depth (white croaker). The depth distribution of larvae of these species that spawn demersal eggs was also variable, ranging from primarily epibenthic (gobbies) to primarily neustonic (sculpins; Cottidae).

We are presently analyzing the potential correlation of various taxa with such environmental factors as station depth, sampling depth, distnce from shore, bottom substrata, presence or absence of kelp beds, temperature, chlorophyll a, zooplankton displacement volume, sewage outfalls, habitat diversity (i.e., submarine canyons), and co-occurrence with other taxa. While preliminary data have suggested some relationships, our sample sizes are, as yet, too small to make definitive statements about these potential controlling variables.

PROJECT COMMUNICATIONS

Publications

1. Brewer, G., D. Cooksey. 1979. The biology of the northern anchovy in relation to its biomass utilization. Biosources Digest 1(2):115-129.

Reports

1. Brewer, G., R. Lavenberg, G. McGowan. 1979. Abundance and vertical distribution of fish eggs and larvae in the southern California Bight: June and October 1978. Report to Southern California Edison, Research and Development Series: 79-RD-20.

Manuscripts

1. Brewer, G., G. McGowen, R. Lavenberg. Nearshore distribution of ichthyoplankton in the southern California Bight. Presented at the California Cooperative Oceanic Fisheries Investigations, Annual Meeting, 22-25 October 2979.

2. Watson, W., G. McGowen. Identification of the atherinid larvae in the southern California Bight. Presented at the California Cooperative Oceanic Fisheries Investigations, Annual Meeting, 22-25 October 1979.

Meetings

1. California Cooperative Oceanic Fisheries Investigation, Annual Meeting, Idyllwild, California, 31 October - 2 November 1978. Brewer, G., R. Lavenberg, G. McGowen. USC Ichthyoplankton Coastal and Harbor Studies (ICHS): Techniques and preliminary investigations.

2. International Symposium on the Early Life History of Fisheries, International Council for the Exploration of the Sea, Marine Biological Laboratory, Woods Hole, Massachusetts, 2-5 April 1979. Brewer, G., R. Lavenberg, G. McGowen. Abundance and vertical distribution of fish eggs and larvae in the southern California Bight: June and October 1978. Also McGowen, G. Composition, distribution, and seasonality of ichthyoplankton populations near an electricity generating station in south San Diego Bay, California.

3. Southern California Academy of Sciences, Annual Meeting, California State University, Northridge, 11-12 May 1979. Ninos, M. Distinguishing characters of the late pelagic laravae of Hypsoblennius in southern California.

4. Under the leadership of G. McGowen, ICHS has met monthly with ichthyoplankton taxonomists who represent other projects involved with fish egg and larval surveys in southern California. The goal of these meetings is to achieve taxonomic standardization. These meetings are presently being formalized by R. Lavenberg and G. McGowen into a Taxonomic Quality Assurance Program (TQAP) that will establish reference collections of ichthyoplankton at the Los Angeles Museum of Natural History as well as the ICHS sorting and identification laboratory at Wilmington. Ultimately, these efforts will culminate in a reference manual for nearshore ichthyoplankton identification.

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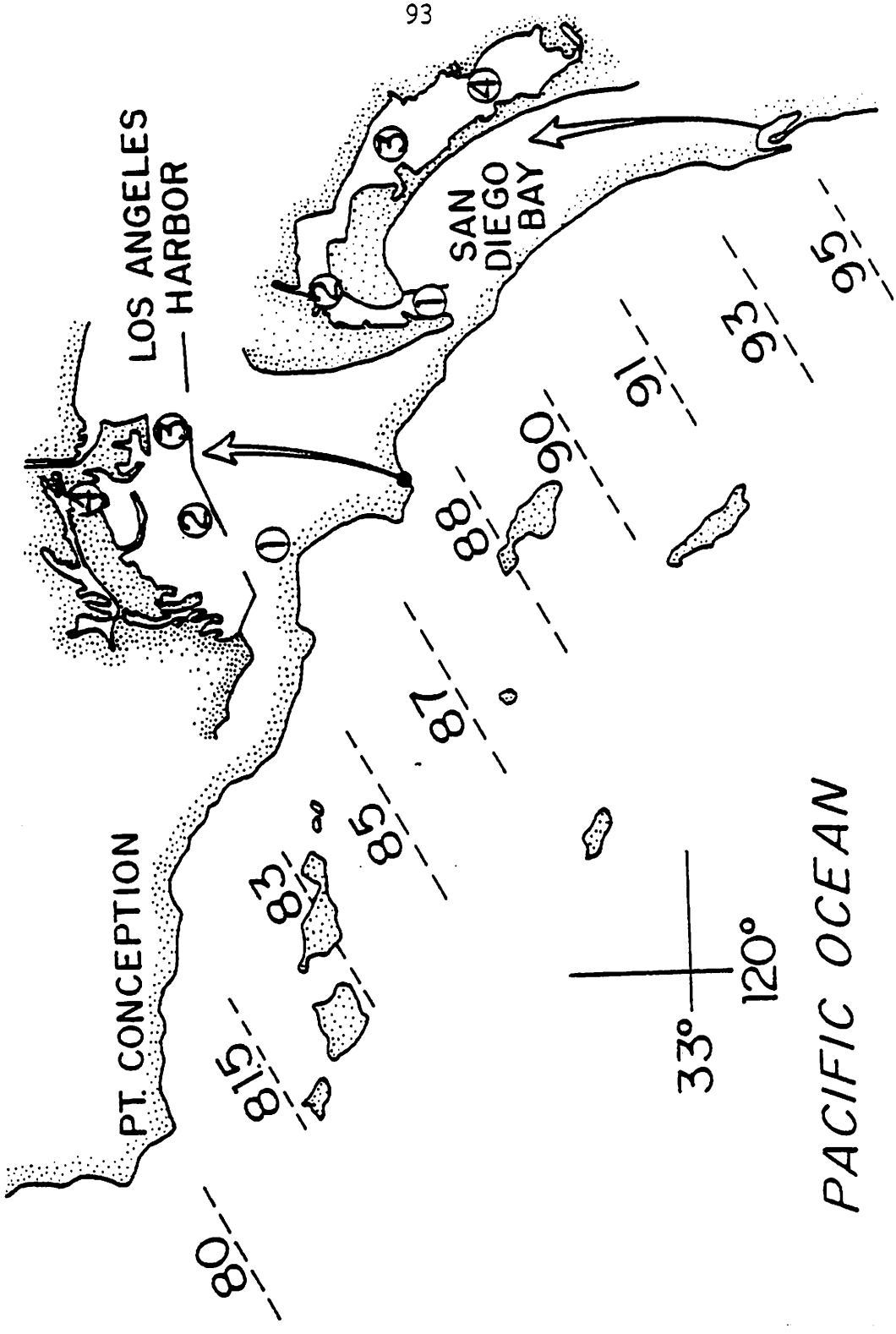

Figure 1. Basic CALCOFI station transects for the southern California Bight. ICHS stations were established over water depths of 8, 15, 22, and 36 m where the extended transects intersect the shore. Additional stations in San Diego Bay and Los Angeles Harbor are shown. Major surface circulation in the Bight is represented by arrows.

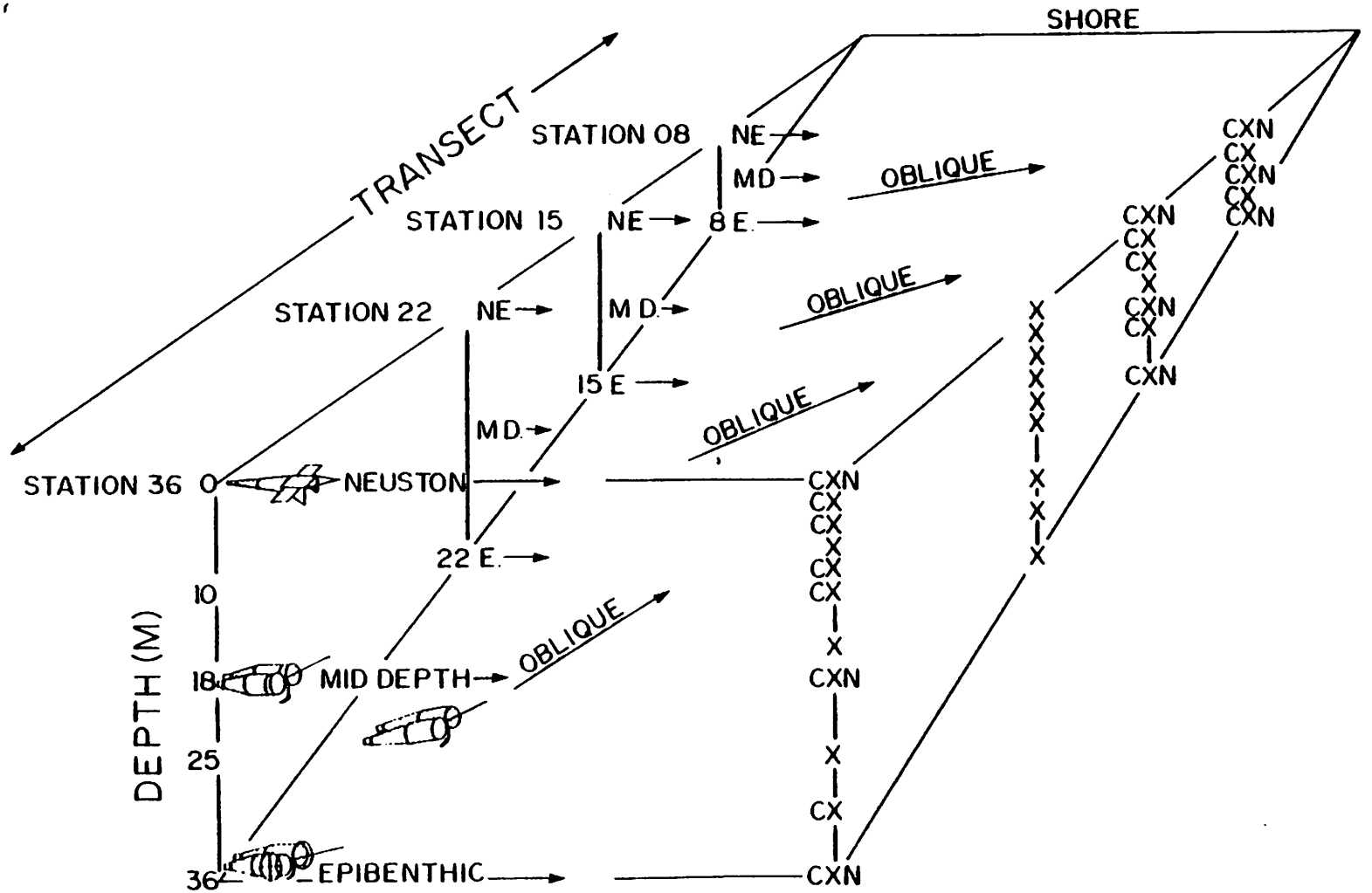

Figure 3. Summary of ICHS sampling strategy for the southern California Bight. NE = neuston tow; MD = middepth tow; C = chlorophyll sample; N = nutrient sample; X = temperature, salinity, dissolved oxygen record.

N

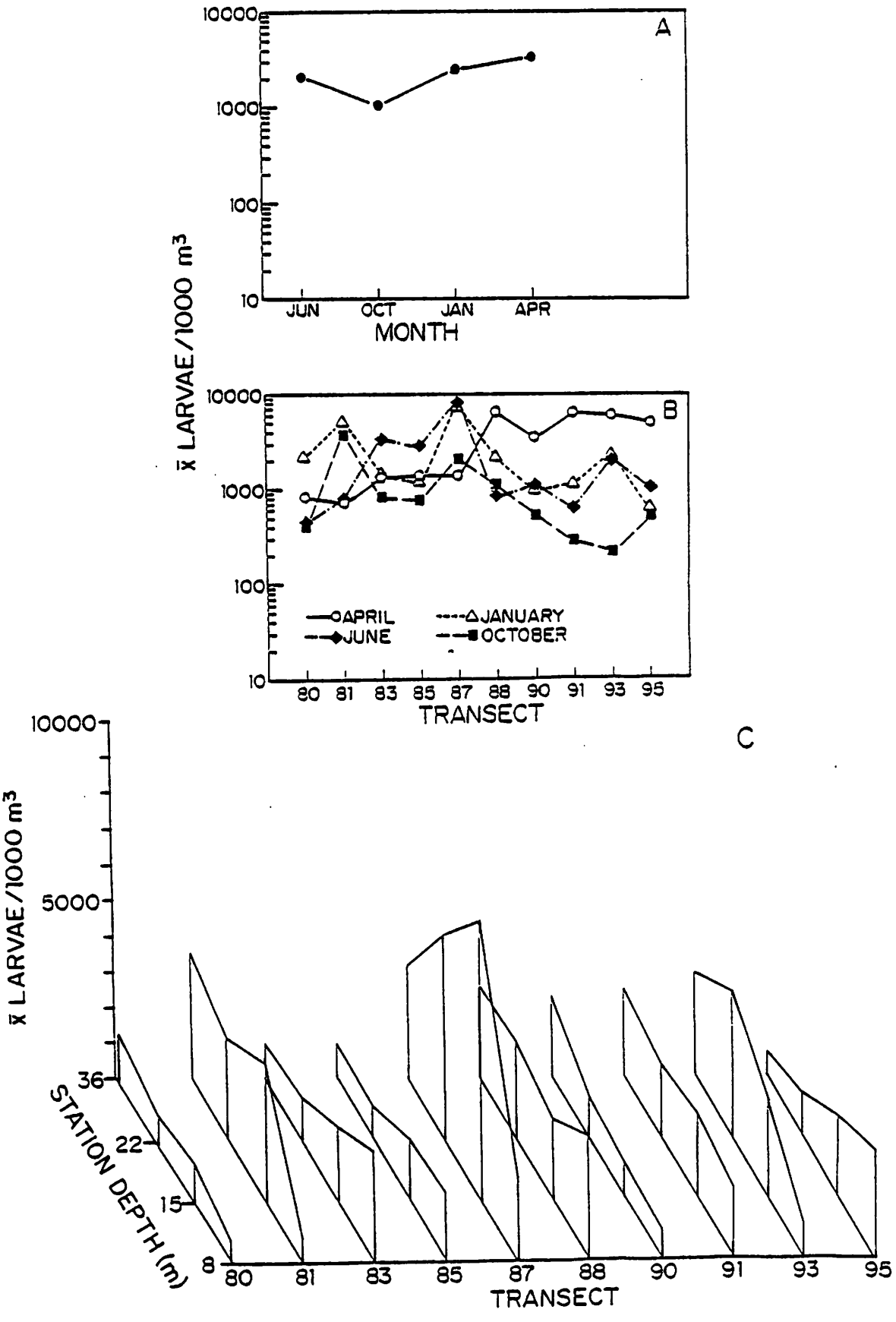

Figure 4. Abundance of total larvae captured by Bongo nets towed obliquely (a) by month; all stations and transects combined; (b) by transect for June and October 1978 and January 1979; (c) by transect vs station depth.

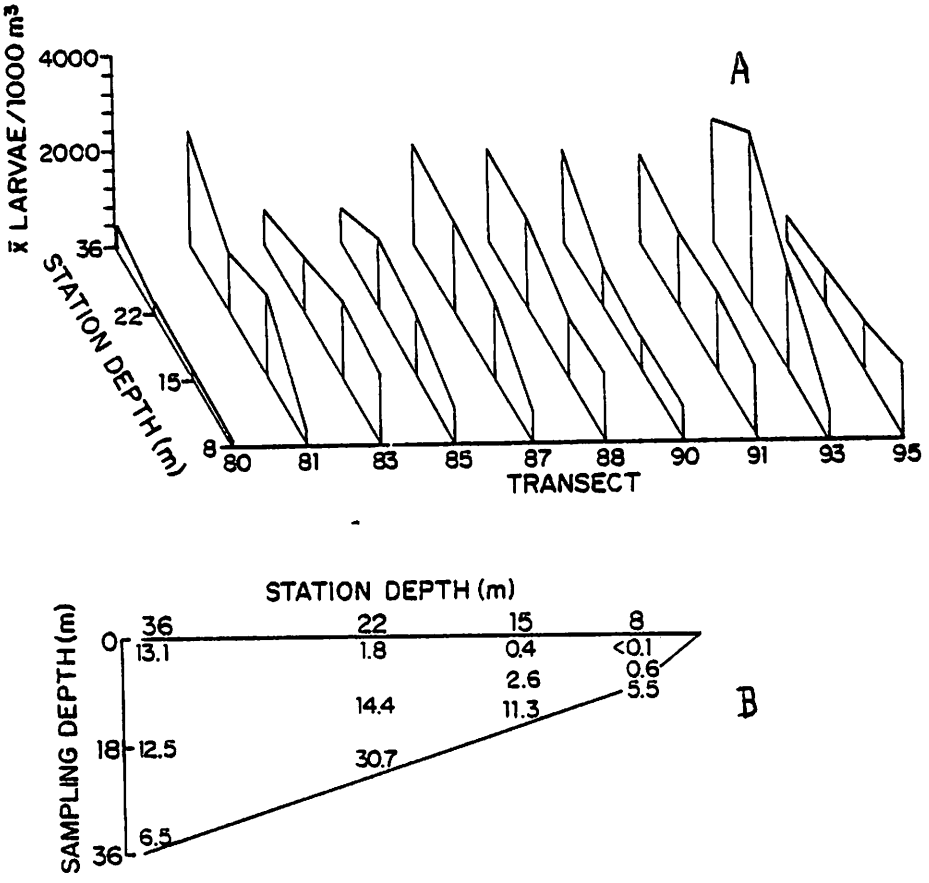

Figure 5. (a) abundance of Engraulis mordax (northern anchovy) by transect vs station depth (four months combined); (b) relative abundance of E. Mordax by station depth vs sampling depth based on the discrete depth samples collected during October (i.e., % of larvae collected by sampling depth.)

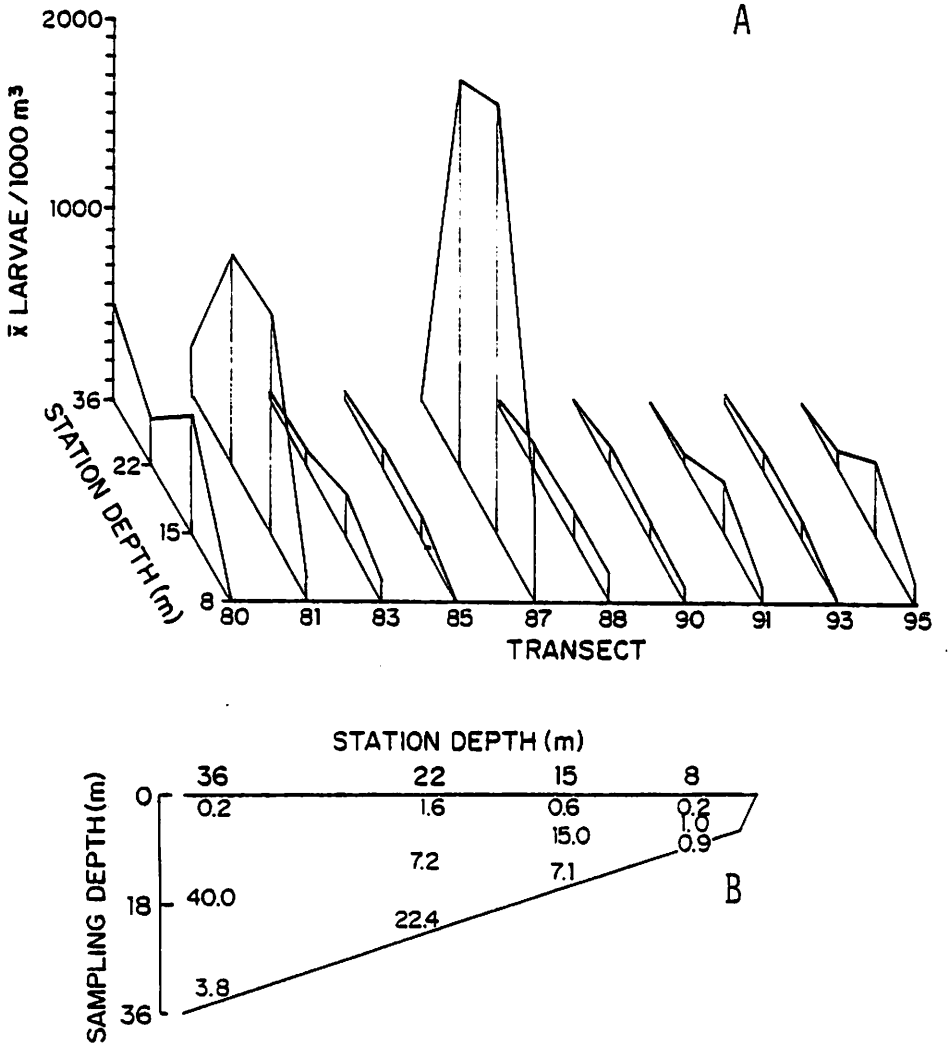

Figure 6. Abundance of Genyonemus lineatus (white croaker) by transect vs station depth (four months combined); (b) relative abundance of G. lineatus by station depth vs sampling depth based on the discrete depth samples collected during October.)

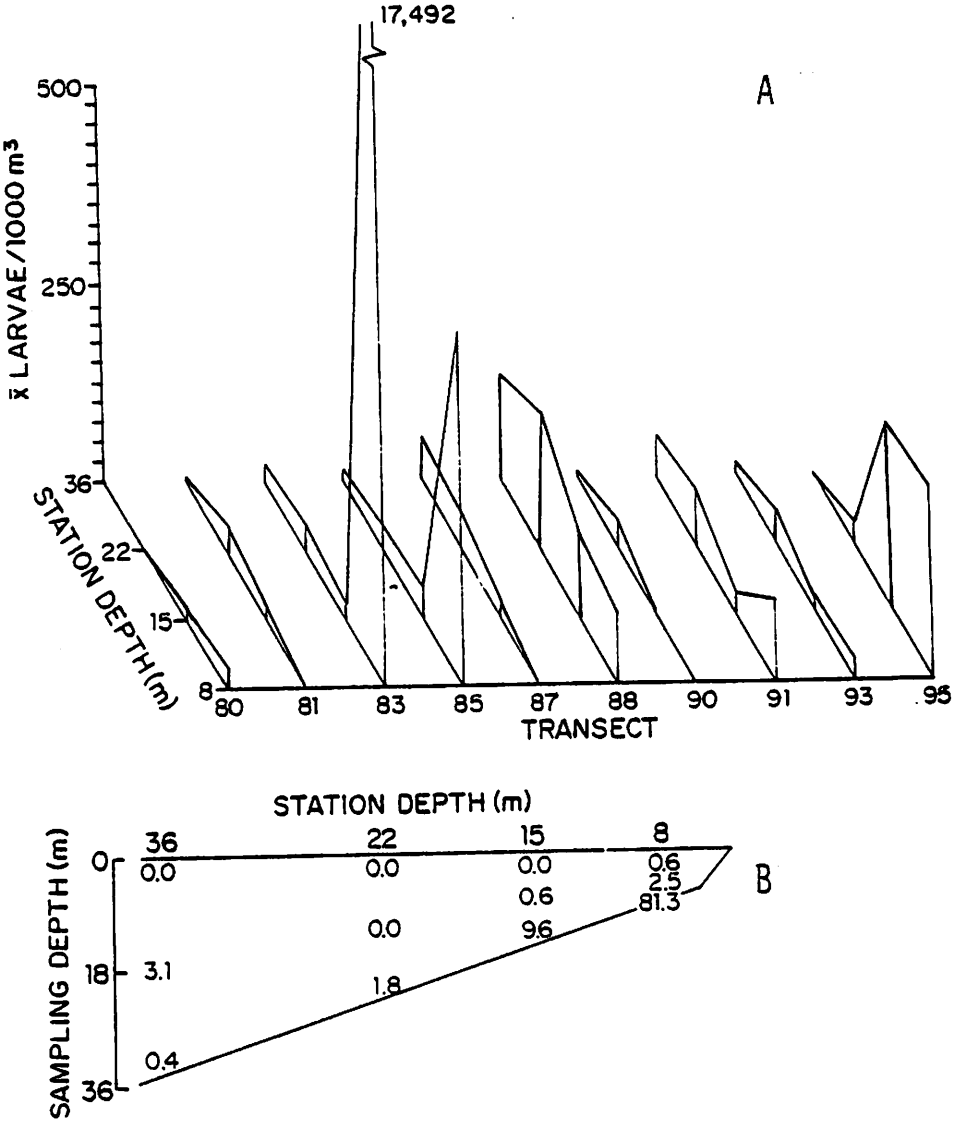

Figure 7. Abundance of Seriphus politus (queenfish) by transect vs station depth (four months combined); (b) relative abundance of S. politus by station depth vs sampling depth based on the discrete depth samples collected during October

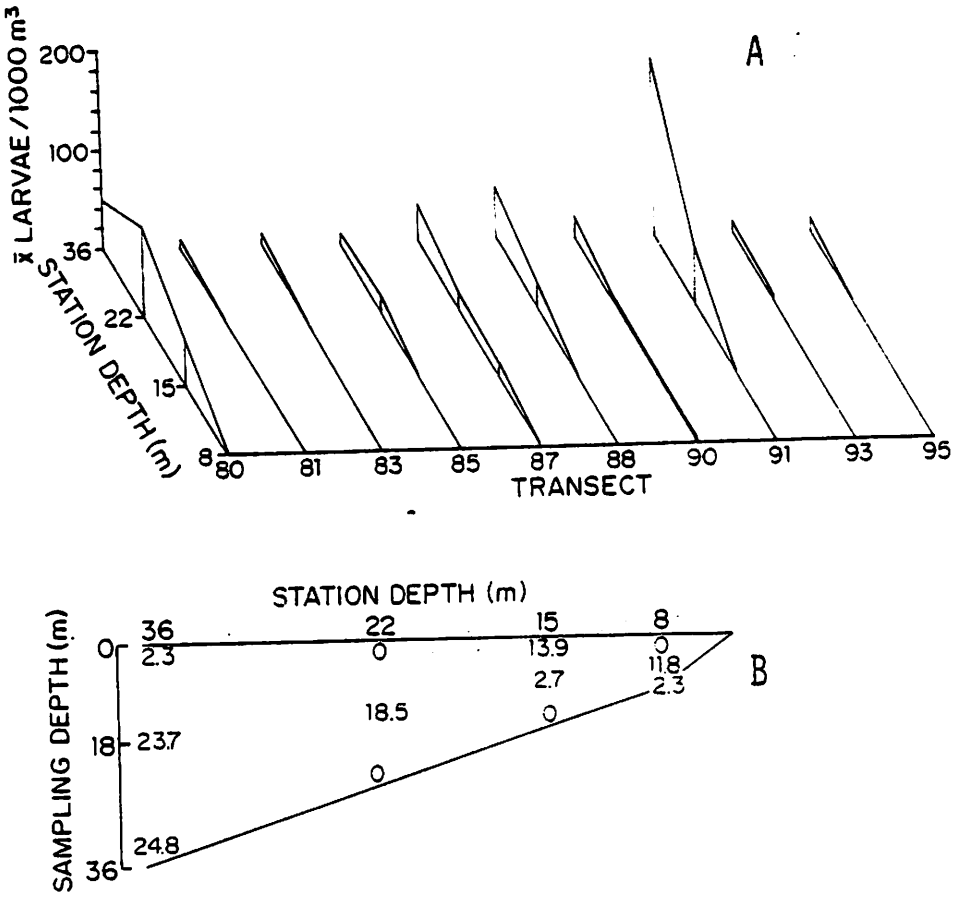

Figure 8. Abundances of Sebastes spp. (rockfish) by transect vs station depth (four months combined); (b) relative abundance of Sebastes spp.by station depth vs sampling depth based on the discrete depth samples collected during October

NON-LIVING MARINE RESOURCES

On the premise that sand and gravel are primary resources used in many phases of construction and to maintain southern California's invaluable beaches and harbors, project R/RD-10 investigated the potential of offshore resources. Land-based deposits of sand and gravel are becoming increasingly difficult to obtain, due to competing land uses and the undesirability of mining such deposits. Exploration of the potential of offshore resources included obtaining basic geologic information on location, volume, texture, and composition of offshore sand and gravel deposits along the San Diego County, California, shelf, and disseminating that information to interested agencies and industries.

SEDIMENT ACCUMULATION AND THE HISTORY OF POLLUTANT ACCUMULATION IN SAN FRANCISCO BAY

Douglas E. Hammond

The welfare of southern California is dependent in many ways on the management of water resoures in the San Joaquin-Sacramento River drainage basin. At present, this system provides a significant fraction of the water necessary for agricultural and municipal use in southern California. As California's share of Colorado River water is reduced in the coming decade, this system will become an increasingly important source of water. The health of San Francisco Bay and the adjacent coastline also depends critically on the management of water resources as well as on pollutant releases in this drainage basin. The impacts of the diversion of water from San Francisco Bay can only be predicted by understanding the operation of the system at present. This project has focused on two aspects which have important implications for water management of this system. These aspects are to construct budgets for sediment and chlorinated hydrocarbons in San Francisco Bay.

The sediment budget is of interest because extensive dredging is required to maintain harbors and navigation channels. The annual rate of dredging in the bay exceeds the annual rate of riverine sediment input. Thus, a major fraction of the material dredged must return to the dredge site. At present, there is considerable disagreement about the efficiency of San Francisco Bay as a sediment trap. Smith (1966) has estimated that one third of the sediment carried to San Francisco Bay by rivers is lost to the ocean. Conomos and Peterson (1977) have estimated that essentially none of this material is lost to the ocean. The cost-efficiency of site selection for disposing of dredge spoils clearly depends on which estimate is correct. If Conomos and Peterson are correct, disposal of material near the dredge site (the current practice) leaves all of this material in the system, ready to return to the dredge site. If Smith is correct, dredging and disposal ultimately removes a significant fraction of the material.

The second aspect of this project is to conduct an inventory for various chlorinated hydrocarbons in bay sediments. Large amounts of pesticides and herbicides have been introduced by the agricultural industry in this drainage basin. The fate of these substances and their breakdown products is largely unknown. They are known to readily adsorb on particulate phases, and a large fraction of the compounds used to date may currently be stored in bay sediments. This project will provide an inventory for several of these compounds. In addition, if a site with relatively undisturbed stratigraphy can be found, information can be obtained on the time history of pollutant delivery to the system.

Our proposed goals for the initial funding year were to:

1. Obtain and curate a collection of large-diameter gravity cores.

2. Identify areas presently accumulating sediments using lead-210 and cesium-137.

3. Measure profiles of chlorinated hydrocarbons at two sites.

An additional goal was defined after the project began, which was to determine the residence time of particulates in the water column using thorium-234. Thorium readily adsorbs to particles, and can act as a tracer for studying the movement of reactive substances and suspended sediment within the system (Broecker et al., 1973).

To date, the following have been accomplished:

1. Large-diameter cores have been obtained at 47 sites in San Francisco Bay. One core from each site was extruded, air-dried, and has been stored. A second core from each site was extruded, sectioned, and frozen. Nearly all of these sectioned samples have been freeze-dried and stored for isotopic and chemical analysis. X-radiographs were taken at 14 sites for the study of sedimentary structures.

2. Vertical profiles for cesium-137 have been measured at nine sites and vertical profiles of lead-210 have also been measured at five sites.

3. Splits of samples from two sites have been sent to Lamont-Doherty Geological Observatory for the analysis of chlorinated hydrocarbons. Their laboratory has outstanding analytical facilities, and they have agreed to collaborate in this project. Their initial analyses are not yet completed, however.

4. Three trips have been made to the bay to measure Po-210/Pb-210 and Th-234/U-238 ratios in suspended matter. Analyses of Po-210, Th-234, and U-238 from the first two trips have been completed.

Although it is premature to make definitive statements about the sediment budget at present, we can make some generalizations from our data. Cesium-137 is a product of atomic weapons testing and labels sediment introduced in the past 20 years. The distribution of this isotope shows highly variable accumulation rates of recent material, much as we anticipated. Shoal areas show low rates of accumulation except near physical obstructions, and deep areas show more rapid rates of accumulation. To illustrate this, Figures 1 and 2 show vertical profiles of cesium-137. Site 13.13S borders the navigation channel in San Pablo Bay. Due to instrument difficulties with our Ge(Li) counting equipment, we have not yet counted all intervals, but this site has 100 - 120 cm of recent sediment and an accumulation rate of 5 - 6 cm/yr. Site 12.45N (Figure 2) in a shoal area, shows cesium-137 only in the upper 16 cm, and, consequently, must have a much lower accumulation rate.

At sites with low accumulation rates, bioturbation is a major complicating factor because it redistributes sediment and istopes. The depth to which bioturbation is effective will vary from one site to another, but is largely confined to the upper 5 - 20 cm, based on x-radiography of sediments. Despite bioturbation, a net accumulation rate(s) may still be obtained by using lead-210, a naturally occurring isotope in the U-238 series. Lead-210 enters the system through both dry and wet deposition from the atmosphere and rapidly attaches to suspended sediment. Accumulation rates may be calculated by constructing a lead-210 balance for the sediment column:

$$s = \frac{\lambda \int_0^{\infty} Pb)_{ex}\, dx}{Pb)_x^o}$$

where:

λ = lead-210 decay constant

$Pb)_{ex}$ = excess lead-210 in sediment

$Pb)_{ex}^{o}$ = excess lead-210 incoming sediment

x = depth in sediment

This calculation yields a net accumulation rate of 2 mm/yr for site 12.45N, about 25 percent of the rate which might have been estimated from cesium. Thus, caution must be used in using isotopes to caclulate sedimentation rates. Sites of rapid accumulation, however, will be only slightly affected by bioturbation because of the limited depth ranges and reworking rates of organisms.

Results from the thorium-234 measurements have shown that the effective residence time of sediment in the water column is 7 to 10 days. This includes the time this sediment is readily available for resuspension. When the Po-210/Pb-210 measurements are completed, the significance of this number will be more apparent, as the average number of times particles are resuspended can then be established. When all measurements of the isotopes discussed above are completed, we will be able to construct a model which can be used to estimate the effective residence time of suspended sediments and reactive pollutants to the water column, the number of times particles are resuspended before being buried, the fraction of river-borne sediment which is deposited in the bay, and the rate of sediment accumulation at individual sites. In addition, when the chlorinated hydrocarbon analyses are complete, the importance of the bay as a sink for agricultural pollutants can be assessed.

PROJECT COMMUNICATIONS

1. Informal discussions with U. S. Geological Survey Estuarine Studies Group, Menlo Park, Ca.

   Dr. H. J. Simpson, Columbia University

2. Newsletter progress report (March 1979) sent to research groups working on San Francisco Bay:

   Columbia University
   United States Geological Survey
   University of California, Berkeley

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3. Smith, B. 1966. Sedimentation aspects of San Francisco Bay. San Francisco Bay Conserv. and Dev. Comm. Report No. 7, pp. 1–49.

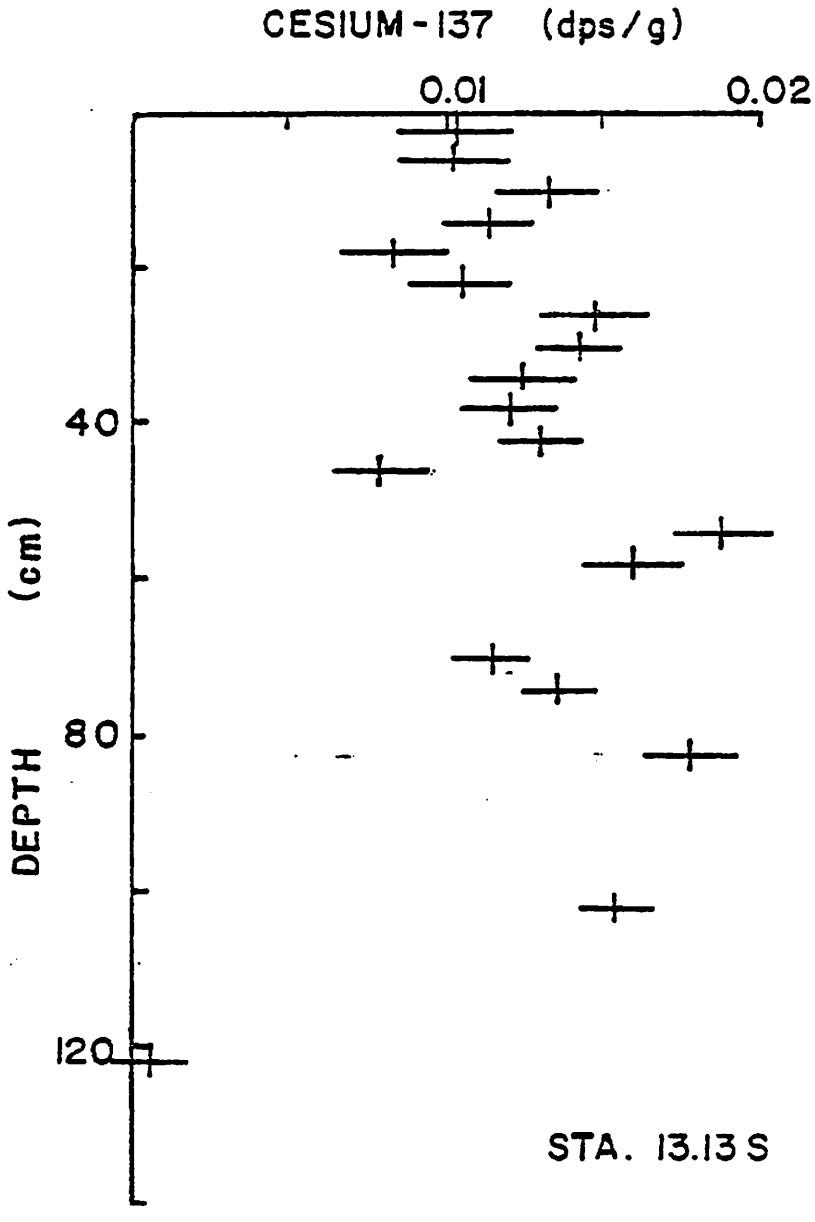

FIGURE 1

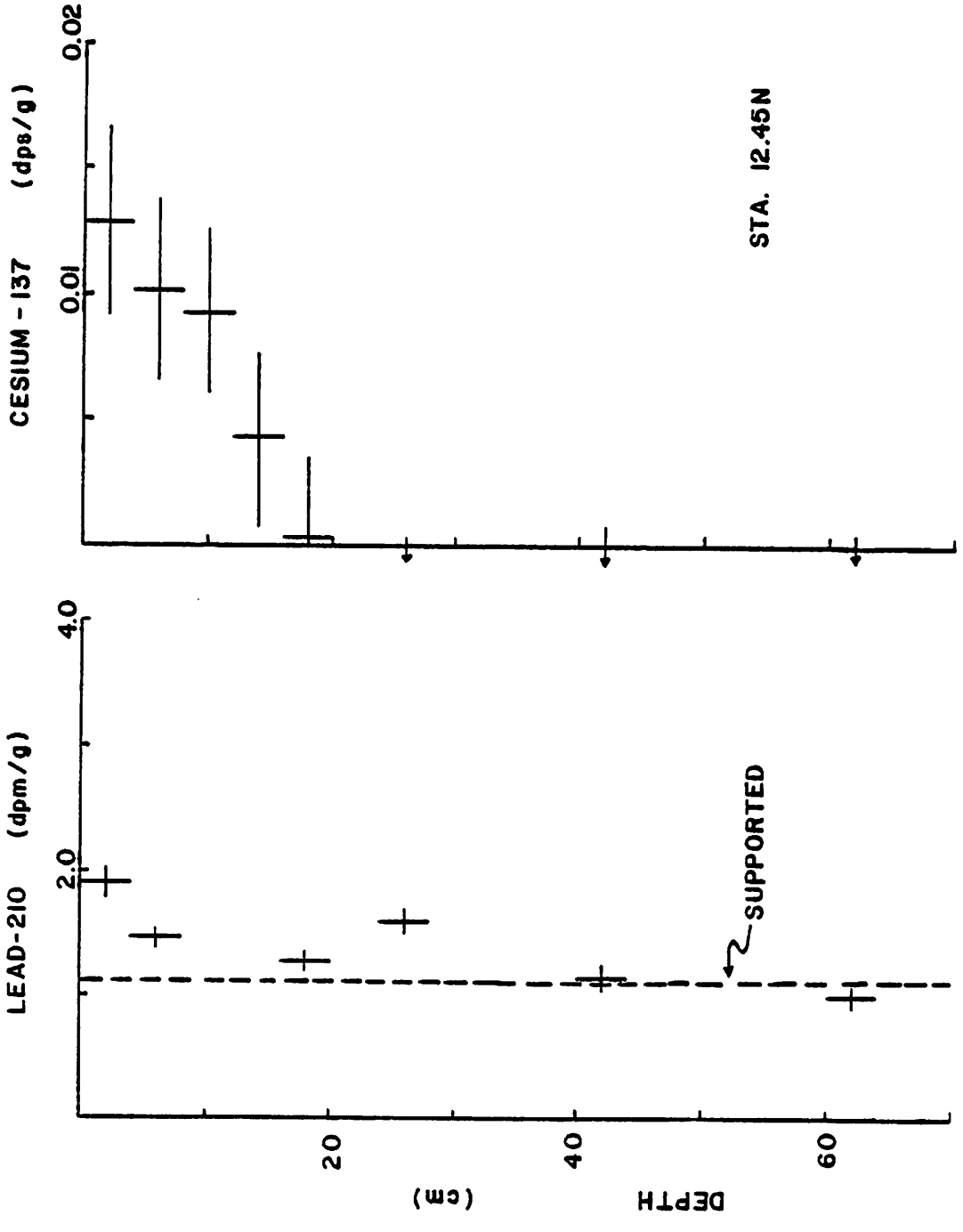
CESIUM - 137 (dps/g)
0.02
0.01
STA. 12.45N
LEAD-210 (dpm/g)
4.0
2.0
SUPPORTED
20
40
60
DEPTH (cm)

FIGURE 2

R/RD-3

OFFSHORE SAND AND GRAVEL RESOURCES IN SAN PEDRO AND SANTA MONICA BAYS, SOUTHERN CALIFORNIA

Robert H. Osborne and Thomas L. Henyey

Sand and gravel are primary resources in many phases of construction and maintenance of southern California's beaches and harbors. Although California has led the nation in the production of sand and gravel since 1942, deposits of saleable-grade material available under present political and economic conditions are rapidly becoming depleted. The sand and gravel needs of the construction, road-building, facilities maintenance, and specialty sand industries can be met by: (1) changing zoning regulations to permit known deposits to be expoited; and/or (2) exploring for new sand and gravel deposits, taking care to evaluate the geological, socio-economic, environmental, and legal aspects of exploitation.

The first alternative can be undertaken only if such deposits can be developed without imposing substantial socio-economic problems or hazards on owners of adjacent property. Additional considerations would be whether areas mined could be rehabilitated in an environmentally acceptable manner, and whether adequate, relatively low-cost reserves would be available for long-term local needs.

Since many land-based sand and gravel deposits are lost to competing land users, and mining of these deposits is generally opposed by urban communities, the feasibility of mining offshore deposits is being evaluated. Many of the potential commercial sources are partly or wholly within offshore coastal areas.

Potential offshore resources, in addition to providing large-scale supplies, could reduce transportation costs. Barges could transport large supplies at relatively low cost to distribution points along the entire southern California coast. Further, geologists and engineers agree that offshore sand supplies are the only practical long-term sources for replenishing beaches and harbors that are eroding from the action of storm waves. One can envision the ideal situation involving a recycling of sand from offshore sinks back to the respective depleted beach.

During June and July 1974, the Coastal Engineering Research Center, in cooperation with the Los Angeles District of the U.S. Army Corps of Engineers, conducted a sediment and shallow structure survey of the inner continental shelf off southern California. The major purpose of this survey was to delineate the character and map the extent of sand resoures that are suitable for beach restoration and nourishment. Although related to this earlier work performed by the U.S. Army Corps of Engineers, the present study differs in that it is directed toward detailed sedimentologic analysis of site-specific areas within Santa Monica and San Pedro Bays (Figure 1).

The geophysical data base for this study consists of 2,010 nm of 3.5-kHz high-resolution seismic-reflection profiles, of which 400 nm were obtained from the Coastal Engineering Research Center. Approximately 1,000 nm of trackline was used to delimit the site-specific areas discussed here.

T. Nardin described and sampled (329 subsamples) 24 vibracores from the Santa Monica Bay and 23 vibracores from San Pedro Bay, which had been collected by the U. S. Army Corps of Engineers. An additional 27 vibracores from Santa Monica Bay (Figure 2) and 26 from San Pedro Bay (Figure 3) were collected during May and June 1978 to define better these and and gravel bodies in specific target areas. The average thickness of recovered core is 3.5 m, and the maximum thickness is 6.75 m. Upon recovery, each vibracore was split lengthwise, photographed, logged, and sampled (379 subsamples from USC cores).

Each of the 708 subsamples obtained was analyzed for the weight percent gravel, sand, and mud (silt and clay). The sand fraction was then analyzed at half-phi intervals by means of a Felix settling tube (Felix, 1969), and the conventional moment measures were computed. The synthesis of geophysical and textural data permitted computation of realistic estimates of the extent and volume of suitable sand and gravel bodies at dredgeable depths in Santa Monica and San Pedro Bays. The seismic-reflect profiles also permit identification of these sand and gravel bodies in unsampled areas.

RESULTS

Santa Monica Bay

Santa Monica Bay is located west of the Los Angeles basin and is bounded by the Santa Monica mountains on the north and the Palos Verdes hills on the south. Its narrow shelf is cut by the Point Dume, Santa Monica, and Redondo submarine canyons (Figure 1). The geology of the Santa Monica shelf has been examined by numerous authors, including Emery (1952), Terry et al. (1956), Yerkes et al. (1967), Green et al. (1975), Vedder et al. (1974) and Nardin and Henyey (1978). Scheidemann (in prep.) is studying the Quaternary stratigraphy of the inner Santa Monica shelf using high-resolution seismic reflection profiles and vibracore data.

The inner Santa Monica shelf is characterized by a progradational Pleistocene stratigraphic package that was subsequently notched during an emergent event in the Late Pleistocene (Figure 4). Early Holocene deposition resulted in the local accumulation of a lower Holocene unit (Hol-I). The ensuing submergence is reflected in the deposition of unit Hol-II which is unconformable with the strata that is assigned to the Pleistocene and Hol-I packages. The most recent submergence is represented by the present shoreline unit (Hol-III),

which locally connects with the uppermost part of unit Hol-II and elsewhere is unconformable on Pleistocene strata.

The examination of vibracore data shows that it is generally possible to correlate sediment type with its appropriate stratigraphic package along the inner Santa Monica shelf. Holocene sediment is typically gray-green to greenish black, silty, fine-grained sand. Pleistocene sediment varies from a clean, well-sorted, white-to-gray, medium sand to a poorly sorted red-brown to gray, silty, coarse sand. Pebbles and cobbles are abundant locally.

More closely spaced seismic tracklines and a great density of vibracores have resulted in substantial modifications in the volumetric estimates of available sand and gravel bodies on the inner Santa Monica shelf (Figure 5). In the southern part of Santa Monica Bay, Site B-I, as designated by the Coastal Engineering Research Center, is believed to contain a minimum of 6×10^6 yd^3 of suitable sand (mean grain diameter between 0.177 and 0.707 mm). Site B-II, immediidiately north of the Redondo submarine canyon, was originally thought to contain a minimum of 16×10^6 yd^3. Subsequent work has demonstrated that Site B-II contains a minimum of 46×10^6 and a maximum of 110×10^6 yd^3 and a maximum of 93×10^6 yd^3 of essentially Pleistocene strata in contrast to the original minimal estimate of 12 x 10 yd^3. Site B-IV is the offshore belt of Holocene strata (units Hol-I and II) that parallels the present coastline from the Palos Verdes hills to Point Dume. It was originally estimated to contain 325×10^6 yd^3, but this is considered of marginal quality (Figure 5).

As a result of the USC coring program, a new location has been discovered between the 5- and 15-fathom isobaths from Marina del Rey to the Santa Monica pier. It is estimated that Site B-V contains a minimum of 17×10^6 yd^3 of exhumed Pleistocene strata (Figure 6). Thus, new estimates for suitable sand and gravel deposits in Santa Monica Bay range from a minimum total of 104×10^6 yd^3. Improved dredging technology will make even greater volume potentially available for use.

SAN PEDRO BAY

San Pedro Bay is the site of a broad shallow shelf, which is trisected by the Palos Verdes fault zone (Figure 1) and an unnamed fault zone (Junger and Wagner, 1977; Fischer et al., 1977). Both vibracoring programs were concentrated east of the Palos Verdes fault zone, and, in most cases have penetrated nearly horizontal Holocene stata. Several vibracores may have penetrated locally uplifted Pleistocene strata east of the unnamed fault zone.

Sediment recovered in these vibracores ranges from well-sorted, white-to-orange sand with occasional pebbles and cobbles to an olive green to dark olive black, sandy silt and clay. Most commonly, the fine-to-medium sand fraction contains a high percentage of argillaceous material.

This study agrees closely with the earlier study performed by the Coastal Engineering Research Center regarding both the locations and volumes of sand and gravel deposits in San Pedro Bay (Figure 7). Sites A-I, A-II, and A-III have been estimated to contain 134 x 10^6, 220 x 10^6, and 102 x 10^6 yd^3 of suitable sand, respectively. Collectively, these sites contain about 456 x 10^6 yd^3 of sand suitable for beach replenishment. Additional vibracoring is needed to determine whether or not suitable material is present between Sites A-I and A-II.

SUMMARY

Recent work by personnel from the University of Southern California and the U.S. Army Corps of Engineers (Coastal Engineering Research Center, has demonstrated the existence of voluminous offshore sand and gravel bodies in Santa Monica and San Pedro Bays. Santa Monica Bay contains from 104 x 10^6 to 285 x 10^6 yd^3 of suitable sand (mean grain diameter between 0.177 and 0.707 mm) and gravel; San Pedro Bay contains about 456 x 10^6 yd^3 of suitable sand and gravel. This material all occurs in water depths within the limits of current conventional dredging technology (between 5 and 15 fathoms).

ECONOMIC ASSESSMENT

Economic models for offshore sand and gravel mining in Santa Monica Bay indicate rates of return of from 4.5 percent to 7.5 percent for an annual production of 2 million tons. The current market rate of interest is 10 percent; consequently, offshore mining for construction aggregate is not of commercial interest at this time. According to the cost estimate mode used in the economic model for beach replenishment, an income of about $1.90 per ton is required to satisfy the 10-percent profit assumption. Thus, beach restoration and nourishment is the best use of offshore sand bodies in Santa Monica Bay under current market conditions.

Although considerable work is needed regarding the extraction, environmental, and social impact, processing, waste disposal, resource management, and marketing procedures, such offshore sand and gravel deposits offer an alternative to substantially supplement land-based supplies. Offshore sand and gravel mining in southern California deserves serious attention by concerned industries and governmental agencies.

PROJECT COMMUNICATIONS

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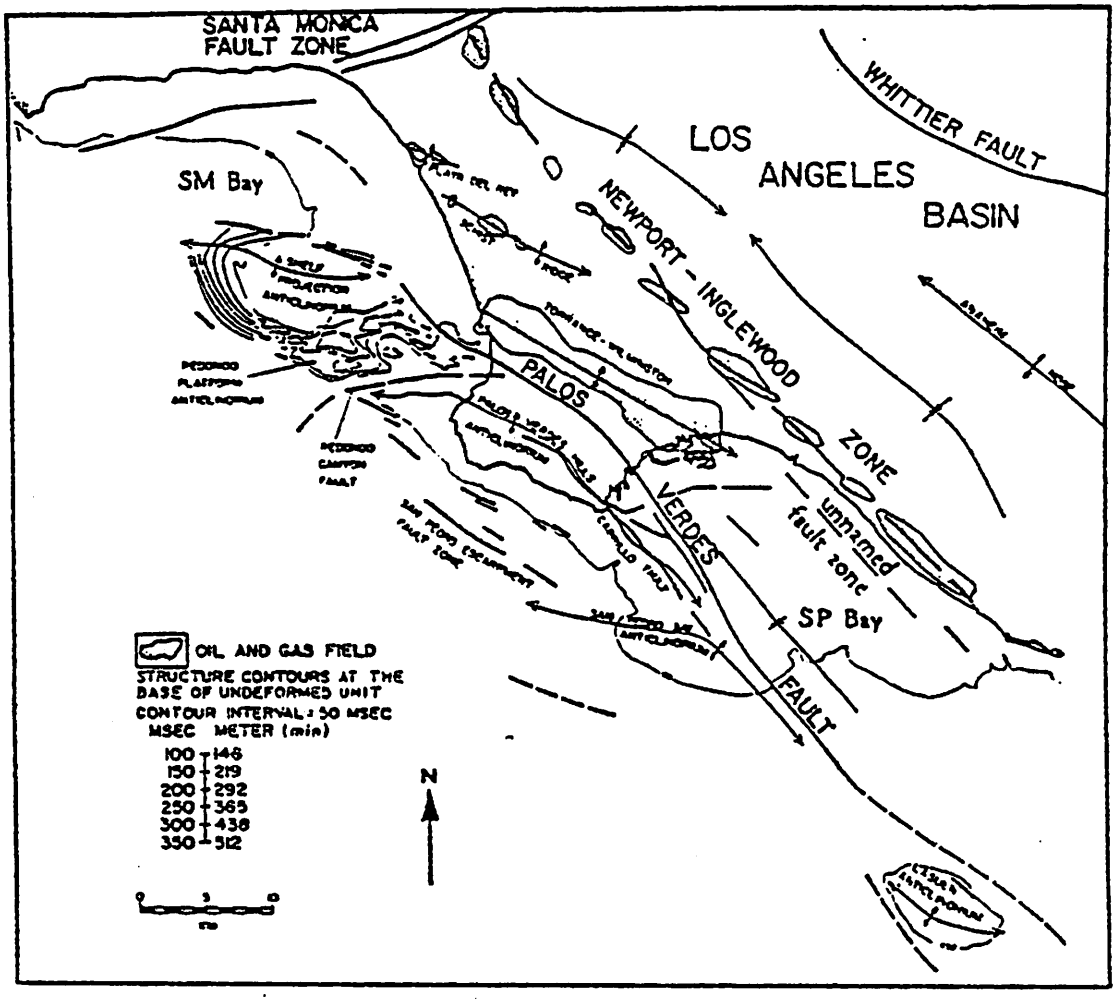

Figure 1. Map showing location of Santa Monica and San Pedro Bays and major structural elements in the study area

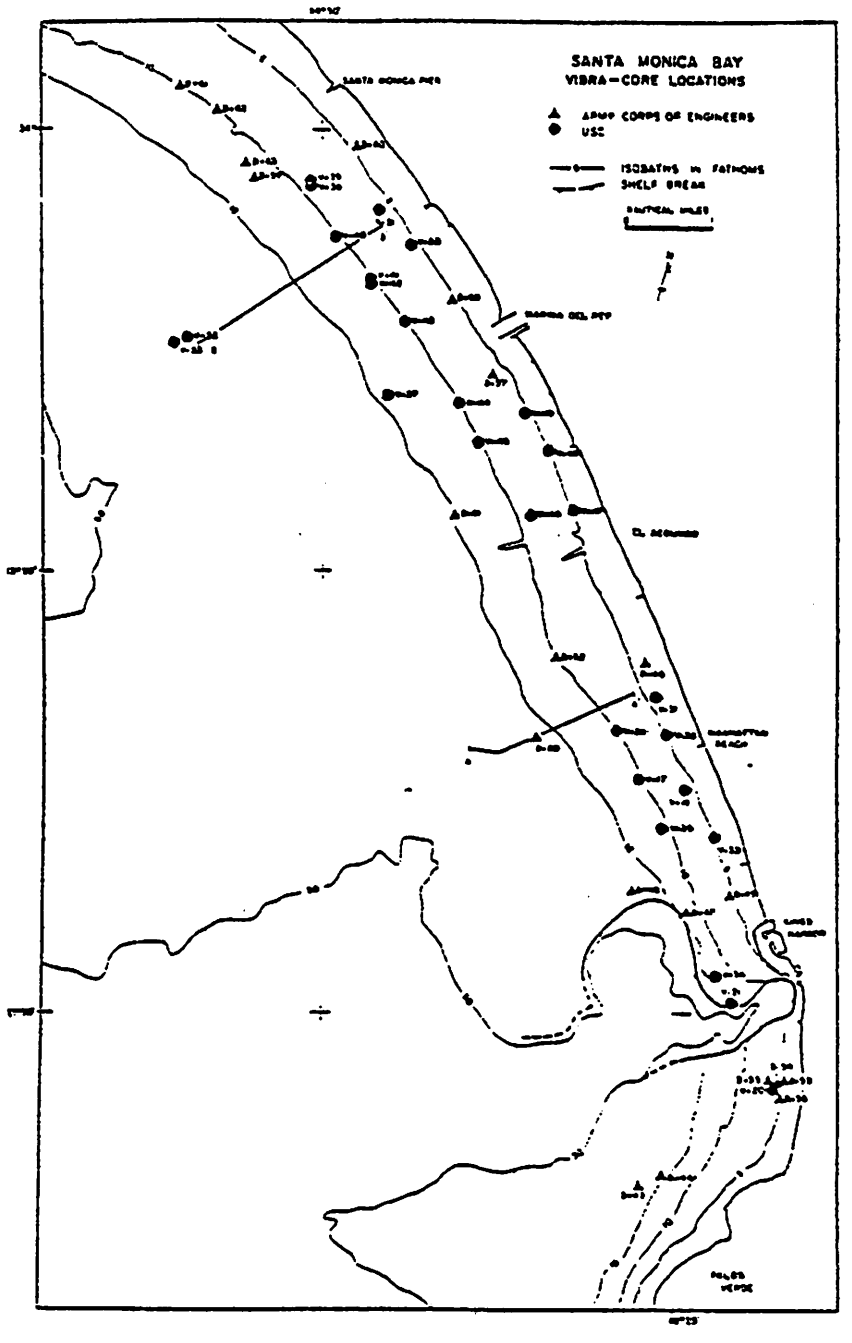

Figure 2. Map showing locations of vibracores in San Monica Bay

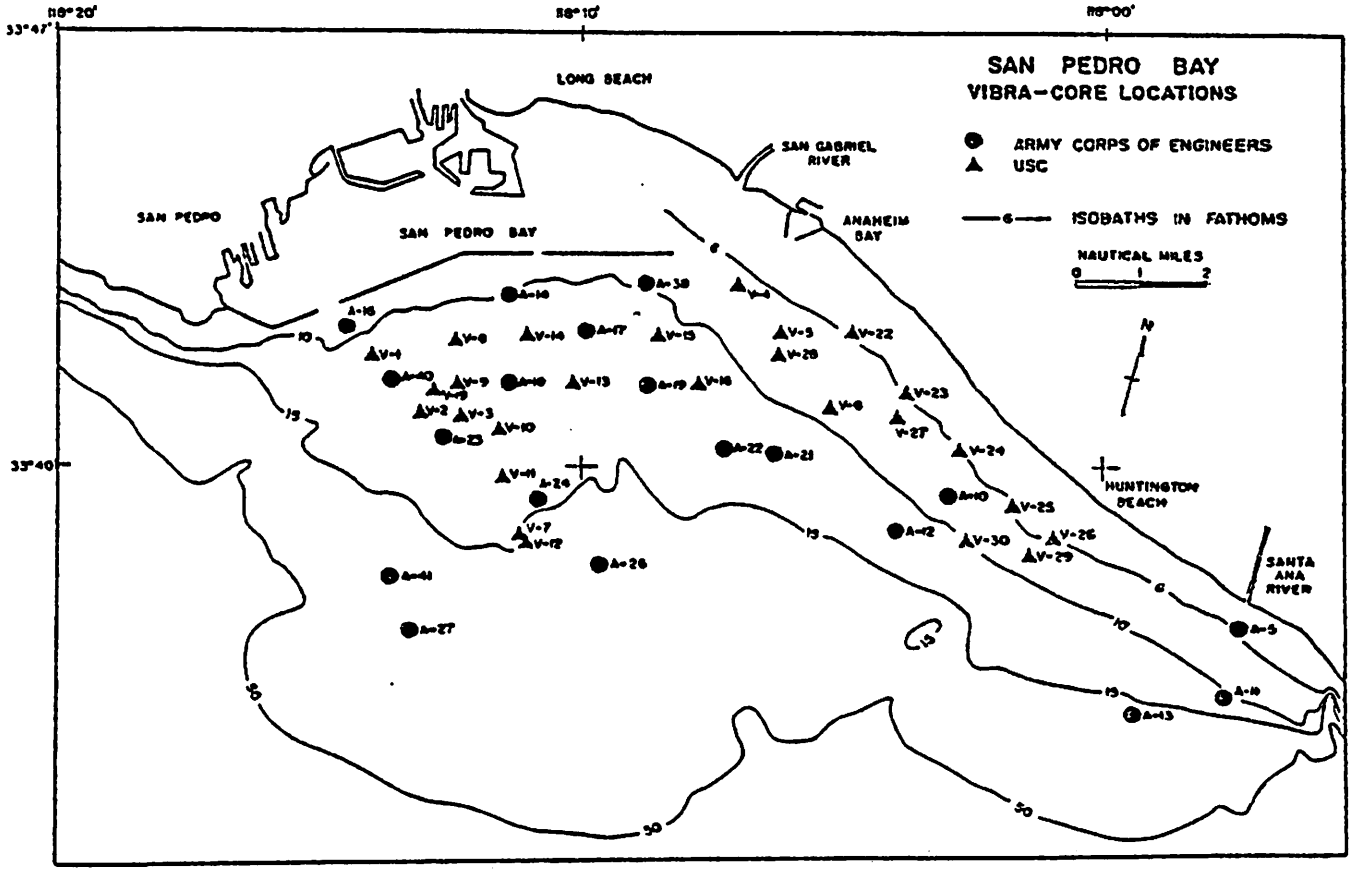

Figure 3. Map showing locations of vibracores in San Pedro Bay

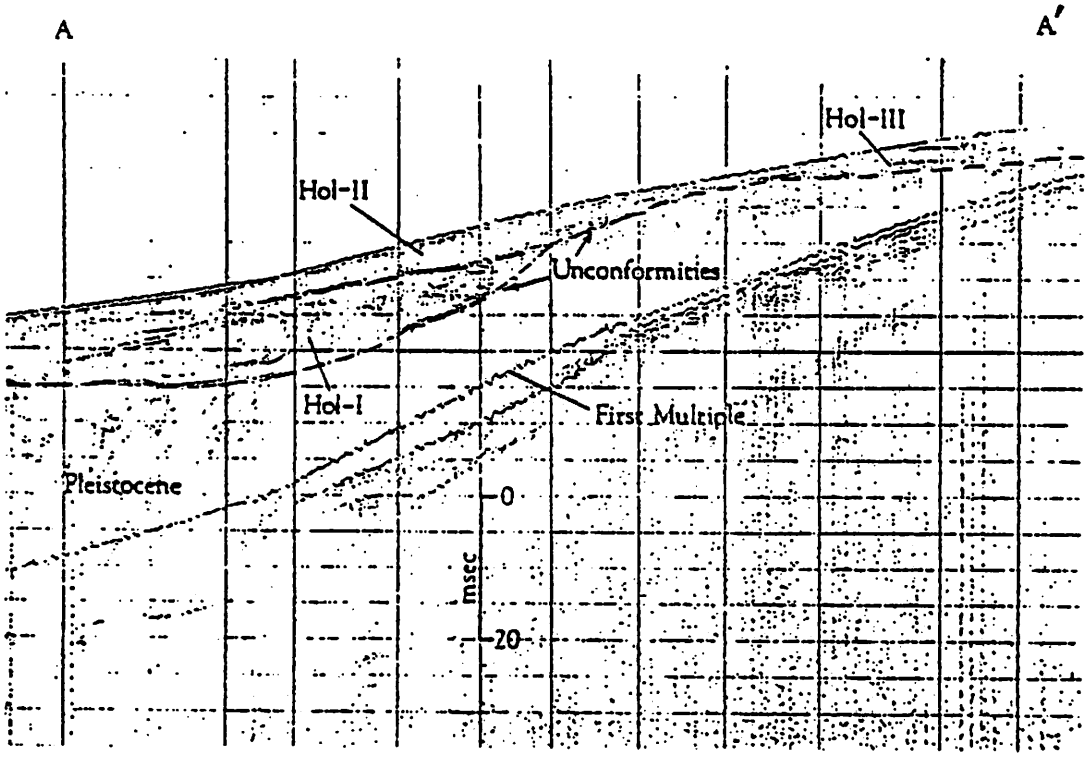

Figure 4. Seismic reflection line A-A', Santa Monica Bay (see Figure 2)

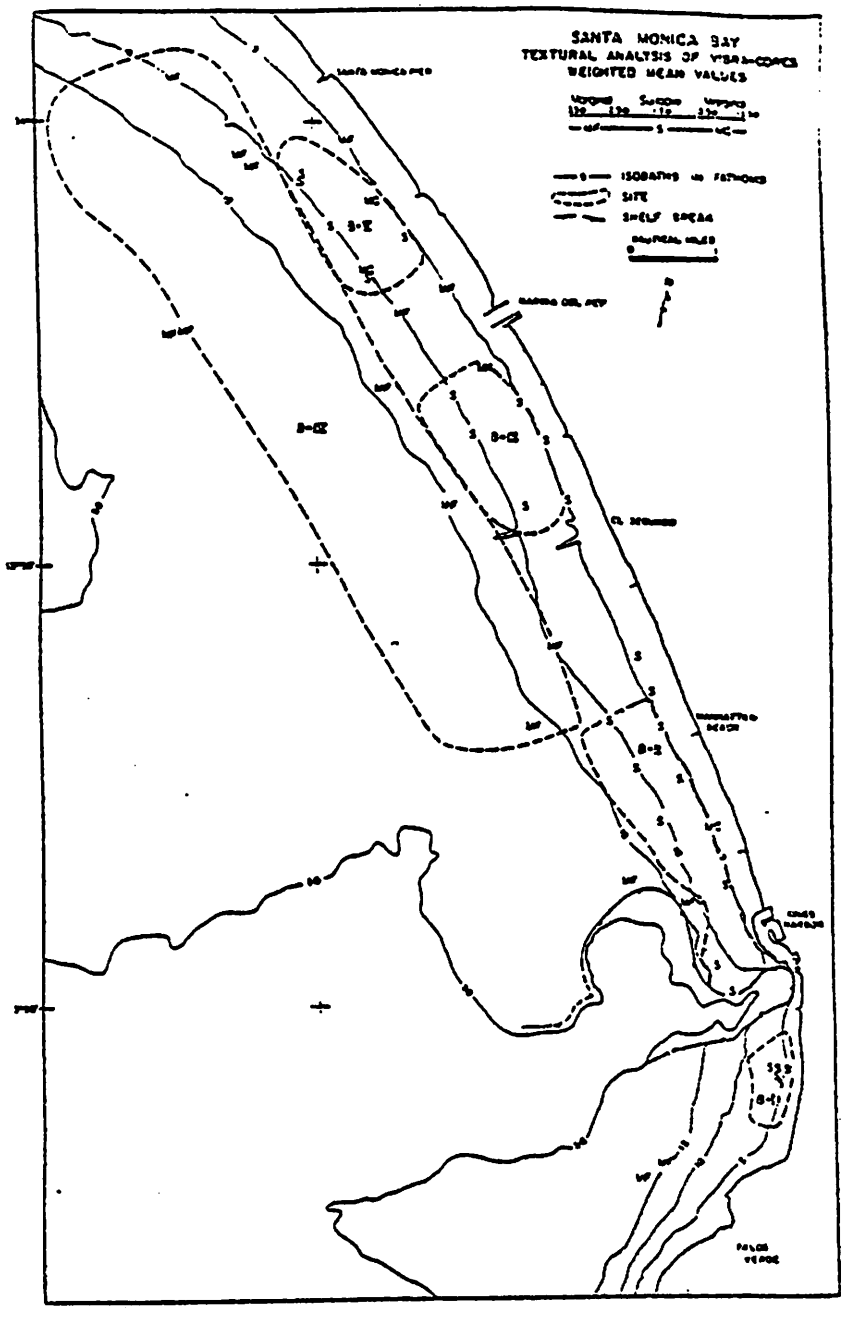

Figure 5. Map showing weighted mean textural values at each vibracore site, Santa Monica Bay

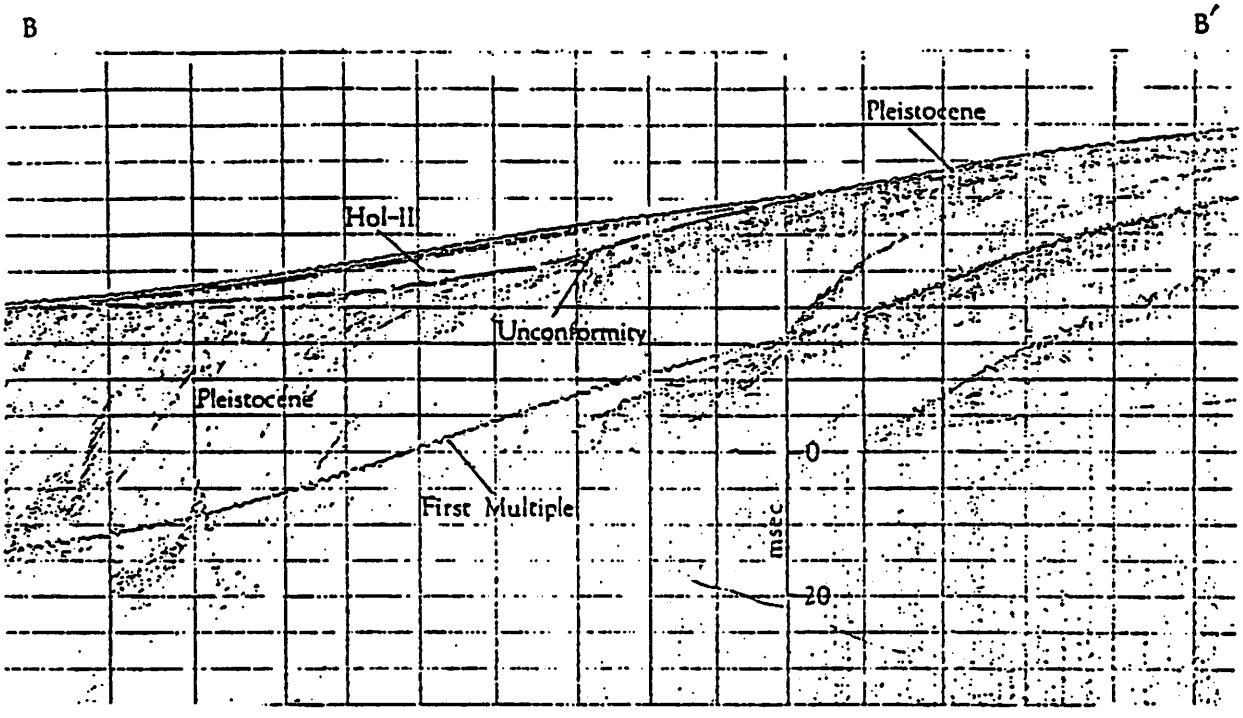

Figure 6. Seismic reflection line B-B', Santa Monica Bay (see Figure 2)

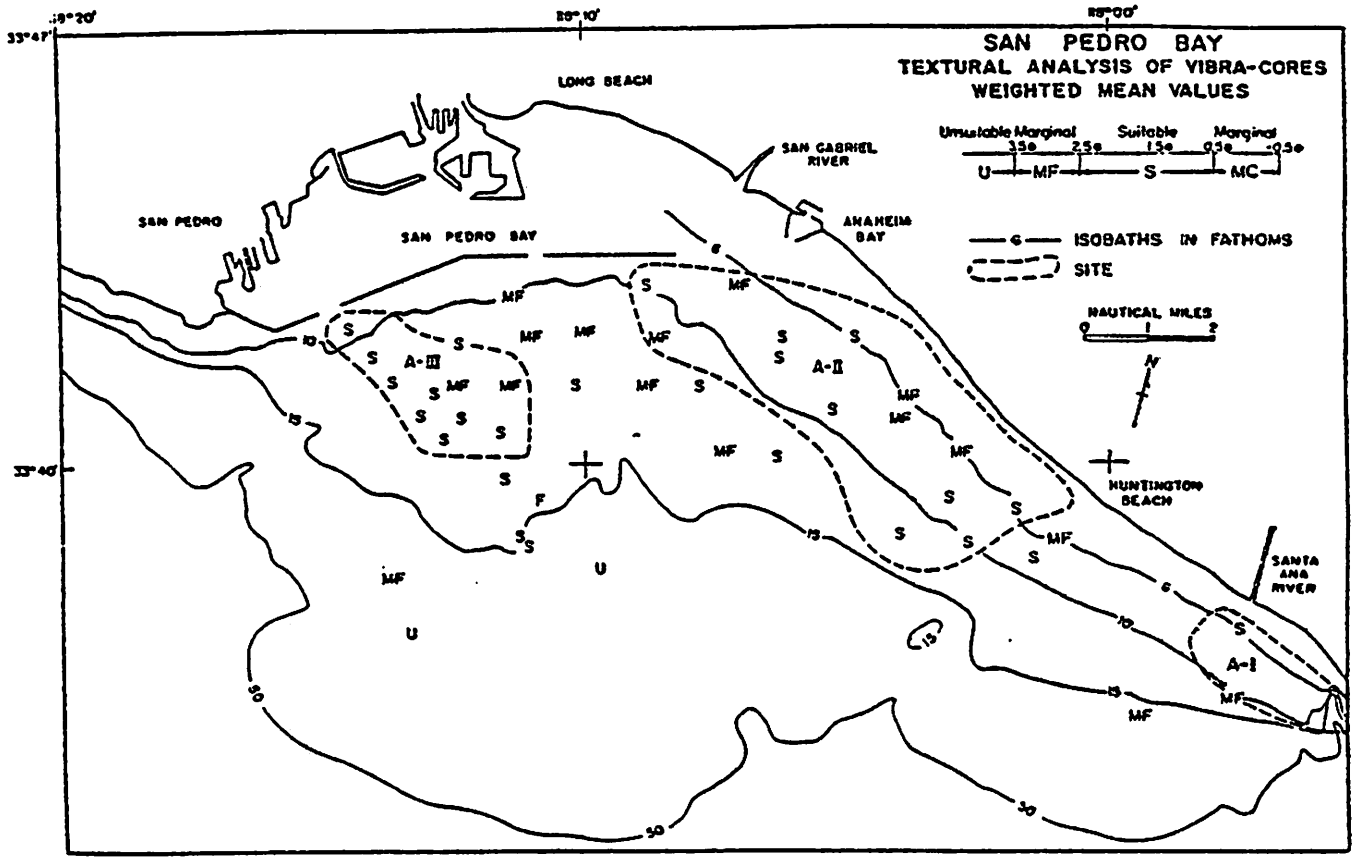

Figure 7. Map showing weighted mean textural values at each vibracore site, San Pedro Bay

COASTAL ENGINEERING

Southern California's harbors are among the largest in the world, and with the increased interest in the environment, the study of water quality is becoming as important as safety conditions in the area of harbor construction, modification, and maintenance.

Project R/CE-4 deals with two aspects of harbor modeling: (1) tide-induced circulation in harbors of arbitary shape; and (2) construction of a viscous model for solving the harbor resonance problem.

PROBLEMS IN HARBOR MODELING

J. J. Lee and L. C. Wellford

This research project includes two aspects of the harbor modeling problem: (1) tide-induced circulation in harbors of arbitrary shape; and (2) viscous model for the harbor resonance problem. In the following discussion, these problems will be addressed simultaneously.

Tide-Induced Circulation

With increased attention to the environment, the study of water quality is becoming as important as safety considerations in the area of harbor construction, modification, and maintenance. The water quality in a harbor is strongly dependent on the circulation patterns therein. As a result, it is important to develop an efficient method for computing the harbor circulations.

Through field measurements (Robinson and Porath, 1974) and hydraulic models (McAnally, 1975), it has been found that there exists a large-scale gyre inside outer Los Angeles Harbor. This gyre acts as a natural oxidation pond to increase mixing and reaeration rates. The previous numerical model was not able to reproduce this gyre.

The presence of tidal forces is the major cause in producing harbor circulations. The goal of the present study is to find an efficient way of predicting tide-induced currents in the Los Angeles-Long Beach harbor configurations. The numerical method developed in this study can be used to reproduce the gyre structure in the harbor.

The objectives of this study are:

1. To develop an efficient numerical model for simulation of tide-induced currents in a harbor of arbitrary shape

2. To demonstrate the use of the model by simulating the circulations in Los Angeles-Long Beach Harbors

3. To verify the proposed model by comparing the simulated results with those obtained from the WES hydraulic models

4. To predict the extent of changes in the circulation pattern when the harbor geometry is modified through construction of moles, fills, or piers in the harbor

5. To test the sensitivity of the model due to changes in various parameters

Viscous Model for Harbor Resonance

The usefulness of a harbor is in large measure dependent on its ability to protect near-shore structures and shipping from hostile wave environments. Thus, in designing a harbor facility, it is necessary to account for the effects of the harbor shape and breakwater position as well as harbor modifications on the wave environment. In particular, it is necessary to be able to predict the wave environment at a resonance for specific harbor configurations. Techniques for defining this environment have been developed. These techniques have successfully established the resonant frequencies of the harbors; however, they have been only partially successful in predicting the actual size of the wave environment at resonance. The problem seems to be that these previously developed techniques neglect dissipative effects which are very important at resonance. This part of the research project has thus been oriented to defining, using more realistic physical models, the wave environment in arbitrarily shaped harbors at resonance.

The goals of the first year of the resarch effort were defined as follows:

1. To assess the scale effects of various physical models on harbor response and thereby to establish the laws governing the viscous dissipation mechanism in connection with harbor resonance.

2. To derive governing equations to account for the energy dissipation as well as possible nonlinear effect at resonance. To utilize a finite-element computer model for the solution of governing equations.

RESULTS

Tide-Induced Circulation in Harbors

A numerical model capable of simulating vertically integrated tidal circulations in a harbor area for a long period of time has been successfully tested.

Experiments have shown that a relatively long simulation time is required for two-dimensional circular motions to reach a dynamic steady state. The model developed in this study allows one to simulate circulations for considerably long real-time, even in the case of a large network with fine spacings. As a result, vortex strengths can be estimated more accurately.

The model was applied to the Los Angeles-Long Beach harbor. Figure 1 shows the depth-averaged circulation pattern in the harbor, induced by a diurnal spring tide with an amplitude of 7.5 ft. This sample figure and other computer results indicate that a large, tide-induced clockwise gyre exists in the harbor for the whole spring tide. This gyre structure, obtained from the numerical model, correlates closely with those found in a hydraulic model tested at U.S. Army Engineer Waterways Experiment Station (McAnally, 1975). The numerical scheme has been proven to be efficient for the hydrodynamic computation of tidal motion in a complicated harbor geometry.

The model was applied to the same study area with a major landfill (Figure 2) in the harbor region. Figure 2 shows the circulation pattern induced by the same spring tide at the same tidal cycle as in Figure 1. The large gyre shown in Figure 1 was eliminated due to the existence of the new tanker terminal. The proposed numerical model can be used as a predictive model to study the change of circulation patterns due to harbor modifications.

Viscous Model for Harbor Resonance

The progress made to date in meeting the objectives of the research project can be summarized as follows:

1. The fluid mechanical laws governing energy dissipation and nonlinearity in the physical problem have been defined. Preliminary work on assessing the relative importance of the various dissipation mechanisms and nonlinear effects have been carried out.

2. Several techniques have been proposed for accounting for dissipation effects in the model. "Distributed" and "localized" dissipation have been considered in defining these proposed techniques. The distributed dissipation is caused by bottom friction. It has been incorporated by considering the Navier-Stokes equations in the viscous sublayer near the bottom. The localized dissipation occurs at the rigid boundary of the harbor. It has been incorporated using a perturbation procedure.

3. A finite-element computer program to analyze the response of an irregular-shaped variable-depth harbor to incident waves has been completed. This code includes triangular, quadrilateral, and serendipity (curved) elements. An automatic mesh generator has been included in the computer code. Work has been completed on comparing the results of this problem. The effects of viscous dissipation have been included in the model. Preliminary work has been completed on comparing the viscous theoretical results with the calculations of other investigators. The comparisons have been very favorable. This work is continuing, and the results of the finite-element analysis are being compared to other analytical and test data.

PROJECT COMMUNICATIONS

1. Chiang, Wen-Li. 1979. Tide-induced currents in a harbor of arbitrary shape. Ph.D. dissertation, Dept. of Civil Engineering, University of Southern California, Los Angeles, Ca. (in progress).

2. Chiang, W.-L., J. J. Lee. 1980. Numerical simulation of tide-induced circulations in a harbor. Paper to be presented at the 2nd Congress of the Asian and Pacific Regional Division of IAHR, Int. Conf. on Water Resources Dev., May 12-14 1980, Taipei, Taiwan, Republic of China.

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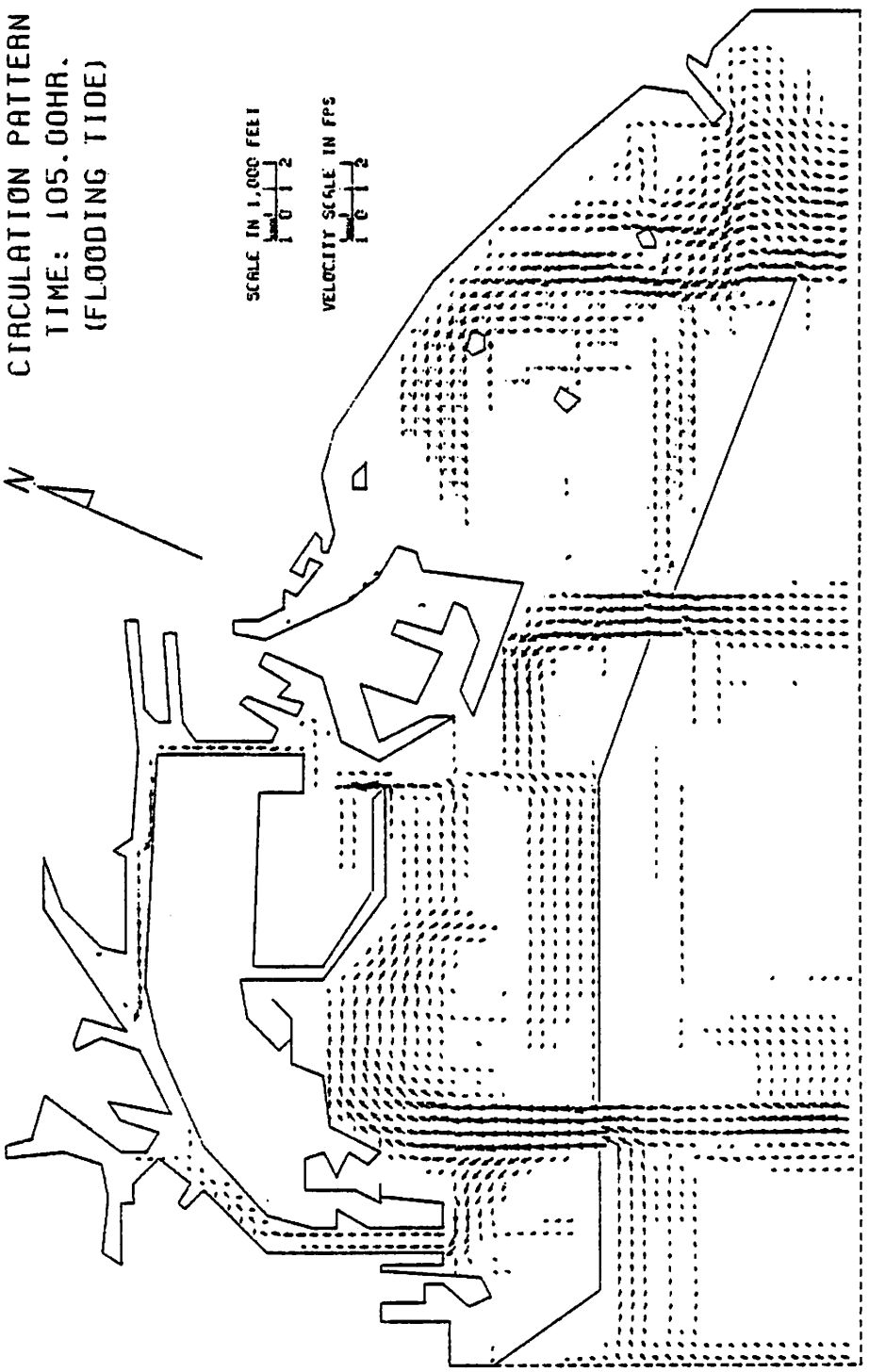

Figure 1 Numerical Simulated Circulation Pattern in Existing Los Angeles-Long Beach Harbor (at t=105 hr. after the motionless state)

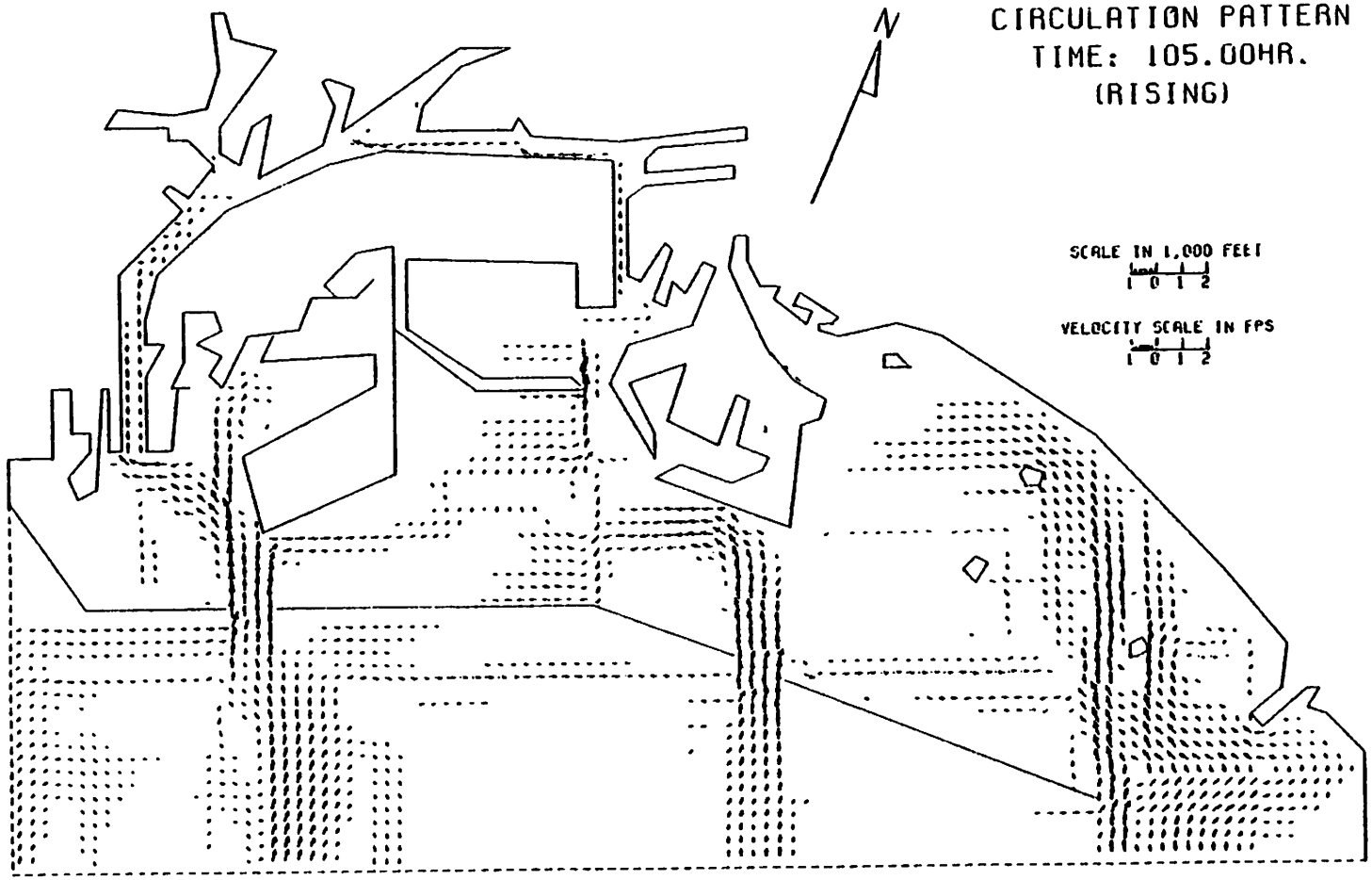

Figure 2 Numerical Simulated Circulation Pattern in a Modified Los Angeles-Long Beach Harbor (at t=105 hr. after the motionless state)

Activity Budget Summary

		OSG	MATCH
Program Management			
M-1	Program Administration and Management	$75,683	$56,232
M-2	Program Development	20,000	10,000
Marine Education and Training			
E/E-1	Marine Education in California	72,690	20,600
E/M-1	Sea Grant Graduate Student Trainee Program	45,000	5,000
Marine Advisory Services			
A/S-1	Marine Advisory Services	103,428	111,863
R/AS-1	Impact Criteria for Access Management in Rocky Coastal Ecosystems	4,380	14,139
Socio-Economic Program - Environmental Quality			
R/CM-11	The Economic Impact of Marine-Related Industries on Southern California	20,394	28,578
R/CD-1	Curriculum Development Research Study to Support on Academic Field in Harbor/Port Management	28,365	14,985
Living Marine Resources - Environmental Quality			
R/EQ-18	Heterotrophic Metabolism of Marine Dinoflagellates	28,820	18,200
R/EQ-19	The Role of Natural Populations of Microheterotrophs in Carbon Cycling in Southern California Coastal Waters	16,137	22,073
R/EQ-20	Ecology of a Small Tidal Lagoon under the Influence of Urban Recreational Use	14,150	11,443
R/RD-6	Southern California's Nearshore Marine Environment: A Significant Fish Nursery	28,305	84,187
Non-living Marine Resources - Environmental Quality			
R/EQ-22	Sediment Accumulation and the History of Pollutant Accumulation in San Francisco Bay	24,992	13,661
R/RD-3	Offshore Sand and Gravel Resources in San Pedro and Santa Monica Bays, Southern California	14,594	34,431
Coastal Engineering			
R/CE-4	Problems of Harbor Modeling	33,062	35,177
	TOTAL	$530,000	$480,569

Institutional Program Summary

		1976-77	1977-78	1978-79
Program Management				
M-1	Program Administration and Management	C	C	C
M-2	Program Development	N	C	C
Marine Education and Training				
E/E-1	Marine Education in California			N-C
E/M-1	Sea Grant Graduate Student Trainee Program	C	C	C
Marine Advisory Services				
A/S-1	Marine Advisory Services	C	C	C
R/AS-1	Impact Criteria for Access Management in Rocky Coastal Ecosystems			N-F
Socio-Economic Program - Environmental Quality				
R/CM-11	The Economic Impact of Marine-Related Industries on Southern California			N-F
R/CD-1	Curriculum Development Research Study to Support an Academic Field in Harbor/Port Management			N-F
Living Marine Resources - Environmental Quality				
R/EQ-18	Heterotrophic Metabolism of Marine Dinoflagellates			N-C
R/EQ-19	The Role of Natural Populations of Microheterotrophs in Carbon Cycling in Southern California Coastal Waters			N-C
R/EQ-20	Ecology of a Small Tidal Lagoon under the Influence of Urban Recreational Use			N-C
R/RD-6	Southern California's Nearshore Marine Environment: A Significant Fish Nursery			N-C
Non-living Marine Resources - Environmental Quality				
R/EQ-22	Sediment Accumulation and the History of Pollutant Accumulation in San Francisco Bay			N-C
R/RD-3	Offshore Sand and Gravel Resources in San Pedro and Santa Monica Bays, Southern California		N	F
Coastal Engineering				
R/CE-4	Problems of Harbor Modeling			N-C

USC Sea Grant Advisory Panel

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Department of Small Craft Harbors

Gary Bane
Interstate Electronics
Ocean Engineering Operations

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Executive Director, Marine Board
National Research Council

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College of Geosciences
Texas A & M University

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Hydro Products

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Trade Development
Port of Los Angeles

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Nossaman, Krueger & Marsh

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Elmer Wheaton
Portola Valley, California

Ex-Officio Member
Dr. Don Walsh
Director
Institute for Marine and Coastal Studies
University of Southern California

Sources of MATCH Funding

California Department of Education
California State Lands Commission
California State University, Long Beach
California State Resources Agency
Department of Boating and Waterways
Department of Water and Power
KCET TV
KNX News Radio (CBS)
KUSC
Los Angeles City School District
Los Angeles County Department of Beaches
Los Angeles County Superintendent of Schools
Los Angeles Harbor Department
Newport Beach Chamber of Commerce, Marine Division
Occidental College
Southern California Edison
Tinker Foundation Corporation
University of Southern California

Cooperating Institutions and Agencies

International

Federal Republic of Mexico
Brazil
Chile
Colombia
Costa Rica
Ecuador
Peru
Venezuela

Federal Government

Bureau of Land Management
Center for Naval Analysis
Environmental Protection Agency
Federal Maritime Commission
National Oceanic and Atmospheric Administration
National Weather Service, Los Angeles
U. S. Army Corps of Engineers
U. S. Navy

State and Local Government

California Coastal Commission
California Department of Boating and Waterways
California Department of Fish and Game
California Department of Parks and Recreation
California Department of Transportation
California Museum of Science and Industry
California Senate Committee on Maritime Affairs
California State Department of Education
California State Department of Health
Regional Water Quality Control Board
Southern California Association of Governments
Southern California Coastal Water Research Project
South Coast Regional Coastal Commission

Los Angeles County

Department of Beaches
Department of Harbors and Harbor Commission
Department of Parks and Recreation
Department of Small Craft Harbors
Flood Control District
Museum of Natural History
Regional Planning Commission
School District
Southern California Answering Network (L. A. Public Library)

Orange County

Department of Harbors
Flood Control District
School District

San Diego County

Aquatic Division
School District

Ventura County

Department of Harbors
School District

Los Angeles City

City School System, Marine Occupation Center
Department of Parks and Recreation
Department of Planning
Department of Public Works (Sanitation District)
Department of Water and Power
Harbor Department
Port Authority
School District

Newport Beach

Marine Safety Division

Carlsbad

Planning Department

Long Beach

Harbor Department
Port Authority

San Francisco

Port

Avalon

City of

Santa Barbara

Museum of Natural History

Orange County

Department of Harbors
Flood Control District
School District

San Diego County

Aquatic Division
School District

Los Angeles City

City School System, Marine Occupation Center
Department of Park

Academic Organizations

Claremont College
California Institute of Technology
California State University, Northridge
Cerritos Community College
El Camino Junior College
Fullerton Community College
Long Beach State University
Loyola University
Occidental College
Scripps Institution of Oceanography
University of British Columbia
University of California, Davis
University of California, San Diego
University of California, Santa Barbara
University of North Carolina
Virginia Institute of Marine Science

Private Organizations

The Aegir Corporation
Autonetics
American Petroleum Institute
California Chamber of Commerce, Sacramento
Catalina Island Company and Avalon Museum Society
Cedars-Sinai Research Medical Center
Charter Boat Owners Association
Clean Coastal Waters (formerly Price Co-op)
Edison Power and Light
Eichhorn and Davis Company
Hilton Hotel
Los Angeles Chamber of Commerce, Maritime Affairs Committee
Malibu Chamber of Commerce
Marine Biological Consultants
Marine Ecological Institute
Marine Technology Society, Los Angeles Region
Marineland of the Pacific
Mark VII Productions; Children's Television Workshop (New York)
Marriott Hotel
Mobile Chemical
National Surf Life Saving Association
Newport Beach Chamber of Commerce
Oceanic Society, Los Angeles
Pacific Lighting Service Company
Pioneer Skippers and other Boating Associations
Rockwell Industries
Sea World, San Diego
Socio Economics Systems
SOHIO; Alaskan Oil Pipeline Division, Long Beach
Soil International
Southern California Gas Company
Southern California Marine Association
Sportfishing Association of California
Swedlow, Inc.
United Fishermen's Organization
Western Oil and Gas Association

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Southern California Gas Company
Southern California Marine Association
Sportfishing Association of California
Swedlow, Inc.
United Fishermen's Organization
Western Oil and Gas Association

The following Radio and TV Stations:

KABC, KCET-TV, KFAC, KFI, KFOX, KGBS, KGER, KHJ, KHOF, KIIS, KLAC, KLOS, KMET, KMPC, KNX, KOCM, KPOL, KRLS, KRTH, KUSC, KWST, KFWB, KOST, KNXT-TV, KNBC, all West Coast Affiliates.

The following Newspapers and Publications:

The Agronaut, Artesia News/Community Advocate, Beach Cities Newspaper. Beverly Hills Courier, Beverly Hills Independent, Brentwood Post, Broadcasting Magazine, Business Week, Chemical Engineering, Community Newspaper Service, Inc., Dean Newspapers, El Pueblo Mexican News, El Segundo Herald, Gardena Valley News, Golden Rain News, Herald American Newspapers, The Hollywood Reporter, Independent Journal Newspapers, Kovner Publications, La Opinion, Lomita News, Long Beach Independent & Press Telegram, Long Beach Navy Dispatch, Los Angeles Daily Journal, Los Angeles Herald Examiner, Los Angeles News, Los Angeles Sentinel Newspaper, Los Angeles Tidings, Los Angeles Times, Malibu News, Malibu Surfside News, Malibu Times, McGraw-Hill, Metropolitan Gazette, National Geographic Magazine, News Advertiser, News Enterprise, New York Times, Palisadian Post/North Shore Mail, Pasadena Independent Star-News, Peninsula Breeze, Peninsula News, Pico Rivera News, Post Newspaper Group, Press-Herald, The Register, San Pedro News Pilot, Santa Monica Evening Outlook, Santa Monica Independent Journal, Seal Beach Journal & Shopper, Seal Beach News, Senior Citizens News, South Bay Daily Breeze, 20 de Mazo, United Western Newspapers, Venice Evening Vanguard, Voice of the Wilderness, Western Outdoor News.

Greater Los Angeles Press Club

PUBLICATIONS

Journal or Book Contributions

Bjur, Dorothy M. "An Innovative Approach to Teaching marine sciences, *Rev. Biol. Trop.*, 26(Supl. 1):9-14, 1978.

Brewer, Gary D. "Reproduction and spawning of the northern anchovy *Engraulis mordax*, in San Pedro, California," *California Fish and Game*, 64(3):175-184, 1978.

Brewer, Gary and Donna J. Cooksey. "The Biology of the northern anchovy in relation to its biomass utilization," *Biosources Digest*, 6(2):115-129, April 1979.

Butler, Stanley. "Deterministic-systemic relationships in overland flow analysis," *Water Resources Bulletin*, 15(2):519-529, April 1979.

Butler, Stanley S. "Overland-flow travel time versus Reynolds number," *Journal of Hydrology*, 32:175-182, 1977.

Duncan, K. L. et al. "Cyclic nucleotide levels in a human breast carcinoma transplanted into athymic nude mice." *Proceedings West Pharmacol. Soc.*, 21:401-403 1978.

Morey-Gaines, Gregory. "The ecological role of red tides in the Los Angeles-Long Beach Harbor food web," *In* Toxic Dinoflagellate Blooms, Taylor/Seliger, eds., pp. 315-320, 1979.

Soule, Dorothy et al. "You can tailer effluent BOD to fit the receiving water ecosystem . . . and enhance the environment," *Bulletin of Cal. Water Poll. Control Assoc.*, 15(1):58-63, July 1978.

Technical Reports

Soule, Dorothy and Mikiniko Oguri (eds). *Marine Studies of San Pedro Bay, Part 14: Biological Investigations; Marine Studies of San Pedro Bay, Part 15: The Impact of the Sansinena Explosion and Bunker C Spill on the Marine Environment of Outer Los Angeles Harbor; and Marine Studies of San Pedro Bay, Part 16: Ecological Changes in Outer Los Angeles-Long Beach Harbors Following Initiation of Secondary Waste Treatment and Cessation of Fish Cannery Waste Effluent.*

Other Products

Brosnan, Peter. "Who Owns the Networks?: An Inquiry Into the Development and Extent of Concentrated Institutional Holdings of Broadcast Company Equities," January 1979. (Masters Thesis), 170 pp.