The Planning and Management of California's Coastal Resources

1977-78 Annual Report

University of Southern California
Sea Grant Institutional Program

Institute for Marine and Coastal Studies
University of Southern California
Los Angeles, California

USC imcs

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Contents

Introduction

Southern California depends on the ocean for its livelihood, recreation, and security. We need not look far to see the impact of the ocean on the region's economy. To take one example, the Ports of Los Angeles/Long Beach affect a five-county area, including Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties. The population of the region, according to the 1970 census, is nearly 10 million, representing nearly half of the population of California and 51 percent of the State's total employed. To serve this geographical region, the Ports handled 25.9 million short tons of cargo and 471,775 passengers in 1974 alone. Maritime commerce in this area generated 107,200 jobs, $1.264 billion in payroll, $4.812 billion in gross revenue, and $1.921 billion of local business purchases in the five-county area.

This economy is significant internationally as well as nationally. In GNP, California is exceeded by only seven nations. Within a 60-mile circle around USC, the GNP is about level with India and Poland, and is more than that of the Netherlands, Australia, Sweden, and Iran, to take a few examples. In 1976 that 60-mile GNP figure was more than $90 billion.

How will the oceans be managed, developed, and preserved in the future? And where will the needed expertise come from--the future geologists, climatologists, recreation specialists, marine biologists, harbor designers and managers, maritime lawyers?

One place they will come from is USC--one of the few institutions in the United States and the only one in this region which can provide the broad training necessary to meet the future manpower needs in substantially all of the marine-related fields.

A vital part of this developing program in marine sciences is the USC Sea Grant Program. Since 1969 this program has concentrated on marine research and educational opportunities that have cut across traditional disciplinary lines. In this way, the full range of USC's academic experience can be brought to bear on important problems and opportunities associated with the southern California coastal zone.

This report summarizes the eighth year of participation in this program. Some 16 projects were undertaken, 11 of which were research projects. They are divided into six substantive areas--Resource Development, Socio-Economics, Environmental Quality, Coastal Engineering, Marine Advisory Services, and Marine Education and Training. The following sections summarize the results of these projects.

Program Development

Donald L. Keach and D. Patrick Hartney

M-2

Sea Grant projects usually require lead time of about one year from submission of the proposal to start-up. 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 dealing with coastal resource management and development;
2. Start-up funding and background research for longer-term research projects;
3. Supplementary funds to be used for one-time advisory visits.

During 1977-78, program development funds were used to support the following research efforts:

Feasibility Study of an Underwater Engine Having Improved Efficiency with Increasing Depth. This project deals with adapting an absorption-type engine to underseas use where advantage can be taken of ambient pressure as the driving force. The absorption process will reduce the pressure within the engine thereby allowing the external pressure to perform work. As the depth increases, such an engine would display increasing power output. The engine output will mainly depend upon the reaction rates of ammonia. Unfortunately at this time data to predict the reaction rate of ammonia is insufficient. The published solubility data is only up to 5 atm, however, the available pressure for ammonia is 307 psia.

Future work on this project will determine the solubility and reaction rate under varying input water pressure and temperature. After the solubility of ammonia is determined, a larger cylinder will be built. Different kinds of spray systems will be tested to compare the corresponding reaction time. A piston scrubbing system will also be investigated in order to make sure there is no aqueous ammonia droplets left inside the cylinder as ammonia gas is fed into the cylinder.

An Investigation of the Interaction of Waves and Structures. The problem of wave forces on marine structures increases its importance with increasing offshore drilling activities. As oil drilling and production facilities gradually advance to deeper water and to areas of fairly intense hurricane activity or larger wave environments, it has become apparent that the wave-induced forces and moments

on structural members require signficant design consideration. This project was initiated to develop general guidelines and analyzing methodology for the interaction of waves and structures as a function of wave characteristics and structural response.

The computer programs generated by this project can, when used in conjunction with the popular Structural Analysis Program (SAP), compute the wave force based on linear wave theory and Stoke's fifth order theory for a given water depth, wave period, and wave height. Each wave theory is written in a subroutine with certain guidelines provided for choosing a particular wave theory. Sub-programs will be added to include other wave theories such as solitary wave theory, cnoidal wave theory, and for other transient dispersive waves. However, the first two theories which are now completely programmed should be adequate for many engineering applications.

Additionally, two approved 1978-79 research projects were given start-up funding during 1977-78. Program Development funding enabled R/CD-1 "Curriculum Development Research Study to Support an Academic Field in Harbor/Port Management" to conduct an extensive literature search prior to project initiation. Additionally, this funding facilitated initial interviews with port practitioners in: San Diego, Los Angeles, Ventura, Monterey, Oakland, San Francisco, Sacramento, Eureka, Lincoln City, Newport, Coos Bay and Portland during the summer of 1978.

Start-up funds were also used by R/EQ-18, "Heterotrophic Metabolism of Marine Dinoflagellates" to isolate the experimental dinoflagellates in pure culture, to eliminate bacteria and to find an adequate growth medium. The early start-up on this project has allowed more time to investigate growth rates and monitor bacterial contaminations which will assure R/EQ-18's timely completion.

Marine Resource Development

A growing and diversifying population in southern California has produced an increasing demand for resources for energy, construction materials, protein, and recreation. Projects in the USC Sea Grant Marine Resources Development Program involve scientific research aimed at expanding the coastal ocean's resource base to meet these needs, and dealing with environmental problems related to their recovery.

The program has several objectives:

1. To identify and evaluate natural resource potential;
2. To assess natural hazards associated with resources (e.g., hydrocarbon seepage);
3. To investigate potential environmental influences of future resource development; and
4. To investigate the physical and biological interactions between the seafloor and the water column, between the offshore and the nearshore, and between natural environments and man.

Offshore Sand and Gravel Resources, San Pedro and Santa Monica Bay, California

Robert H. Osborne and Thomas L. Henyey

R/EQ-16

Southern California continues to grow in population and economic strength. Projections for the next decade suggest that these trends will continue. Careful planning is required to preserve the region's natural beauty and to systematically develop natural resources whose sources, in many cases, are already being greatly strained.

Sand and gravel are primary resources used in many phases of construction as well as to maintain southern California's invaluable 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 and could be in short supply by 1980. The sand and gravel needs of the construction, road-building, facilities-maintenance, and specialty sand industries can be met by either:

1. Changing zoning regulations to permit known deposits to be exploited. This can be undertaken only if such deposits can be developed without posing substantial socioeconomic problems or hazards to adjacent property owners. 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.

2. Exploring for new sand and gravel deposits, taking commensurate care to evaluate the geological, socioeconomic, and environmental aspects of exploitation.

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

Offshore resources, in addition to providing potentially large-scale supplies, could help alleviate transportation costs. For example, barges could transport large supplies at relatively low cost to offshore distribution points along the entire southern California coast. Further, geologists and engineers agree that offshore sand supplies are the only practical long-term source of replenishment of beaches and harbors eroding from storm wave action. One can envision the ideal situation involving a recycling of sand from offshore sinks back to the respective depleted beach.

State officials must have adequate knowledge about California's offshore sand and gravel resources in order to control and manage their exploitation. It is also important to note that offshore mining operations present a new set of legal, socioeconomic, and environmental problems which must be thoroughly researched.

Goals

Overall Goals

1. To obtain basic geological information concerning the location, volume, texture and composition of offshore sand and gravel deposits in San Pedro and Santa Monica Bays.

2. To perform a cost-benefit economic analysis of mining potential commercial deposits in the study area.

3. To disseminate resultant information to interested agencies and industries.

Specific Goals

1. Completion of textural and compositional analyses of offshore sand and gravel deposits in site specific areas.

2. Synthesis of petrologic and geophysical (acoustic reflection) data to permit extrapolation of sediment types into unsampled areas.

3. Spot vibracoring to complete sampling in critical sites to resolve uncertainties as data are compiled and synthesized.

4. Construction of computer-generated isopach, isolith, structure contour and lithofacies maps on a site-specific and areal basis.

5. Initiation and completion of a cost-benefit economic analysis concerning the mining of offshore sand and gravel deposits.

6. Report writing and distribution of resultant information to concerned organizations.

1977-78 Results

The 1977-1978 grant period was largely devoted to the acquisition of vibracores and site-specific high-resolution seismic reflection profiling, as well as textural and petrographic analyses of obtained sand samples. This work is fundamental to the identification and evaluation of potential commercial sand bodies. This effort is summarized as follows:

I. Vibracore samples obtained from the Army Corps of Engineers.

Total number of vibracores: 47

- Number of vibracores from San Pedro Bay: 23
- Number of vibracores from Santa Monica Bay: 24
- Average length of vibracores: 464 cm
- Maximum length of vibracores: 612 cm
- Number of subsamples collected: 329
- Average number of subsamples per vibracore: 7.00

Textural analyses completed: 329 subsamples

Petrographic analyses completed: 54 representing 36 subsamples from 14 vibracores

Petrographic analyses in progress: 50 representing 32 subsamples from 11 vibracores: completed February, 1979

II. Surface sediment samples (Nancy Savula, M.S. thesis, USC)

Total number of surface sediment samples: 33

Number of samples from San Pedro Bay: 21
Number of samples from Santa Monica Bay: 12

Textural analyses completed: 33
Petrographic analyses completed: 53 representing 33 samples

III. Vibracore samples obtained during 1977-1978 contract period

Total number of vibracores: 53

Number of vibracores from San Pedro Bay: 26
Number of vibracores from Santa Monica Bay: 27
Average length of vibracores: 346 cm
Maximum length of vibracores: 675 cm
Number of subsamples collected: 379
Average number of subsamples per vibracore: 7.15

Textural analyses completed: 379
Petrographic analyses in progress: 241 representing 150 subsamples from 52 vibracores: completed February, 1979

IV. Grand totals

Total number of vibracores: 100

Number of vibracores from San Pedro Bay: 49
Number of vibracores from Santa Monica Bay: 51
Number of subsamples from vibracores: 708
Number of surface sediment samples: 33
Total number of textural analyses: 741
Total number of petrographic analyses: 398

V. Geophysical data amassed to date

Acquired prior to October, 1977: 1500 nautical miles of high-resolution reflection profiles
Acquired during March, 1978: 110 nautical miles of high-resolution reflection profiles
Acquired from Army Corps of Engineers: 400 nautical miles of high resolution reflection profiles
Total: 2010 nautical miles of high resolution reflection profiles

Transmission of Results

Inasmuch as 1977-1978 was devoted largely to data collection, no formal publications were prepared. However, informal meetings were held with governmental officials representing the California State Lands Commission, the California Department of Navigation and Ocean Development, and the U.S. Geological Survey, Conservation Division.

Socio-Economic Program

The USC Sea Grant Program has a long-term commitment to be a repository of knowledge and skills concerning California, and particularly the southern California coastal zone. It is not an easy commitment to carry out because the breadth of activities that occur on and near the coast (that make. it almost a laboratory of urban coastal zone problems) requires such varied skills and such a broad range of knowledge.

A commitment over time requires that a coherent program be created. Such a program should be based on sufficient expertise to understand which are the important problems to study. The study of these problems should follow a consistent plan, be undertaken by a knowledgeable cadre of ocean and coastal specialists, and operate at the minimum cost consistent with high quality results. The research results should be synoptic in the sense that the insights from separate disciplines are blended as policy advice. Finally, the research results should be cumulative. We should be able to build upon what we have created.

For this reason a socio-economic research program was undertaken in 1977-78, and three projects were begun in that year.

The submission of the study, "Coastal Environmental Monitoring Data Base Inventory: Phase I," by M. Beth Olsen and Charles Hubay, was requested by the Associate Director of Marine Policy Studies, IMCS, because of his belief that he could bettter manage the broad range of future studies of California coastal problems if an index of available data were prepared. First, it would provide the information necessary to test the feasibility of future proposal studies. Second, by eliminating redundant data-gathering, he could reduce the cost of the data-gathering phase of future projects. Third, he felt that by encouraging the use of common data, future studies could be cumulative in their effect.

"The Impact upon California of World Ocean Decisions," by Robert Friedheim, is intended primarily to identify future ocean decision problems for California and national leaders. The project attempts to describe and forecast what policies major ocean-using states, particularly Pacific Basin states, may take in the future and begin to assess the impact upon California's interests if foreign states act as they say they will act.

"Onshore Impacts of the Development of Ocean Resources," is aimed at developing a model useful for testing the impacts upon local coastal communities of siting among them onshore facilities necessary for the exploitation of offshore oil and gas.

The California Coastal Act of 1976 requires all coastal communities to prepare a compliance plan by January 1980. "Planning Methods for Coastal Communities," directed by Alan Kreditor and Tridib Bannerjee, attempted to show local officials how to comply with this new law.

Coastal Environmental Data Base Inventory: Phase I

M. Beth Olsen and Charles A. Hubay

R/CM-1

Within the USC Sea Grant Program, research projects are funded to investigate widely varying aspects of the California coastal zone. Often, much of the initial research effort must be spent in a search for relevant data sources. This preliminary process is often time-consuming, sometimes fruitless, and generally costly. To facilitate that process, this project identified and described many of the basic data sources available for the Los Angeles County region. The basic focus was on information which is routinely collected and/or published. The objective of the project was to provide a research resource--a compendium of summary descriptions of the kinds of data available as well as the characteristics of the various data sources.

Results

A final project report has been completed and sent to the USC Sea Grant Program Office. The report includes an inventory of data sources, i.e., descriptions of over 150 data sources relevant to studies of the Los Angeles coastal region. The data sources make available data relevant to studies of environmental, demographic and land use issues, as well as biological and geological topics. While the coverage was generally restricted to data available for Los Angeles County, the inventory attempted to include information on sources which extended past the limits of the county.

Each inventory entry represents a single data file, report, or data gathering activity. The description of the entry includes some of the basic parameters relevant to the

data provided by that source. Each data source in the inventory is described in the following manner:

Source: The agency which publishes the report or collects and maintains the data file.

Title: Title of the publication or data file referenced, or descriptive title of the file contents.

Variables: Summary listing of major variables in the file.

Subject Matter: A listing or description of the data content. Where feasible, the actual data items are listed.

Subject Unit: The unit of analysis; the basic type of unit to which the data apply, i.e., person, industry, fishing boat, etc.

Subject Frame: The group from which the subject unit came, or of which the unit is a member, i.e., Los Angeles County labor force, garment industries of the nation, registered commercial fishing vessels of the State of California, etc.

Geography Unit: The smallest geographic unit for which the data are provided.

Geography Frame: The total area coverage unit for these data sources. For example, while data may be reported by census tract (unit), the total area which is reported is for the state (frame).

Time Unit: The smallest time unit for which the data are displayed. If, for example, an annual report published the data by quarter, and also summarized by year, the time unit would be reported as the quarter.

Time Frame: The historical framework for the information. That is, the initial date at which the information was begun, the time series range for which the data are available. For example, if the series has been continuously collected since 1970, but was discontinued in 1976, the time frame would be 1970 through 1976.

Comments: Comments worthy of special mention or concern to the researcher.

Accessibility: Who has access to the information and how to obtain the publication or data file. The address to contact to get the information is provided, where available.

File Medium: Whether the data are provided in a published report, computerized data file, or manual files maintained in the agency offices.

The inventory attempts to document in a consistent summary format some of the most important characteristics of potentially useful data sources. These data sources have been categorized into general topic areas for presentation as follows:

1. Statistical Data Books
2. Population--General
3. Population--Migration
4. Health
5. Crime
6. Voting and Registration
7. Employment and Labor Force
8. Economics
9. Transportation
10. Ports and Waterborne Commerce
11. Exports and Imports

12. Land Use--Construction and Permits
13. Land Use--Other
14. Commercial Fisheries
15. Recreation--Fishing
16. Recreation--Boating and Marinas
17. Recreation--Other
18. Agriculture
19. Pollution
20. Energy--Oil, Gas, and Electricity
21. Meteorology and Climatology
22. Earthquakes

Completion

This work was completed in May of 1978, and the final project report, including the data sources inventory, was submitted at that time. While not exhaustive, this inventory should represent a useful resource for the initial identification and screening for acquisition of data for the coastal region. As such, this effort could be viewed as a starting point in the systematic collection of data resource information for the Sea Grant Program. The costs of implementing a system designed to collect and maintain such information as reported in this inventory is extensive. As a result, the USC Sea Grant Institutional Program would probably neither be able nor desire to implement such a system. However, the recommendation is that extensive efforts be made to maintain the inventory of data contained in this report.

This could be done on an ongoing basis. As researchers discover new data resources or utilize any of the data sources covered in this inventory, they could make comments concerning the files, their validity, or changes in the generating agencies. If a sustained effort to update this inventory is made, future researchers will have considerable advantages in evaluating researchable areas, as well as flexibility in drawing upon wider data resources.

The Impact Upon California of World Ocean Decisions

Robert L. Friedheim and Robert E. Bowen.

R/CM-3

During the last few years the nations of the world have been making, and, indeed, will continue to make, decisions that will have an impact upon the various economic, political, social, and scientific interests of the State of California. New marine legal norms are emerging, primarily justified and legitimized through the international debate in the United Nations Conference on the Law of the Sea (UNCLOS III). Unilateral claims to expanded coastal territory are becoming common. Jurisdictional claims over economic activities, such as fishing, within 200 miles of the coast is an option being taken by a large number of coastal states. The United States made such a claim through the Fisheries Conservation and Management Act in 1976. Strong coastal-state control over such factors as vessel source pollution in the coastal zone will likely become accepted international law.

The thrust of this project is to identify what those key decisions are and to offer a broad based evaluation of the potential impacts of those decisions upon California. A knowledge of those probable decisions and how they will affect California is essential to sound policy-making.

Goals

The specific goals of the project are:

1. To identify the ocean policy preferences and interests of those nation-states whose ocean policy decisions will probably affect California's interests.

2. To forecast the probable ocean policy behavior of these states.

3. To develop a catalogue, preferably in computer readable form, of those California ocean interests that may be affected by foreign ocean policy decisions.

4. To estimate what the impact will be upon California of ocean policy decisions by foreign states, especially Pacific Basin and major ocean-using states.

5. To begin the process of formulating and assessing the alternative responses available to California decision-makers to cope with foreign ocean policy decisions.

6. To deliver the knowledge acquired and policy alternatives explored in forms appropriate to the needs of California public and private decision-makers.

Research and Results

The initial step in this process is to identify the marine-related preferences or desires of the nations of the world over a range of issues while placing particular emphasis on those nations that either border the Pacific Basin or are dependent for

outside access on the oceans of the Basin. This emphasis is central due to the clear economic dependence California has defined on the resources and trade routes of the Pacific.

The identification of these preferences was carried out by means of content analyzing statements made over time by national representatives at UNCLOS III, and was originally collected under the direction of Dr. Friedheim while at the Center for Naval Analysis in Arlington, Virginia. These statements were organized and ordered and served as the input data for a model using Baysian forecasting techniques. These techniques allowed the analyst to offer a general forecast of the probable behavior of nation-states with regards to questions of ocean policy. The calculation and analysis of these forecasts took several months and culminated with a related interim paper, "Neglected Issues At the Third United Nations Law of the Sea Conference" by Robert L. Friedheim and Robert E. Bowen (Friedheim and Bowen). This paper was presented as the "stage-setting" paper at the Law of the Sea Institute's 12th Annual Conference on October 23, 1978 in the Hague, the Netherlands. This process is complete and the necessary data exist in sufficient breadth and detail to carry out further analysis.

When this stage was complete the research effort turned to the identification of California's marine-related needs and interests. We initially divided this material into four basic categories: first, transportation and trade; second, offshore oil and gas; third, marine living resources; and, fourth, marine hard minerals. However, this process has taken longer than we had expected. The availability of the type of data needed for an impact evaluation study is limited. We have faced a number of difficulties acquiring sufficiently operationally defined goals from California-based industry and state agencies that would identify, in concrete ways, their interest in the marine environment. Additionally, in order to carry out the kinds of quasi-experimental impact evaluations that we are interested in it is preferred, if not necessary, for us to have a number of data sets that have been collected over time so that we might gain some more meaningful insight into the impacts already registered upon California. These difficulties are not necessarily specific to California or to those students of marine social science. Indeed they have been recognized by a number of authors as being generic problems to those attempting impact evaluation studies.* In many ways, we seem to be "breaking new ground." The data we are collecting are unique both in form and in volume. We are making progress and there appears to be interest in our findings from a number of agencies and institutions.

In terms of the potential for future research, the possibilities are numerous. The marine-related decisions made by other nations are occurring with more than some reasonable frequency. The UN Law of the Sea Conference appears to be nearing a conclusion. Whether or

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*Note: For a good discussion of these and other related problems, see: Freeman, Howard E. 1977. The present status of evaluation research. In *Evaluation Studies Review Annual*. Vol. 2. Edited by Marcia Guttentag and Shalom Saar. Beverly Hills, California: Sage Publications, pp. 17-51.

not a consensus agreement will be reached is, however, still unclear.

Nevertheless, even if no treaty is signed the debate has heightened international awareness of the sea and that the future will witness continued changes in marine law is undeniable. Continued research into the potential impacts of those fluxations would clearly be both important and useful.

References

Friedheim, Robert L. and Robert E. Bowen. Neglected issues at the Third United Nations Law of the Sea Conference. In *Law of the Sea: Neglected Issues*. Edited by John K. Gamble. Honolulu: University of Hawaii Press, forthcoming 1979. A revised version of this paper will appear under the same title in *Ocean Management*, a Dutch journal, this spring or summer.

Onshore Impacts of the Development of Ocean Resources

Harry W. Richardson and Peter Gordon

R/CM-10

The aim of this project was to investigate the onshore impacts (economic, fiscal, and environmental) associated with the development of offshore ocean resources, specifically oil and gas. The distinctive aspect of the research was to trace these impacts to a spatially disaggregated level, namely eighty-one cities and unincorporated areas in the counties of Los Angeles and Orange. This degree of spatial disaggregation is critical to an effective evaluation of onshore impacts in a highly urbanized metropolitan region such as Southern California. Also, the attitude of individual cities to offshore developments may be strongly influenced by what these developments mean to the cities themselves in terms of new jobs, tax and expenditure implications, and air quality.

The project involved the following steps:

1. The construction of an impact model for the two counties to measure the changes in population, employment, local fiscal variables and air quality associated with the siting of onshore terminal facilities.

2. The collection of data on population, employment, work trips and service trips, taxes, public expenditures, and air pollution levels that allows the impact model to be operationalized.

3. The development of alternative scenarios of offshore resource extraction and their corresponding onshore facilities for testing the model.

4. The execution of computer simulations to compare the results of the different scenarios.

5. Interpretation of the results.

Components of the Model

A. Economic Impacts. The model used was a variant of the Lowry model[1] adopted for employment and population forecasting. Zonal employment is estimated from the equation

$$E = I - [(\hat{A}B\hat{C}D + \hat{F}G)]^{-1} E^b \qquad (1)$$

where E = vector of total employment by zone

E^b = vector of basic employment by zone

I = identity matrix

$\hat{A}$ = diagonal matrix of service workers required per household by zone

B = spatial distribution of household demand matrix by zone

$\hat{C}$ = diagonal matrix of households per worker by zone

D = matrix for distributing the labor force among residential zones

$\hat{F}$ = diagonal matrix of workers required in service industries per worker by zone

G = spatial distribution of worker demand by zones.

The population distribution is obtained from

$$H = \hat{C}D\,[I - (\hat{A}B\hat{C}D + \hat{F}G)]^{-1} E^b \qquad (2)$$

where H = vector of households by zone.

The simulations in the model were subject to a zero population growth constraint for the region as a whole. This constraint implies that there is sufficient slack in the regional labor market for the existing labor force to satisfy the increased demand for labor. This seems reasonable in view of the regional unemployment rate of about 7 percent and the fact that the maximum employment impact from any scenario was 21,420 or only 0.72 percent of total employment in the study region.

The allocation of total employment into basic and nonbasic categories to generate the basic employment vector for Equation (1) was obtained via the location quotient method. The location quotient for industry i in region j (L_{ij}) is given by

$$L_{ij} = \frac{E_{ij}/P_j}{E_{in}/P_n} \qquad (3)$$

where n = the nation. The proportion of economic activity considered basic in any sector is given by

$$\frac{L_{ij}^{-1}}{L_{ij}} .$$

B. Fiscal Impacts. The fiscal impacts were based on the hypothesis that induced expansions or declines in population and employment in any jurisdiction will generate changes in public service

[1] I. S. Lowry, *A Model of Metropolis* (Santa Monica: Rand Corporation, RM-4035-RC, 1964).

expenditures. The method assumes that the size of the local budget is expenditure-determined, not tax-determined. The size of the impact was estimated by using expenditure-population and expenditure-employment coefficients obtained via regression analysis. Separate equations were calculated for Los Angeles and Orange Counties, namely

Los Angeles:

$$\begin{aligned} EXP = &- 2{,}865{,}000 + 135.2\,Pop \\ &\quad (8.5) \quad (11.2) \\ &+ 232.4\,Emp \\ &\quad (7.8) \end{aligned}$$

$$R^2 = .99 \qquad (4)$$

Orange County:

$$\begin{aligned} EXP = &- 528{,}400 + 121.4\,Pop + 63.1\,Emp \\ &\quad (0.73) \quad (5.7) \quad (1.2) \end{aligned}$$

$$R^2 = .91 \qquad (5)$$

C. Air Pollution Impacts. The air pollution impacts were estimated with the aid of the hypothesis that spatial "externalities" at any location, such as air pollutants which are not traded in a market, are reflected in the price of land (and structures). People are willing to pay land (and property) value premiums for locations with clean air, while inferior air quality will be associated with land (and property) value discounts. Via multiple regression techniques it was possible to estimate partial regression coefficients of the impact of individual air pollutants on land values. The estimated equation was

Land price per acre

$$\begin{aligned} = &\ 12.79 - 0.61\,LCBD - 0.136\,LNER \\ &\quad (5.03) \quad (1.56) \quad (0.71) \\ &+ 0.340\,LPOT - 0.419\,LOCE \\ &\quad (1.24) \quad (3.96) \\ &- 0.012\,TAX + 21.20\,NO_2 - 39.0 \\ &\quad (0.15) \quad (1.19) \\ &- 39.0\,SO_2 + 1.06\,CO - 15.97\,O_3 \\ &\quad (3.81) \quad (1.65) \quad (2.08) \end{aligned}$$

$$R^2 = 0.56 \qquad (6)$$

where LCBD, LNER, LPOT, and LOCE = logarithmic distance from the CBD, nearest employment center, maximum accessible location for workers, and from the ocean

where LCBD, LNER, LPOT, and LOCE = logarithmic distance from the CBD, nearest employment center, maximum accessible location for workers, and from the ocean

TAX = local tax rate

NO_2 = nitrogen dioxide

SO_2 = sulfur dioxide

CO = carbon monoxide

O_3 = ozone.

The pollution levels in each city from an onshore facility at Long Beach were measured with the aid of a diffusion model of the following kind

$$P_r = P_s e^{-gr} \qquad (7)$$

where P_r = pollution level at distance r

P_s = pollution emission at source

r = distance

and g = slope of the dispersion gradient.

The value of g varies according to climatic factors, especially wind direction. Sulfur dioxide levels were obtained by this method, while ozone levels were estimated with the aid of a map developed for the EIR

(Environmental Impact Report) of the Sohio Pipeline Project. There were no carbon monoxide emissions, and nitrogen dioxide emissions were not estimated because of the wrong sign on the NO_2 regression coefficient. Given the partial regression coefficients for SO_2 and O_3 expressed in dollar values per acre of land of .001 ppm, the SO_2 and O_3 emissions for each zone, and the area of each zone, the land value decrements associated with the air pollution impacts is then derived by simple multiplication. Because of lack of information on the air emissions associated with the scenarios examined, emissions from the Sohio Pipeline Project had to be used as a demonstration of the methodology. These could not be directly compared with the public expenditure impacts from the scenarios, but it was possible to draw qualitative conclusions. The tax base impacts of air quality deterioration tended to be much larger than the public expenditure impacts due to changes in population and employment. Also, the cities with relatively large public expenditure impacts tended to experience large land value decrements, compounding their fiscal problems. However, the absolute magnitude of both impacts remained small.

Results

The model was run for twenty different combinations of possible outcomes of offshore oil and gas development, derived by combining together several scenarios suggested by the Bureau of Land Management. For space reasons the results of only one scenario are reported here. This is what is called Scenario 3, which consists of most probable resource estimates (assuming Sale 48 development takes place) with pipeline transportation. Table 1 shows the increases in basic employment between 1979 and the year 2000 at Los Angeles Harbor and at Long Beach. Table 2 presents the total employment and public expenditure impacts of Scenario 3 for the 1979-2000 period. In Table 3 the spatially disaggregated impacts for population, employment and public expenditures associated with Scenario 3 are displayed for each city (or zone) in the study region in the peak impact year (1985).

It was assumed that all the basic employment increases occur locally, i.e., in Long Beach and in the Los Angeles Harbor zone. The number of additional jobs in Long Beach (1,977) is divided between 937 direct and 1,040 indirect jobs, while in Los Angeles Harbor the 1,113 additional jobs consist of 650 direct and 463 indirect jobs. The higher multiplier in Long Beach than in the Los Angeles Harbor zone implied by these figures reflects the fact that Long Beach is much more diversified with a wider array of service industries.

Employment impacts decline with distance. Above-average employment changes are experienced in the nearest twenty-one zones, while significantly below-average employment changes occur in the forty-seven most distant zones. In thirteen intermediate zones the employment impacts diminish sharply beyond 17 miles. The expenditure changes show a similar picture: the nearest twenty-three zones exhibit above average expenditure impacts (i.e., $\geq$ 0.12 percent) while the forty-seven most distant zones show below average changes (negative in thirty-nine of these zones). Finally, with respect to population impacts, twenty-seven out of the nearest thirty zones register population increases, but

population declines in the most distant forty-seven zones. However, the population changes are small in all cases (with the range +0.77 percent to -0.22 percent).

These results suggest that the absolute impacts of new oil and gas developments on each city are quite modest, but there are major variations among cities in these impacts. Thus, spatial disaggregation makes a difference in highly urbanized regions. It is clear that impacts decline rapidly with distance from the site of the facilities, and the rate of decline is best expressed as a negative exponential function of distance from the site.

The air pollution impacts (expressed in land value decrements) associated with the Sohio Pipeline Project are shown in Table 4. They show a wide diversity of experience among cities. In eighteen zones the land value impacts are negligible, and in seven others they are less than $100,000. At the other extreme, in sixteen zones the decrements exceed $1 million each, totalling more than $30 million, or 65 percent of the overall land value decrement for the region as a whole. Apart from in Long Beach itself, the most extreme cases are Pomona ($4.79 million) and West Covina ($3.23 million).

Conclusions

This research has revealed the following findings:

1. Employment impacts associated with offshore oil and gas development decline exponentially with distance from onshore facilities.

2. However, the absolute size of these impacts tend to be small because the industries involved are so capital-intensive.

3. Accordingly, the fiscal impacts on individual cities due to changes in population and economic activity (employment) are also small, though again they vary with distance.

4. The air pollution impacts on land values in each zone are measurable, though they are significant only in a few cities.

These results are helpful to local planners and policymakers because although they reveal gainers and losers, no city would suffer major disruption in economic, fiscal, and environmental quality terms as a result of offshore oil and gas development. The only possible exceptions to this generalization are the cities where onshore facilities might be located. In these cases, the benefits of job gains and tax revenues would have to be weighed against the costs of environmental deterioration.

This research effort might usefully be extended in several directions: sectoral disaggregation of the local economic impacts; testing the sensitivity of the fiscal impact model to post-Proposition 13 conditions; obtaining direct measures of air pollution emissions associated with particular kinds of onshore facilities; and improvement in the air pollution diffusion model.

Increases in Basic Employment in Most Probable Case (Scenario 3)

Year Year	LA. Harbor	Long Beach
1979	21	31
1980	72	104
1981	99	139
1982	211	303
1983	325	464
1984	496	698
1985	650	937
1986	476	673
1987	376	537
1988	246	351
1989	170	245
1990	139	201
1991	116	167
1992-2000	same as 1991	

Table 2

Aggregate Impacts: Scenario 3

Year	Employment		Expenditure	
	No.	%	$ '000	%
1979	272	0.01	57.5	0.0
1980	923	0.03	194.8	0.1
1981	1,250	0.04	263.9	0.02
1982	2,698	0.09	569.2	0.04
1983	4,143	0.14	874.0	0.06
1984	6,274	0.21	1,323.7	0.09
1985	8,331	0.28	1,757.0	0.12
1986	6,036	0.20	1,273.5	0.09
1987	4,794	0.16	1,011.3	0.07
1988	3,135	0.11	661.3	0.05
1989	2,178	0.07	459.5	0.02
1991	1,485	0.05	313.3	0.02
1992-2000 same as 1991				

Table 3

Geographical Impacts of Scenario 3 in the Peak Year of 1985

Zone	Distance	Population		Employment		Expenditures	
		No.	%	No.	%	$'000	%
L.A. Harbor	4.1	+1338	0.77	+1113	1.82	439.1	1.26
Long Beach	4.3	+2564	0.71	+1977	1.41	804.9	1.02
Carson	6.1	+ 302	0.43	+ 183	0.67	83.5	0.64
Lakewood	7.4	+ 400	0.49	+ 284	0.80	120.0	0.73
Seal Beach	8.1	+ 45	0.25	+ 34	0.42	7.7	0.35
Palos Verdes	9.0	+ 91	0.31	+ 73	0.62	29.4	0.77
Torrance	9.3	+ 392	0.26	+ 371	0.51	139.3	0.41
Compton	9.4	+ 184	0.20	+ 150	0.41	59.9	0.33
Paramount	9.7	+ 92	9.27	+ 56	0.45	25.5	0.55
Los Alamitos	9.7	+ 25	0.44	+ 14	0.35	4.1	0.90
Bellflower	9.8	+ 111	0.25	+ 87	0.53	35.4	0.50
Gardena	10.8	+ 49	0.18	+ 49	0.41	18.2	0.49
Cypress	11.2	+ 43	0.20	+ 30	0.40	7.2	0.28
Lynwood	11.2	+ 31	0.08	+ 49	0.32	15.9	0.26
Willowbrook	11.5	+ 25	0.11	+ 29	0.29	10.2	0.54
Redondo Beach	11.9	+ 96	0.13	+ 97	0.33	35.8	0.26
Norwalk	12.4	+ 61	0.09	+ 97	0.36	30.8	0.25
Manhattan Beach	12.8	+ 21	0.07	+ 42	0.34	12.8	0.30
Downey	12.9	+ 72	0.08	+ 107	0.29	34.7	0.19
South Gate	12.9	+ 36	0.06	+ 61	0.28	19.3	0.19
Westminster	13.2	+ 24	0.07	+ 49	0.32	6.1	0.13
Hawthorne	13.3	+ 59	0.08	+ 86	0.27	28.1	0.20
Westmont	13.8	- 3	-0.03	+ 16	0.28	3.3	2.74
Buena Park	14.1	+ 30	0.04	+ 85	0.29	9.1	0.09
Florence Graham	14.6	0	0.00	+ 19	0.24	4.4	0.13
Bell Gardens	14.7	+ 7	0.05	+ 17	0.28	5.1	0.74
La Mirada	14.7	0	0.00	+ 54	0.25	12.6	0.13
Garden Grove	14.9	+ 81	0.08	+ 118	0.31	17.4	0.12
Huntington Park	15.2	+ 3	0.01	+ 29	0.24	7.2	0.20
Fountain Valley	15.6	+ 11	0.06	+ 23	0.35	2.8	0.14
Inglewood	15.7	- 12	-0.01	+ 106	0.23	23.1	0.10
Huntington Beach	15.8	+ 117	0.13	+ 111	0.32	21.3	0.17
South Whittier	15.9	- 20	-0.05	+ 34	0.21	5.3	0.08
South L.A.	17.2	+ 129	0.02	+ 652	0.28	169.0	0.13
Pico Rivera	17.3	- 16	-0.05	+ 25	0.18	3.7	0.07
Anaheim	17.6	- 36	-0.02	+ 129	0.18	3.8	0.01
Whittier	18.1	- 82	-0.09	+ 51	0.16	0.7	0.00
Costa Mesa	18.5	- 47	-0.06	+ 51	0.18	- 2.6	-0.02
Fullerton	18.7	- 62	-0.07	- 83	0.16	- 3.0	-0.02
East L.A.	18.8	- 73	-0.09	+ 47	0.16	1.2	0.01
La Habra	19.3	- 37	-0.09	+ 26	0.16	- 2.8	-0.05
Santa Ana	19.4	- 82	-0.05	+ 120	0.19	- 2.4	-0.01
Montebello	19.6	- 27	-0.08	+ 22	0.16	1.5	0.03

Table 3 (continued)

Zone	Distance	Population		Employment		Expenditures	
		No.	%	No.	%	$'000	%
Culver City	20.6	- 38	-0.12	+ 19	0.13	- 0.6	-0.01
Monterey Park	20.9	- 46	-0.13	+ 18	0.13	- 2.1	-0.04
Newport Beach	21.1	- 16	-0.04	+ 28	0.17	- 0.2	-0.00
L.A. Central	21.2	- 527	-0.11	+ 271	0.11	- 8.2	-0.01
Orange	21.4	- 17	-0.09	+ 8	0.07	- 1.5	-0.06
Brea	21.5	- 12	-0.12	+ 4	0.12	- 1.3	-0.14
Hacienda Heights	21.8	- 51	-0.15	+ 12	0.09	- 4.1	-0.08
Rosemead	21.8	- 55	-0.15	+ 13	0.10	- 4.4	-0.09
Placentia	22.4	- 2	-0.02	+ 7	0.22	0.1	0.01
Tustin	22.6	- 15	-0.06	+ 20	0.18	- 0.6	-0.02
Alhambra	23.1	- 85	-0.14	+ 24	0.11	- 5.8	-0.05
El Monte	23.4	- 163	-0.18	+ 29	0.08	-15.2	-0.08
Villa Park	23.4	- 6	-0.09	+ 2	0.15	- 0.7	-0.13
L.A. (East)	23.7	- 242	-0.12	+ 88	0.13	-12.3	-0.03
San Gabriel	24.1	- 78	-0.17	+ 18	0.10	- 6.3	-0.08
Santa Monica	24.3	- 111	-0.12	+ 48	0.11	- 3.7	-0.02
L.A. (Westside)	24.3	- 623	-0.13	+ 245	0.13	-27.1	-0.02
Yorba Linda	24.3	- 2	-0.04	+ 4	0.21	0.0	0.00
La Puente	24.3	- 45	-0.15	+ 11	0.10	- 3.6	-0.09
Beverly Hills	24.5	- 54	-0.14	+ 17	0.12	- 3.3	-0.06
West Hollywood	25.2	- 38	-0.12	+ 13	0.13	- 2.1	-0.05
Baldwin Park	25.9	- 50	-0.14	+ 14	0.11	- 3.5	-0.07
West Covina	26.5	- 125	-0.18	+ 24	0.09	-11.4	-0.09
Arcadia	27.4	- 127	-0.20	+ 16	0.07	-13.5	-0.12
Pasadena	27.9	- 258	-0.20	+ 32	0.06	-27.3	-0.10
Glendale	28.8	- 265	-0.18	+ 52	0.09	-23.7	-0.08
Covina	29.3	- 113	-0.19	+ 17	0.07	-11.2	-0.10
Rest of Orance Co.	29.7	- 11	-0.01	+ 84	0.25	3.9	0.03
Burbank	30.2	- 180	-0.19	+ 24	0.05	-18.6	-0.09
Altadena	30.6	- 64	-0.12	+ 6	0.06	- 7.1	-0.18
Laguna Beach	30.8	- 7	-0.07	+ 7	0.18	- 0.5	-0.05
Monrovia	31.1	- 99	-0.21	+ 9	0.06	-11.2	-0.15
Azusa	31.2	- 107	-0.20	+ 14	0.07	-11.1	-0.12
Glendora	32.9	- 81	-0.22	+ 7	0.05	- 9.3	-0.17
Pomona	33.2	- 212	-0.20	+ 22	0.05	-23.5	-0.11
San Juan Capistrano	37.1	- 3	-0.09	+ 3	0.20	- 0.2	-2.76
L.A. (West Valley)	37.9	- 920	-0.21	+ 89	0.05	-103.5	-0.11
Total	--	0	0.00	8331	0.28	1,757.0	0.12

Table 4

Air Pollution Impacts on Land Values

City	Distance (Miles)	Emissions (ppm) SO_2	(ppm) O_3	Area (Acres)	Land Value Decrement ($'000)
Long Beach	--	.004	.0	34,182	5,332.4
L.A. (Harbor)	4.1	.00225	.0	18,905	165.9
Carson	6.1	.00195	.0	9,321	708.9
Lakewood	7.4	.00167	.007	6,596	1,166.9
Seal Beach	8.1	.00155	.0	6,240	377.2
Palos Verdes	9.0	$.2 \times 10^{-6}$	.0	10,188	0.1
Torrance	9.3	$.6 \times 10^{-5}$	.0	16,071	3.7
Compton	9.4	.00131	.0	13,205	674.6
Paramount	9.7	.00126	.005	3,265	421.2
Los Alamitos	9.7	$.45 \times 10^{-5}$	.005	3,194	255.6
Bellflower	9.8	.00124	.01	3,209	667.6
Gardena	10.8	$.21 \times 10^{-5}$	.0	719	0.1
Cypress	11.2	~ 0	.005	4,160	332.4
Lynwood	11.2	.00106	.003	2,858	255.1
Willowbrook	11.5	.00103	.0	2,904	116.7
Redondo Beach	11.9	.0	.0	5,155	0.2
Norwalk	12.4	.0	.01	6,454	1,030.8
Manhattan Beach	12.8	.0	.0	2,187	~ 0
Downey	12.9	.00087	.007	8,439	1,229.7
South Gate	12.9	.00087	.003	4,937	404.0
Westminster	13.2	.00084	.0	5,926	0.1
Hawthorne	13.3	.0	.0	4,585	194.1
Westmont	13.8	.0	.0	2,136	~ 0
Buena Park	14.1	.0	.005	7,673	612.7
Florence Graham	14.6	.00070	.0	1,605	43.8
Bell Gardens	14.7	.00069	.005	1,896	202.4
La Mirada	14.7	.0	.01	6,519	1,041.1
Garden Grove	14.9	.0	.0	11,693	~ 0
Huntington Park	15.2	.0	.0	921	~ 0
Fountain Valley	15.6	.00062	.0	5,677	137.3
Inglewood	15.7	.0	.0	8,908	~ 0
Huntington Beach	15.8	.0061	.0	19,680	468.2
South Whittier	15.9	.0	.01	3,944	629.8
L.A. (South)	17.2	.00052	.0	16,968	344.1
Pico Rivera	17.3	.00052	.007	5,174	683.3
Anaheim	17.6	.0	.0	21,177	~ 0
Whittier	18.1	.0	.01	11,800	1,884.3
Costa Mesa	18.5	.0	.0	9,670	~ 0
Fullerton	18.7	.0	.005	14,445	1,153.4
East L.A.	18.8	.00043	.005	6,214	600.4
La Habra	19.3	.0	.005	4,282	341.9
Santa Ana	19.4	.00040	.0	17,325	270.3
Montebello	19.6	.00039	.007	3,975	504.8

Table 4 (continued)

City	Distance (Miles)	Emissions (ppm) SO_2	O_3	Area (Acres)	Land Value Decrement ($'000)
Culver City	20.6	.0	.0	2,931	~ 0
Monterey Park	20.9	.00033	.005	5,030	466.4
Newport Beach	21.1	.00032	.0	8,666	108.2
L.A. (Central)	21.2	.00032	.0	24,774	309.2
Orange	21.4	.00031	.0	10,176	123.0
Brea	21.5	.0	.005	3,674	293.4
Hacienda Heights	21.8	.0	.01	10,363	1,654.9
Rosemead	21.8	.00030	.005	4,940	452.2
Placentia	22.4	.0	.005	3,091	246.8
Tustin	22.6	.00027	.0	2,790	29.4
Alhambra	23.1	.00026	.005	4,645	418.0
El Monte	23.4	.00025	.01	9,965	1,688.5
Villa Park	23.4	.00024	.0	2,150	20.1
L.A. (East)	23.7	.00024	.0	16,572	155.1
San Gabriel	24.1	.00023	.005	2,875	255.3
Santa Monica	24.3	.0	.0	5,303	~ 0
L.A. (Westside)	24.3	.0	.0	65,996	~ 0
Yorba Linda	24.3	.0	.005	1,824	145.6
La Puente	24.3	.00022	.01	3,257	548.1
Beverly Hills	24.5	.0	.0	2,654	~ 0
West Hollywood	25.2	.0	.0	1,228	~ 0
Baldwin Park	25.9	.00018	.01	3,163	527.3
West Covina	26.5	.0	.01	20,195	3,224.9
Arcadia	27.4	.00016	.007	6,937	818.7
Pasadena	27.9	.00015	.005	18,281	1,566.6
Glendale	28.8	.00013	.0	22,085	112.0
Covina	29.3	.0	.01	6,854	1,094.5
Burbank	30.2	.00011	.0	10,855	46.6
Altadena	30.6	.00010	.005	4,187	350.6
Laguna Beach	30.8	.00010	.0	1,587	6.2
Monrovia	31.1	.00010	.01	10,812	1,768.7
Azusa	31.2	.0	.01	6,369	1,017.1
Glendora	32.9	.00008	.01	11,457	1,865.3
Pomona	33.2	.0	.01	30,008	4,792.0
L.A. (East Valley)	33.3	.0	.0	79,686	~ 0
San Juan Capistrano	37.1	.00006	.0	6,144	14.4
L.A. (West Valley)	37.9	.0	.0	59,910	~ 0

Planning Methods for Coastal Communities

Alan Kreditor and Tridib Banerjee

R/CM-7

This project originally proposed to develop a prototype methodology for conducting planning in an urban coastal zone. As the research progressed, however, it became clear that the state administrative agency (the California Coastal Commission) was rapidly developing an "approved" methodology for developing local coastal plans and that local jurisdictions were likely to be severely constrained in using alternative techniques. We determined that our proposed efforts were being pre-empted by the state agency.

In response to the rapidly changing context in which coastal planning was taking place, we determined to concentrate our efforts on an alternate opportunity which was presented by the Coastal Act of 1976. The drafters of the legislation conceived of the actual substance of planning taking place at the level of 68 individual cities and counties covering 1100 miles of coastline. Overlaid upon these 68 jurisdictions was a pattern of six regional coastal com. missions charged with assisting and overseeing the planning process. Most of the six regions spanned coastal commissions implicitly were charged with coordination between the various localities in their jurisdiction doing coastal planning. Since most of the state is composed of rural coastline, the coordination problem has not been a serious one, except for the south coast region.

In this region, composed of Los Angeles and Orange Counties, there are 18 jurisdictions preparing local plans. Also, from our experience, there was a notable lack of inter-jurisdictional regional coordination in planning efforts.

To test our hypothesis and to gain additional perspective into the problem we conducted a series of coordination workshops beginning in April, 1978 and continuing through September. We were assisted in our efforts to a considerable extent by Jim Fawcett, the Coastal Planning Specialist with Marine Advisory Services. Invited to the workshops were planning directors, coastal planning coordinators and senior planning staff from all coastal jurisdictions in the region.

At the first workshop, representatives of five cities relatively advanced in the coastal planning process were invited to make presentations on the progress their city or county was making, as well as to enumerate on problems they had experienced. In an afternoon session, all attendees were encouraged to join in the discussion and to identify critical problem areas. From that discussion, four major issues arose: citizen participation; ports, harbors and marinas; regional transportation; and regional coordination. In two similar workshops held in August and September, 1978, regional transportation and regional coordination problems and tentative solutions were proposed.

Project conclusions were that regional coastal commissions must assume the role of regional coastal planning coordinators. Existing regional

planning agencies are unlikely to become instrumental in this role. In the absence of such regional coordination at the state agency level, the end result of a coastal planning process such as that in California will be a patchwork of coastal plans inconsistent with one another and ineffective at promoting the public interest as envisioned by the California Legislature in 1976.

Marine Environmental Quality

Two interrelated areas of focus of the USC Sea Grant Program are Environmental Quality and Resources Development. In keeping with the public service philosophy of Sea Grant nationally, our program is strongly based on the local southern California Bight and developed in the context of relating the local investigations to principles applicable to other national coastal zone management problems.

In outer Los Angeles Harbor the effluents from three canneries and a primary waste treatment plant supply nutrients. These have been recognized by Project R/EQ-5 as supporting increased populations of organisms as toxic waste inputs to the Harbor have been controlled. A zone of bio-enhancement can now be identified, a concept accepted by the Regional Water Quality Control Board.

R/EQ-3 sought a better understanding of the role that organic wastes might play in the nutrition of fishes and benthic invertebrates.

A number of new marinas are in the feasibility or planning stages in southern California, but knowledge of the relationships between water quality factors and the productivity of the fauna is insufficient as yet to dictate design criteria for new marinas or methods of improving existing ones. R/RD-5 undertook a case study of Marina del Rey, the largest manmade recreational harbor in the world.

R/EQ-2 investigated the induction of tumors in fishes by a chemical common in urban wastes, benzo(a)pyrene, which is a known carcinogen. Indications are that the substance may be carried into inshore waters in runoff.

R/RD-3 will contribute information which will enable predictive models to be developed for the response of dissolved oxygen to changes in human activities in semi-enclosed basins, such as estuaries and harbors.

The Potential of Cannery Wastes to Enhance Receiving Water Nutrient Quality

Dorothy F. Soule, Mikihiko Oguri, and John D. Soule

R/EQ-5

The present report summarizes ecological investigations on the effects of effluents from fish cannery wastes and the municipal treatment plant (TITP) in outer Los Angeles Harbor over a period of some eight years. Field investigations, experimental field and laboratory investigations, and computer analyses have been carried out under the following estimated conditions and times:

1971-74: Prior to Dissolved Air Flotation (DAF) pre-treatment of cannery wastes; urban primary TITP wastes

1975-77: DAF treated cannery wastes; primary TITP wastes

April-October 77: DAF cannery wastes; secondary TITP effluent

October 77-January 78: Canneries hook up to TITP; secondary TITP effluent

January-May 78: Variable secondary TITP (Chlorination May 9-August 30, 78)

March 9-August 30, 78: Chlorination of TITP

June-August 78: TITP upset, primary plus suspended solids

September-December 78: Secondary TITP

The 1976-78 field and laboratory investigations were funded by the City of Los Angeles Department of Public Works for their Environmental Impact Report (EIR) on the Terminal Island Treatment Plant outfall location.

The preparation of a special report on this research to the Environmental Protection Agency, Washington, D.C. was funded by the Tuna Research Foundation in order to make current information available to the Environmental Protection Agency for incorporation into their Report to Congress on the effects of fish cannery effluents on marine waters.

On-going research on Los Angeles and Long Beach Harbors (San Pedro Bay) since 1970 has been funded by a number of public agencies and private entities. These include: The Port of Los Angeles, the Port of Long Beach, the USC Sea Grant Program (Dept. of Commerce, NOAA), the U.S. Army Corps of Engineers, Pacific Lighting Service Corporation, Southern California Gas Company, and many others. The studies have often been cooperatively funded and multidisciplinary in scope. Fourteen volumes of the series *Marine Studies of San Pedro Bay, California* and a number of special reports by Harbors Environmental Projects have been published on Los Angeles-Long Beach Harbors since 1972 (University of Southern California).

Evaluation of Results Related to Bioenhancement

Following the intensive control of toxic wastes and cleanup efforts mandated by the Los Angeles Regional Water Quality Control Board in 1970, the formerly depauperate harbor experienced an enormous increase in species, higher taxa, and populations unprecedented in the area, in the period from 1971 to 1974 (Reish, 1971; Allan Hancock Foundation, 1976; Soule and Oguri, 1976).

The harbor was, in 1973-1974, the richest soft-bottomed marine area in southern California. It was dependent upon the nutritious organic fish processing wastes and primary Terminal Island Treatment Plant (TITP) wastes which were mixed by the currents and winds in the area. The harbor was defined as "bioenhanced" on the basis of:

1. Species diversity
2. Evenness, hierarchical diversity
3. Total populations, richness
4. Biomass
5. Presence of essential food web species
6. Species of commercial/ recreational value
7. Rare or endangered species
8. Potential for mariculture

In 1977-78, studies similar to the 1973-74 investigations (both by Harbors Environmental Projects, USC) were made to assess the present state of the harbor on the basis of the same criteria, following the conversion of cannery effluents and domestic wastes to secondary treatment in the Terminal Island Treatment Plant (TITP). Results of these studies have been presented to the Environmental Protection Agency for their Report to Congress on Fish Processing Wastes (Soule and Oguri, 1977a).

In addition, an expanded report is being published (Soule and Oguri, 1979b) for incorporation, under the California Environmental Quality Act Guidelines, by citation in the City of Los Angeles Terminal Island Treatment Plant Environmental Impact Report (EIR).

The following findings are of note:

1. The shift in nutrients is from complex organic proteins, amino acids, fats, carbohydrates and ammonia to production of nitrate and nitrite. These mineralized nutrients have only limited availability to the food web, by way of phytoplankton. Amines are also present, which are not generally utilized.

2. The bird populations were down to 40 percent of prior levels. The gull species experienced the greatest loss.

3. The fish populations in 1978 were down from 10-20 times for white croaker and perhaps 100-fold for anchovies. These were the two most common species in the harbor in 1972-74. The average number of species per trawl dropped from ten to six. Near the TITP outfall the species averaged 9.5, indicating its importance in supplying the only remaining attraction for the fish.

4. The phytoplankton population means, measured by chlorophyll *a*, are grossly similar for both periods. However, the produc-

tivity and assimilation ratios, representing the rates at which the phytoplankton produce food for other organisms, are drastically reduced, presumably due to loss of nutrients, or to inhibition. The drop in consumer populations would indicate that a decrease in the net phytoplankton crop has occurred.

5. Zooplankton are perhaps least affected, since they are carried into the harbor on the changing tides; however, endemic harbor populations exist. Species diversity has been slightly increased overall, but the total numbers of organisms have varied greatly. It is likely that the greatly reduced fish population resulted in much reduced predation of zooplankton, so that a much smaller zooplankton stock could still result in about the same net population. Decreased predation can also result in increased species diversity, which would falsely imply an improvement in the ecosystem. There are also limiting factors for the zooplankton population, such as a reduction in nutrients.

6. Benthic organisms in the enhanced area in 1973-74 numbered greater than twenty-five species and 35,000 organisms per m^2. The mean species diversity for the outer harbor increased steadily from 1971 through 1976. It dropped to 1972-73 levels in 1978.

The mean numbers of organisms per m rose from 2861 in 1971 to 27,806 in 1973, a ten-fold increase. They declined in 1975 (coincident with installation of dissolved air flotation [DAF] treatment by the canneries) to 63 percent of 1973 levels, and dropped to 27.6 percent in 1976, 27.7 percent in 1977, and 26.8 percent of 1973 levels in 1978.

Some of the previously most common species that were fed on by bottom fish have decreased or disappeared at times. This could seriously affect fish larvae or adults at crucial periods in their life cycles.

Fish Populations

The mean number of fish per trawl in the Los Angeles-Long Beach outer harbors experienced a four-fold drop between 1973 and 1978; a small temporary increase occurred in 1977, but it was followed by a continued precipitous drop in 1978. This contrasts with an almost two-fold increase between 1972-73 and 1977, in party boat catch in the area outside the harbor, a curve that was interrupted only by small decreases in 1975-76. Thus the trend in the harbor has been distinctly downward over the 1973-1978 period.

There is no indication that cessation of cannery discharges had been beneficial to harbor fish populations; rather, it appears that the change has been detrimental. It is impossible to state at this time that cessation is *the* only cause of the large decrease because of the many unknowns. However, the 1973-74 drop may have been a natural regression from the peak of a cycle which resulted when the control of toxic wastes was instituted in 1970-71. The drop preceded in time the 1975 installation of DAF treatment of cannery wastes and would presumably have leveled off to a more stable level. The precipitous drop in December 1977 coincided precisely

with the tremendous drop in nutrients due to the cessation of cannery effluents and diversion of all wastes to TITP secondary treatment, coupled with nutrient loss due to the drought. In July 1978, the peak return of fish to the harbor coincided with the peak period of TITP malfunction during which large amounts of BOD and suspended solids were released to the entire central outer harbor. The counts dropped again as soon as the malfunction was corrected.

The two important fish species were particularly affected. White croaker dropped ten- to twenty-fold over the 1973-78 period. It was the principal fish caught by low income shore anglers, and now sells for about $3 per pound in local markets as "butterfish." Anchovy dropped by a factor of perhaps 100-fold in the same period. The harbor had previously been the home of a very large population of 0-1 year age class anchovy. This compares with a four-fold drop in the same period in anchovy stock offshore. The large drop in gull species in the harbor, which fed on anchovies and fish "gurry" (floating protein-fat coagulates), may be related to the decline in nutrients and hence in anchovies.

The TITP sewage outfall now seems to be the only nutrient area left in the harbor that shows larger fish populations than the other trawl stations. It is therefore very important to maintaining the now-small fish population in the harbor. The work was done in cooperation with Dr. John S. Stephens of Occidental College.

Bird Populations

The average number of all marine birds sighted per observation period in 1973-74 was 5,665, while the average number per period in 1978 was 2,280. This is a reduction of about 60 percent. The major differences occurred primarily in fall and winter months. The change in species numbers was varied; most loons and grebes increased, as did the Brown Pelican and cormorants. Among ducks, the abundant Surf Scoter suffered about a 60 percent decrease. The abundant Sanderling, among shorebirds, declined elevenfold.

All gull species declined; the Western Gull by a factor of four, the California Gull by twenty-three times and Heermanna Gull by 2.5 times. This represents the largest numbers of birds.

The endangered Least Tern and Royal Tern increased, but all other terns decreased. However, Least Tern nesting had been disrupted during the 1973 and 1974 surveys by construction. Purposeful disruption occurred again in 1978 and no nesting occurred, but eighty-five nests had been present in 1977. Sightings are otherwise infrequent and the increase in 1978 is small.

Changes in bird populations may be due to the very large decrease in anchovies and/or in solid or particulate matter from the wastes. Liquid protein "salts out" in sea water and cannery wastes formerly contained some coagulates and particles which floated on the water and were fed upon by many birds.

This work was done in cooperation with Dr. Dennis Power, Director of the Santa Barbara Museum of Natural History.

Phytoplankton Resources

Monitoring of phytoplankton productivity, chlorophyll *a* (a photosynthetic pigment), and assimilation ratio in the outer Los Angeles Harbor was carried out before, during, and after changeover of the Terminal Island Treatment Plant to secondary waste treatment and the diversion of cannery wastes into the plant for treatment prior to discharge.

The chlorophyll *a* concentrations during this period showed similar annual patterns, indicating that the changes had not disrupted the development of phytoplankton populations. However, the levels of productivity and assimilation were substantially reduced by the conversion of the TITP sewage plant to secondary treatment in 1977, although these parameters appeared to follow the same seasonal periodicities as previously.

After the diversion of the cannery wastes into the treatment plant, completed in January 1978, further sharp reductions were found in both productivity and assimilation ratio. The cyclic pattern was obscured in 1978, but this may have been due, in part, to a major plant upset in the summer of 1978.

Zooplankton Resources

Species diversity of copepods and cladocerans is generally higher outside the harbor than it is inside, and appears to be higher in winter than in summer. Species diversity was reduced at the onset of TITP secondary treatment in April 1977, but was accompanied by a bloom of *Acartia tonsa*. A high-to-low gradient in diversity existed prior to full secondary treatment from Station A1 (outside) to A3 (middle harbor) to A7 (outfalls). After full secondary, Station A1 was still highest in diversity but A7 was next highest and A3, located between the two, was the lowest.

The so-called zone of enhancement in the harbor, if it still exists for zooplankton, has apparently retreated to the area around the TITP outfall, on the basis of initial analyses, but the concentration levels are lower as well.

In total concentrations, the ratio of A1:A7 was 1.5:1 before full secondary treatment of cannery wastes. The ratio of A1:A7 became 4:1 after full TITP secondary treatment. The numbers of organisms per m^3 were very low in the fall of 1977; they improved somewhat in 1978.

Benthic Resources

While the distributions of the benthic organisms have not changed appreciably over the period of 1975-1978, since publication of the report to the U.S. Army Corps of Engineers (AHF, 1976), the principal trends have been a large decrease in population sizes, expecially of the more abundant species, and a decline in number of species.

There was a slight trend towards increased species diversity at all stations in 1975-76. However, this may have been an artifact of multiple sampling done then, and to crustacean taxonomic studies that increased identifications. These were, therefore, restricted in the computer analyses herein. The numbers of species declined

steadily from March 1977 through October 1978.

By October 1978, samples showed faunal changes at both A1 (outside the harbor) and A7 (in the outfall area). Since benthic worms are a principal food for bottom fish, other fish, crustaceans and birds, a large population decrease would have significant effects on those species. The drop in predator populations did not produce increased diversity or populations.

Microbiological Cycling of Nutrients

Investigations by Dr. Sullivan and his assistant of microheterotrophs in outer Los Angeles Harbor and in adjacent waters showed that the monthly average was about 2.5 times more bacterial standing stock inside the harbor than occurred outside the harbor, after full secondary waste treatment of cannery and TITP wastes began. The cells collected inside the harbor were also somewhat larger than those collected outside. There was a thirty-fold drop in total bacteria following full secondary treatment.

Annual variations in population density of bacteria included two peak periods, one in late spring and one in early fall. These peaks either coincided with or followed phytoplankton blooms closely.

Samples were collected in September 1977 prior to the diversion of the cannery wastes into the treatment plant for secondary waste treatment. These showed concentrations of cells that were directly proportional to distance from the station nearest the outfalls. The outfalls station had twenty-seven times more bacteria than the station outside the harbor.

Samples taken from the same stations one year later in September 1978 showed an almost uniform distribution of bacterial cells within the harbor and only a three-fold difference between the station nearest the outfalls and the one outside the harbor. The exception occurred during TITP malfunction, which caused a ten-fold increase in bacteria in June-October 1978.

Investigations of the utilization of the bacteria as food sources for marine organisms were conducted, using radioactively labeled bacteria and a marine ciliate, both isolated from harbor waters and cultured in the laboratory. Similar studies were also carried out using species of marine invertebrates that are common in the harbor, including a polychaete and two bivalves. These studies showed that the ingested bacteria were utilized anabolically and as a respiratory substrate. In a situation where the bacterial population was non-limiting, the quantity ingested was dependent on the number of organisms feeding on them.

Studies using natural populations of bactivorous plankton collected from a series of stations in the harbor showed that consumption of bacteria varied with the concentration of bacteria.

This suggests that the reductions in bacterial population as a result of the changes in the waste discharges in the harbor have removed an important food resource for the fauna of the harbor.

Conclusion

The reports on field collections or observations all show perturbations in the data coinciding in time with

the sequence of events occurring at the Terminal Island Treatment Plant and localizing around the site of the outfalls. In general, there were net reductions in fish, zooplankton, phytoplankton, bacteria and benthic invertebrates as well as reduced bird sightings following the conversion of the plant to secondary treatment. Further reductions, even more pronounced, ensued following the diversion of the fish cannery effluents into the treatment plant. These parameters showed significant increases during the months when the treatment plant suffered an upset. During this period high levels of suspended solids and BOD were released. Where data are available these showed sharp drops in the populations sampled after the problem at the treatment plant was alleviated. The reappearance of birds and fish during the episode indicates that the harbor is now only an optional feeding area of opportunity for adacent populations along the coast.

It is now apparent that the harbor has been converted from the richest and most diverse soft-bottom community on the southern California coast to a less productive environment. The loss of food resources previously contained in the effluents has resulted in large order net reductions of organisms that fed directly or indirectly on the wastes. In brief, the food web that previously existed has been reduced in scope and magnitude by so-called improvements in physical water quality. The bioenhancement which was previously in evidence has dropped greatly; indeed, total removal of wastes would probably eliminate enhancement altogether.

The studies presented here are felt to document the ecological role in the harbor played by the effluents discharged there. When the effluents contain much organic matter, as shown by the BOD and suspended solids levels, biomass and productivity are high. This was the pattern prior to the conversion to secondary treatment and during the plant upset. Low levels of biological productivity and standing stock prevailed during periods when the treatment plant was removing most of the BOD and solids. What was once a highly productive and diverse biological resource has been made much less so.

We believe that a return to release of *managed* levels of cannery wastes into the harbor without secondary treatment of those wastes would create a better nutrient balance in conjunction with secondary TITP wastes, and would be beneficial to the ecology. This might restore the enhanced condition that prevailed prior to full TITP secondary treatment. We feel that there are too many concomitant drops in a wide variety of taxa and biological processes to attribute all of them to coincidence. Differences between harbor fluctuations and ocean fluctuations can be seen, which coincide in time with waste treatment events in the harbor.

The cannery wastes were not toxic in the same sense that metals and chlorinated hydrocarbons are toxic; high nutrient wastes do require more even distribution of the environment, however. Cannery wastes are very different from some toxic wastes in that they cannot be concentrated in tissues, nor bioamplified by passage through several consumers, as some heavy metals and toxic substances are concentrated.

Energetic Role of Amino Acid and Protein Metabolism in the Kelp Bass (*Paralabrax clathratus*)

Arnold Dunn and Karen Bever

R/EQ-3

The potential nutritional value of fish cannery wastes to organisms found near the Los Angeles Harbor cannery outfalls has been under study for some time. The effluent is comprised of waste water high in proteins and amino acids originating from the commercial processing of fish catches. Protein levels as high as 53 mg/L have been measured in the water near the outfall boils (Bever 1977). Amino acid levels approximate 0.15 uM (Bever unpublished data). Coincident with the elevated levels of organic material is the presence of large populations of fishes and benthic invertebrates (Stephens et al. 1974). An understanding of the role this organic waste might play in the nutrition of these organisms is necessary to the capable management of such wastewater outfalls.

Although utilization of this rich organic nitrogen source can be examined at all trophic levels, our research has been directed toward evaluation of the potential for direct uptake of proteins and amino acids from the sea water by fishes. Investigations by Chamberlain et al. (1975) suggested that the small harbor goby, *Clevelandia ios*, was capable of incorporating radioactivity from dissolved glutamic acid-U-^{14}C into its tissues. We have expanded this study using the intact, free-swimming carnivorous fish *Paralabrax clathratus* (kelp bass) and the common white croaker, *Genonymus lineatus*, which is found in large numbers off the cannery outfalls.

Three areas have been of major consideration during this study.

1. What is the contribution of proteins and amino acids to the metabolism of carnivorous fishes? That is, is the biochemical machinery for processing amino acids, the breakdown products of proteins, functioning at a elevated level? An indicator of the importance of amino acid metabolism is the process of gluconeogenesis, the biochemical conversion of amino acids to glucose. Although glucose is required for important physiological functions such as muscle contraction and mucus production in fishes, it is supplied in limited quantities in the diet of carnivores (primarily protein-consumers). Thus we monitored the disappearance of an intravascular tracer dose of ^{14}C-amino acid and the subsequent appearance of the ^{14}C label in plasma glucose.

2. If the protein-enriched ambient sea water is swallowed, can the fish make use of the added nutrients? This was tested by administering ^{14}C-amino acid via a stomach tube and measuring the appearance of

radioactivity in the plasma of free-swimming fish via an intravascular cannula.

3. Can intact fish extract amino acids directly from the sea water? Uptake could result via swallowing or via transport across the gills during respiration. Fish were placed in sea water containing added radioactive amino acids and the plasma was examined for the appearance of ^{14}C label.

Kelp bass were obtained by trapping in Big Fisherman's Cove, Catalina Island. White croakers were taken by hook and line or taken from bait tanks aboard commercial anchovy bait dealers in the Los Angeles-Long Beach Harbors. The experimental animals were anesthetized with MS 222, and a 60 cm polyethylene cannula was implanted in the ventral aorta. This and subsequent procedures are detailed by Bever et al. (1976) and Bever and Dunn (1976). For the experiments requiring stomach tubes, a polyethylene cannula was inserted in the stomach of the fish and anchored by surgical silk to the roof of the mouth. The tubing exited via the thin membrane between the head and the maxillary. After the recovery of the fish which remained free swimming in aquaria, tracer quantities of glucose-6-^{3}H and either alanine, glutamic acid, or aspartic acid-U-^{14}C were injected via the indwelling venous cannula at time zero. Serial blood samples were drawn at appropriate intervals subsequent to isotope administration for analysis of the quantity and radioactive content of plasma glucose and amino acids. A mixture of amino acids labelled with ^{14}C was given either in the ambient sea water or administered through the stomach tube. Sampling and assay procedures were carried out as described above.

Metabolic Capability for Using Amino Acids

As reported previously and confirmed by subsequent experiments, all three amino acids disappeared rapidly from the plasma of kelp bass with no significant difference between the uptake of individual amino acids or with different conditions of fasting. Essentially 50% of the administered tracer had been taken up within five minutes. By 30 minutes, less than 10% remained (Table 1). Gluconeogenesis from amino acid carbon was similarly rapid. Maximal incorporation of ^{14}C into plasma glucose occurred prior to 60 minutes in all fish examined, with substantial incorporation occurring within the first five minutes after isotope injection. In the case of fed fish receiving aspartic acid-U-^{14}C, maximal incorporation took place within five minutes. The glucose synthesized at this time was kinetically indistinguishable from tritiated glucose injected along with the amino acid dose.

During prolonged fasting (20-79 days) glucose turnover (glucose replacement rate, R_o) remained essentially unchanged (Table 2). The glucose mass (total body glucose/100g body weight) also was stable. In order to maintain these parameters in the face of starvation, glucose must be synthesized from carbon precursors or glycogen stores. Our work suggests that glycogen stores remain unchanged so an alternative source of glucose must be found. The amount of glucose originating from alanine

Table 1

Disappearance of Radioactive Amino Acids from the Plasma of Fed and Fasted Kelp Bass[a]

	% Dose Remaining in Estimated Extracellular Space					
	5min	15min	30min	60min	120min	180min
Fed fish	48±8	29±10	8±1	3±1	1±0	0
Fasted fish	52±8	15±2	8±2	4±2	3±1	2±1

[a]Data from all three amino acids have been grouped together. Values are ± standard error of the mean.

Table 2

The Effect of Fasting Upon Parameters of Glucose Metabolism and Upon Amino Acid Gluconeogenesis[a]

	Fed	Fasted	Starved
Glucose replacement rate (mg glucose/min/100g weight)	0.035±0.006	0.025±0.003	
Glucose mass (mg glucose/100g weight)	6.1±0.7	5.3±0.5	
Glutamic acid (%)	0.31±0.19	1.80±0.36	2.37±0.60
Aspartic acid (%)	3.11±0.97	0.11±0.01	0.87±0.40
Alanine (%)	1.49±0.55	2.31±0.85	0.40±0.05

[a]Values are ± standard error of the mean. Amino acid values represent the maximal % of the administered dose incorporated per mg plasma glucose.

and aspartic acid decreases with fasting; however, that from glutamic acid increases significantly (Table 2). These results indicate that there are profound rearrangements in amino acid gluconeogenesis during fasting which may increase the importance of amino acids supplied in the ambient sea water.

Uptake of Amino Acids through Ingestion

In addition to demonstrating that carnivorous fishes have an enhanced capability to use amino acids as metabolic fuel, a more direct relation between organic nitrogen supplied in the sea water and uptake into body tissues must be demonstrated. The preceding results indicated that kelp bass have a pronounced ability to convert amino acids to glucose under both fed and fasting conditions. This is not unexpected due to the nature of their diet (high protein, low carbohydrate). Can they, however, utilize amino acids and proteins present in the sea water surrounding the fishes? A series of fish were given a mixture of uniformly labelled amino acids directly in the stomach via a stomach tube, and the appearance of radioactive label in the plasma of the experimental animals was monitored.

As much as 42% of the dose could be accounted for in the estimated extracellular space of the fish, with the maximum amount appearing prior to 60 minutes. Thus if the amino acids are swallowed along with prey items or as a result of swallowing water, they will ultimately be metabolized at rates comparable to those seen in the preceding section.

Uptake of Amino Acids Directly from Sea Water

In an environment high in dissolved amino acid and proteins, does the kelp bass extract substantial quantities of amino acids from the sea water? This is obviously the major question in determining the relevance of cannery effluent to the nutrition of harbor fish. Cannulated kelp bass were placed in aquaria containing 200uCi of mixed amino acids with and without added cold amino acids to simulate the quantities of primary amines found in harbor waters. In spite of the high radioactivity of the sea water, two hours were required to observe significant quantities of ^{14}C in the plasma of the subjects. This radioactivity continued to accumulate up to eight hours when the experiments were terminated. Addition of cold carrier to the sea water to approach harbor levels made no significant difference to the uptake. The maximum plasma activity observed only represented an estimated 0.008% of that present in the sea water. Even considering the rapid metabolism of amino acids by the kelp bass, this uptake would not appear to contribute significantly to the nutrition of fish of this size (250-480g). Dissolved amino acids may play a more significant role in larval or juvenile fish nutrition. Clearly the potential for utilization of amino acids as an energy source is present in carnivorous fishes, however, such organic nitrogen present in the ambient water would only serve as a supplement to the capture of vertebrate and invertebrate prey. Comparative studies with the white croaker are inconclusive as these fish are fragile and quite subject to handling stress. Preliminary experiments indicate that glucose turnover may be more rapid than

that of the kelp bass. The amount of glucose produced by amino acid gluconeogenesis is at this point not known.

Biosynthesis of Trimethylamine and Trimethylamine Oxide

Trimethylamine (TMA) and trimethylamine oxide (TMAO) are tertiary amines found in marine organisms which when acted upon by bacterial decomposers contribute to the characteristic odor of decaying sea life. Although significant quantities of TMA and TMAO are found in the tissues of marine fishes, little is known of their origin. Our Sea Grant intern, Mr. Bob Charest, has established techniques for the precise separation of these two amines and potential precursors in the biosynthetic pathway. Initial results obtained from injecting ^{14}C-TMA into free-swimming, fasted cannulated kelp bass indicates that:

1. Biosynthesis of TMAO as measured by the appearance of ^{14}C TMAO proceeds from the reduction of TMA. Betaine, another tertiary amine, may be a precursor for TMA since label was observed in an elution peak corresponding to that of betaine. A reversal of the proposed synthetic sequence would account for the label in compounds other than TMA and TMAO.

2. Due to the large amount and high specific activity (CPM/mg) of ^{14}C-TMAO in the liver compared with other tissues, it is likely that TMAO is synthesized in the liver rather than in muscle, although muscle contains the highest concentrations of TMAO in the kelp bass.

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The Environment and Living Resource Potential of Marina del Rey Harbor, California

Dorothy F. Soule, Mikihiko Oguri, and John D. Soule

R/RD-5

Marina del Rey is the largest man-made recreational harbor in the world, created some 15 years ago from coastal wetlands and Ballona Creek, and facing southwest on Santa Monica Bay. Prior to the present project, no biological survey had previously been carried out on the marina nor on the area prior to development. It had been observed that at times water quality was poor, and the fauna appeared to be depauperate, while other marinas nearby did not show such patterns. The County of Los Angeles Department of Small Craft Harbors initiated a contract with Harbors Environmental Projects for studies beginning in July 1976, and requested assistance from the USC Sea Grant Program, which started in October 1976. The combined studies cover monitoring, identifying sources of impact on water quality, and developing recommendations for improving the marine environment.

Thirteen stations were established in the marina area, eleven in the marina channels, plus one in the Ballona Creek flood control channel, and one in the bird sanctuary area. At monthly intervals zooplankton and phytoplankton samples were taken, and water temperature, salinity, dissolved oxygen, pH and transparency were measured at one-meter intervals through the water column at each station. Surface water samples were taken to measure the concentration of nutrients and to determine phytoplankton productivity and pigments. Zooplankton were sampled by making vertical tows with a conical net. Benthic collections were made with a grab sampler at less frequent intervals to determine the populations of organisms in the bottom sediments. Fish were sampled by trawl and gill netting. Both the waters and sediments were sampled and analyzed chemically to determine presence or influx of pollutants.

Water temperatures were highest in August 1976 and lowest in March 1977, with the inner slips and shallow areas of the marina showing higher temperatures than the outer stations. Salinity values were similar to those expected from sea water, except after a rain when a less saline layer would appear on the water surface. Dissolved oxygen and pH showed similar trends, being high in surface waters during the warmer months and lower in cooler months. Transparency of the waters is often inversely related to suspended sediments, so that values of 80%-90% were found in summer months and these dropped to 45%-50% in the winter, particularly after a rain.

Following rainfall it was evident that dissolved oxygen in the marina dropped sharply. In September 1976, following a rainfall, the oxygen concentration dropped to about 4 ppm at many stations, and at station 13 in the bird sanctuary area values of 0.2 to 1.3 ppm were found. An-

other rain in January 1977 resulted in values of less than 2 ppm at most stations. Special samples collected in March after a rainfall showed high chemical oxygen demand (COD) but low biological oxygen demand (BOD), suggesting that the low oxygen was due primarily to organic or inorganic material in the runoff. However, photographs taken by James Quinn (DSCH) of an incoming tide after a rain showed clearly that debris such as styrofoam cups and grass clippings had been carried down Ballona Creek and back into the marina.

Special sampling cruises were made two and five days after a rainfall of 0.89 inches during March 16, 1977. On 18 March water samples were collected at four stations, and on 21 March both water and sediment were taken for chemical analysis at the USC Environmental Engineering laboratory. Immediate oxygen demand (IOD) dropped between the two dates at station 4, nearest the Venice canal tidegate, and at station 7, while an increase was noted at stations 10 and 12. Heavy metals decreased and both DDT and PCB increased in the waters during the three days between samplings. Water sampling data from the Los Angeles County Flood Control District, taken 15 April 1977 near the Lincoln Blvd. overpass (Station No. 41118) at Ballona Creek offer the only comparison available for the marina samples taken in March. This location is just inland from the perimeter of Marina del Rey and from station 12, near the mouth of Ballona Creek.

The levels of copper, iron, zinc, cadmium, lead and nickel were lower at station 12 than they were at Lincoln Blvd. Flood Control Station. On the other hand, levels of chromium and mercury were from 2 to 20 times higher at the downstream location, station 12. This might be explained by additional effluent entering the channel, or by sediment deposition and resuspension in the tidal prism, if the laboratory analyses are truly comparable.

Finer sediments appear to occur in the inner parts of the marina. In general, sediments from stations nearest the entry to the marina were lower in both organic material and heavy metals than those from stations in the inner parts of the marina. Station 3 was consistently the lowest in almost all parameters, and station 10 was highest.

Phytoplankton productivity, pigments and assimilation ratio showed seasonal trends of a moderate bloom in April 1977 and secondary, sometimes localized, blooms through the summer and fall. Winter values were the lowest recorded. In general, the most productive stations were station 1 at the entry, and station 8 near the beach; the least productive were station 3 near the Venice canal tidegate, station 7 near the boat launching ramp, and station 10 near the bird sanctuary. The effect of rainfall and runoff is not immediately apparent, although blooms were noted at most of the stations one month after rainfall in September 1976 and January 1977. Rainfall in March may have engendered general bloom conditions in April, but this is also the time for the spring bloom which occurs generally along this coast.

Zooplankton in Marina del Rey show a ubiquitous occurrence and general dominance by *Acartia tonsa*, with a higher diversity in the outer stations, numbers 1-5, than in the inner stations. Seasonally high population levels occur in summer and low levels are found in the winter months. Station 3 is the most depauperate of all, showing lower numbers throughout the year. Number 11 is also one of the poorer stations.

Benzo (a) pyrene Induction of Tumors in Flatfish

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E/EQ-2

Benzo(a)pyrene (BaP) is a ubiquitous contaminant of the marine environment originating from a variety of sources including industrial effluent and the petroleum industry. It is a chemical carcinogen and is being found in increasing amounts in marine animals and sediments.

Initial studies have been undertaken to establish that BaP is a significant contaminant in the Los Angeles Harbor. We examined mussels, (*Mytilius eduilis*) which are known to accumulate BaP, seawater and sediment collected from stations within the Los Angeles Harbor. Of the eleven stations, values ranged from 7.9 to 537.7 micrograms BaP/kg wet weight. Our results definitely establish that significant levels of the BaP exist in the Los Angeles Harbor.

Using harbor environmental levels as a guide we have subsequently undertaken the following studies: 1) acute toxicity and chronic tumor induction, 2) BaP metabolism and distribution, and 3) effect on fecundity.

Our findings indicate species variability in toxicity ranging from 50 µg BaP/g fish in sandabs to 200 µg BaP/g in marine killifish. Twenty-four hours following injection 70% of the initial dose was recovered from the body of the fishes. Of the retained dose 3% was in the form of water soluble metabolites. Eighty percent of water soluble metabolite was found in liver and 20% at injection site. The metabolic pathway appears to differ from that in marine mammals. Fish appear to utilize sulfate conjugation as a predominate pathway whereas mammals undergo glucuronide conjugation as the principal path.

Studies on fecundity indicates that incubation of grunion eggs in sand containing BaP resulted in changes in morphology, growth and heart rate of the developing embryos. Furthermore, hatching success decreased markedly with increasing BaP concentration. Similar results have been obtained using guppies, a live bearing aquarium fish. Mothers chronically exposed to BaP gave birth to less than one-third as many fry as normal controls.

Polycyclic aromatic hydrocarbons (PAH) are recognized environmental contaminants. The source of these carcinogenic pollutants are numerous, including industrial effluent, petroleum spillage which accompanies offshore drilling, domestic waste, and the runoff of asphalt roads. PAH's have been found and measured in marine bottom sediments and in marine animals. Many of these compounds, particularly benzo(a)pyrene (BaP) and its metabolites, are known to be potent chemical carcinogens.

The role of BaP in the induction of cancer has been established in mammals but not in fishes. Although

numerous PAH's, for example 3-methylcholanthrene, are known to be marine contaminants, we selected BaP because it is known to contaminate areas in rather high levels and there is worldwide concern with this specific compound and its metabolites. There also exists a rather abundant literature on the chemistry and the biological activity of this compound and its metabolites.

Epidermal papillomas occur in the natural populations of several species of flatfish (*heterostomata*) found in southern California inshore waters and as a result flatfishes are a natural choice for these studies. Flatfish species include the Dover Sole *Microstomus pacificus*, the Speckled Sandab *Citharichthys stigmaeus*, the Tongue Sole *Symphurus atricauda*, and the Horney Head Turbot *Pleuronichthys verticalis*. Despite many speculations, the cause of these neoplasms is still unknown. Therefore, we undertook this study to investigate whether or not BaP might play a role in tumor induction in fish. Establishment of a causal role would include: 1) Evidence that BaP existed in the environment in significant levels, 2) development of tumors by chronically exposed fish, 3) data regarding distribution and metabolism of BaP, and 4) possible link to period of fish life cycle in which exposure might take place.

Environmental Levels of BaP

Dunn (1976) has recently developed rapid and reliable procedures for measurement of BaP in marine tissue and sediment samples. He has proposed the use of such measurements as an index of the carcinogenic load on aquatic organisms.

Levels of BaP in water samples, tissue of *Mytilius eduilis* (mussels concentrate BaP and thus serve as excellent indicator organisms) and fish tissues were measured using Dunn's modification (1976) of the technique developed by Howard et al. (1966). Fish were sacrificed and liver, muscle, gastrointestine, and gonads dissected. Like organs from each sample were pooled. An aliquot of each pooled organ sample was dried at 80°C for 48 hours to determine water content. The remainder was frozen at -70°C in the dark until further analyzed as outlined below.

BaP was extracted from all samples in ethanol and KOH. An aliquot of radioactive BaP (100 cpm ^{14}C-BaP ca. 5ng) was added to the sample as a standard for losses during the extraction procedure. The tissues were digested by refluxing and rinsing in ethanol. The samples were then extracted in isooctane and BaP separated from the isooctane extract by column chromatography on Fluorisil; elution from a column with benzene, followed by rotary evaporation and extraction with dimethylsulfoxide and isooctane.

The extract was subjected to thin layer chromatography on a cellulose acetate thin layer plate. Standards of 10 ng of BaP was applied to one side of the plate. Plates were developed in ethanol/water/toluene. The BaP band was located and outlined under long wave ultraviolet light. Dunn (1976) has found that the BaP band (Rf of 0.3 after 2 hours development) was always the lowest fluorescent band on the plate. The adsorbent at the position of the BaP band was scraped off the plate and the BaP extracted from the cellulose acetate by washing in hot methanol followed by hexadecane in isooctane. The

methanol and isooctane were removed by rotary evaporation leaving BaP in the hexadecane for fluorimetry.

The quantity of BaP in the sample was measured fluorimetrically in hexadecane using the baseline technique of Kunte (1967). Samples and standards of BaP in hexadecane were excited at 365 nm in a spectrophotofluorimeter and the emission spectrum recorded from 375-500 nm. An artificial baseline drawn between the minima in the spectrum occurring at 418 and 448 nm and the height of the peak at 430 nm above this baseline was measured.

After fluorimetry the amount of radioactive BaP internal standard in each sample was determined by scintillation counting and the quantity of BaP lost during the extraction procedure calculated. The amount determined by fluorimetry was corrected for the contribution of the radioactive tracer and the amount lost in the extraction procedure. The quantity of BaP in the original sample was expressed as µg BaP/kg wet weight tissue.

Using this method significant levels of BaP were found to exist in mussels and water in various locations in the harbor. Samples of harbor water yielded levels from <0.4 ng/ml to 14.8 ng/ml. Mussel samples ranged from less than a few µg/kg to over 500 µg/kg wet tissue.

Most remarkable findings were associated with the explosion of the SS Sansinena. This accident involved a 70,000 ton tanker which exploded in December of 1976 while docked at the north end of the Los Angeles harbor near Cabrillo Beach, releasing between 20-32,000 barrels of bunker oil. *Mytilius eduilis* were collected at selected sites near the explosion. Significantly high BaP levels were obtained (up to 250 µg/kg wet tissue) at the sites near the tanker shortly after the explosion (Figure 1). These values became lower with the passage of time. Those sites recorded at Fish Harbor and Bait Barge represent stations within the Los Angeles Harbor but a distance from the explosion site to serve as controls for the stations immediately within the explosion site. From Figure 1 it can be appreciated that these latter two stations remained relatively constant and independent of the values seen close to the explosion.

Toxicity and Chronic Exposure

Preliminary studies were undertaken to determine toxicity of BaP to killifish (*Fundulus parvipinnis*) and a representative flatfish the Speckled Sandab (*Citharichthys stigmaeus*). Several routes of administration, including topical application, injection, oral administration, and addition to aquaria water were studied. Epidermal injection, mixing with food and topical administration were selected for chronic studies. Injection vehicles were investigated including dimethylsulfoxide, acetone, water, corn oil and triotanoin. Corn oil proved to be most suitable. Killifish were quite resistant to BaP toxicity by comparison to sandabs. Final dose from chronic administration was 50 µg/g for killifish and 5 µg/g for sandabs injected epidermally. Feeding experiments involved 1 percent w/w BaP mixed with fish chow, fed 0.5 gm/day. Topical doses of 1 µg/10λ of acetone were applied once a week.

More than 200 fish, plus an equal amount of controls, have been chronically exposed by the above routes

of administration for up to ten months with no evidence of tumor development.

Current studies are underway to combine exposure treatments with tumor promotors. Alternative species such as Tongue Fish and Dover Sole are also under investigation.

Distribution and Metabolism of BaP

The metabolic activation of polycyclic aromatic hydrocarbons such as BaP to carcinogenic intermediates via the mixed function oxidase enzymes has long been shown to be the sine qua non for action of these compounds. For this reason the distribution and metabolism of benzo(a)pyrene (BaP) in the killifish (*Fundulus parvipinnis*) after a subcutaneous injection of ^{3}H-BaP was determined. Various tissues were extracted with twenty volumes of chloroform:methanol (2:1) and five volumes water. By this means, levels of aqueous (metabolized) and organic (non-metabolized) BaP were determined in the liver, gallbladder, kidney and injection site at times from twenty-four hours to one week after injection. These studies indicated that 70 percent of an initial dose of 12 ng/gm ^{3}H-BaP could be recovered from the body of the fish twenty-four hours after injection. Three percent of this retained dose was found to be water soluble. Of this water soluble fraction 80 percent was found in the liver and gallbladder and 20 percent at the injection site.

To identify the intermediate metabolites, hepatic microsomes were prepared from induced and uninduced fish and incubated *in vitro* with ^{3}H-BaP. The metabolites were separated and quantified by means of high pressure liquid chromatography (HPLC). Figure 2 shows the results using induced and basal level microsomes from *Citharichthys stigmaeus*. The profile of metabolites is essentially that seen in mammals susceptible to BaP carcinogenesis. The microsomal enzymes (mixed function oxidases) show both inducibility and an ample production of the carcinogenic metabolite 7,8-dihydro - 7,8-dihydroxybenzo(a) pyrene. Both of these characteristics have been shown to be necessary for the carcinogenicity of BaP.

Under laboratory conditions, however, *C. stigmaeus* appears to be more resistant to BaP carcinogenesis than animals exhibiting a similar profile of metabolites generated by microsomes. For this reason, conjugated metabolites produced *in vivo* were studied. The source of the conjugate were bile samples from *F. parvipinnis* and *C. stigmaeus* taken twenty-four hours after intraperitoneal injection of 60 g/gm ^{3}H-BaP. Metabolites released from sulfate and glucuronide conjugation were determined by incubation with either sulfatase or B-glucuronidase followed by HPLC. In the case of *F. parvipinnis*, conjugates not released by either enzyme (approximately two-thirds) were found to be positive for divalent sulfur and negative for amino acids. This is consistent with the characteristics of mercaptan acids (glutathione conjugate derivatives).

In terms of metabolite excretion *C. stigmaeus* produces approximately 22 percent of the biliary conjugates produced by *F. parvipinnis*. Furthermore, the 22 percent produced by *C. stigmaeus* is comprised largely of sulfate conjugates.

It is too early to say whether or not this drastic reduction of total biliary conjugates is responsible for the resistance of *C. stigmaeus* to BaP carcinogenesis. A number of

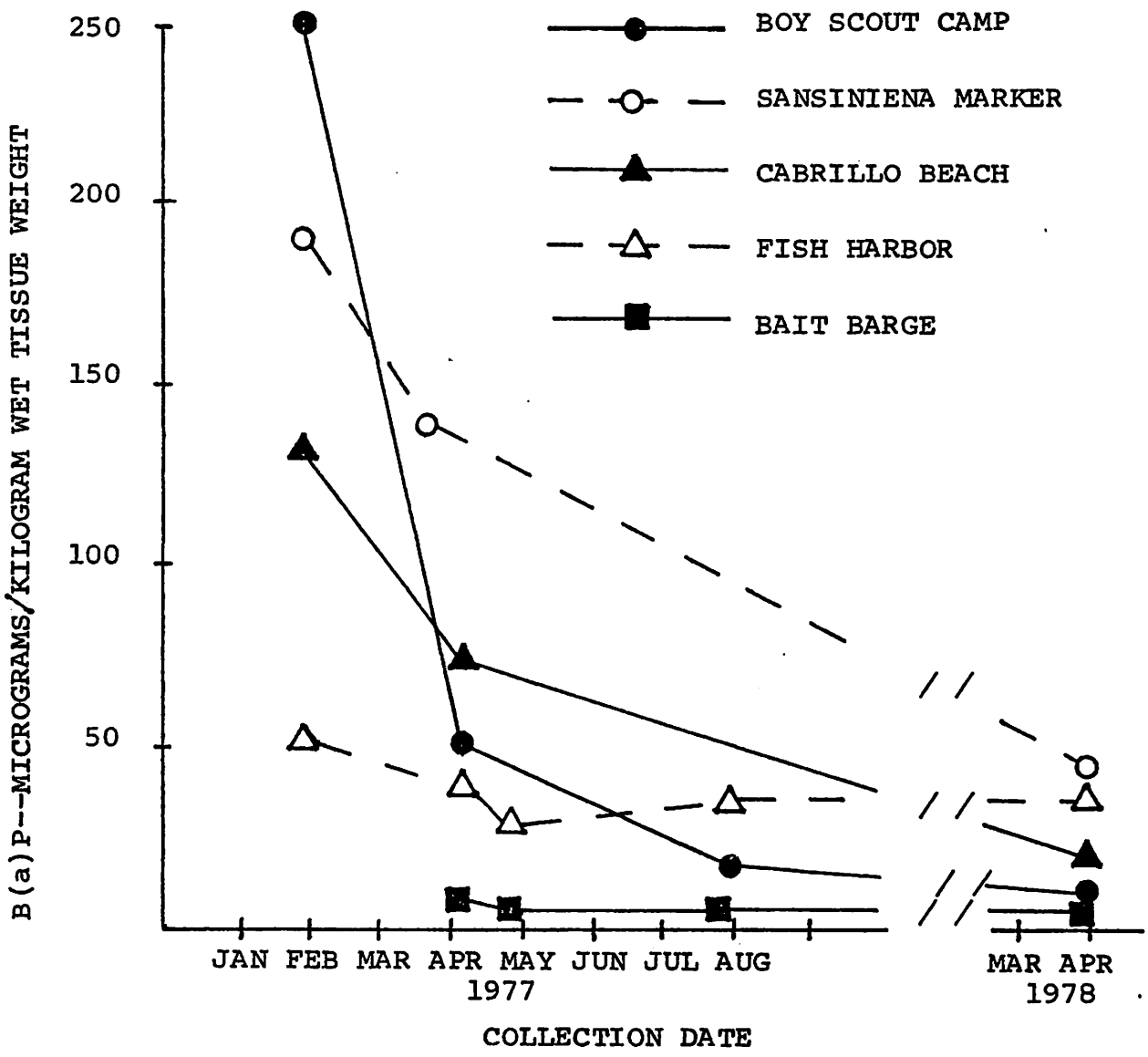

Figure 1. Benzo(a)pyrene levels in mussels (M. eduilis) in the Los Angeles Harbor

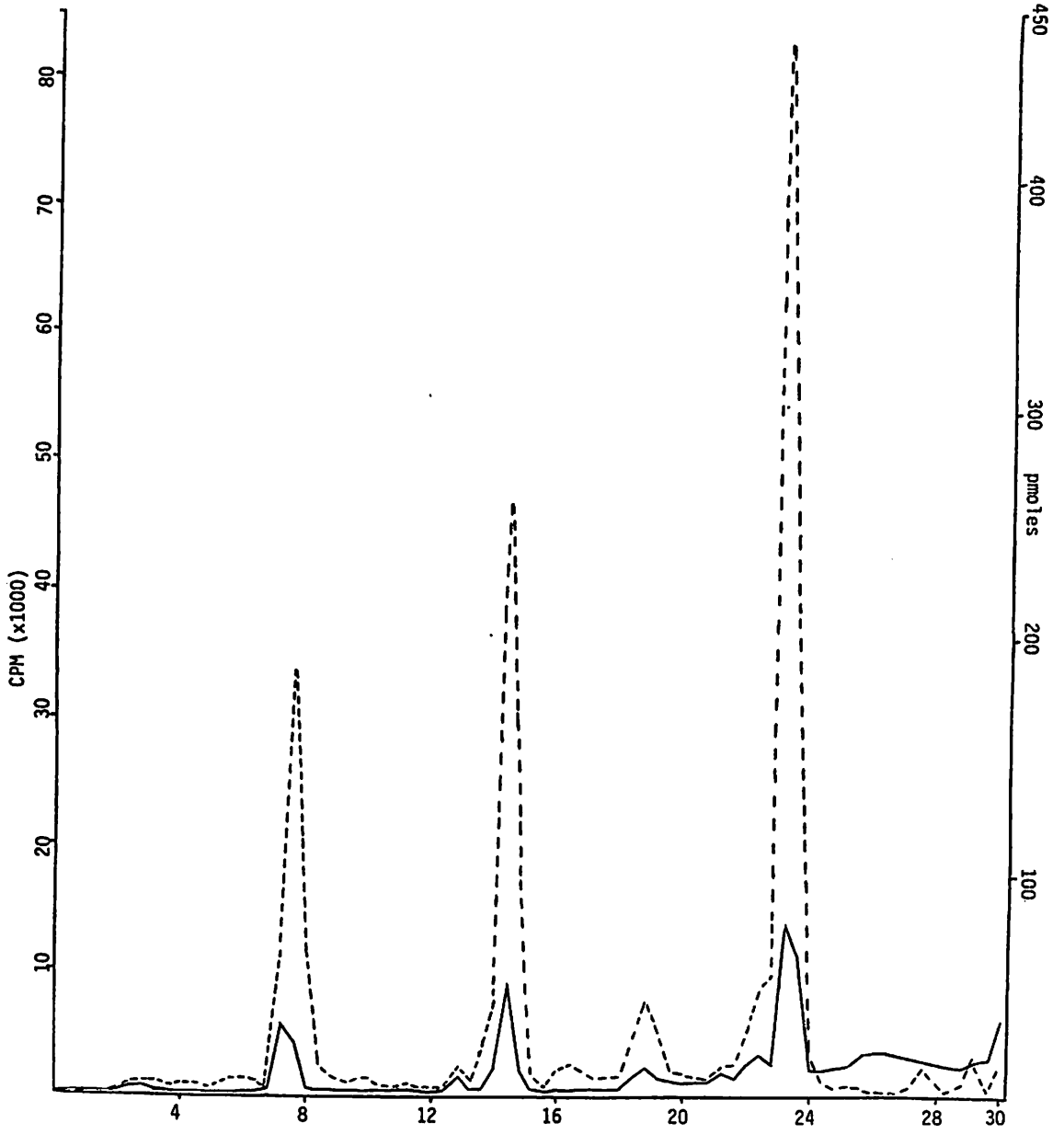

Figure 2. Retention Time (Minutes)

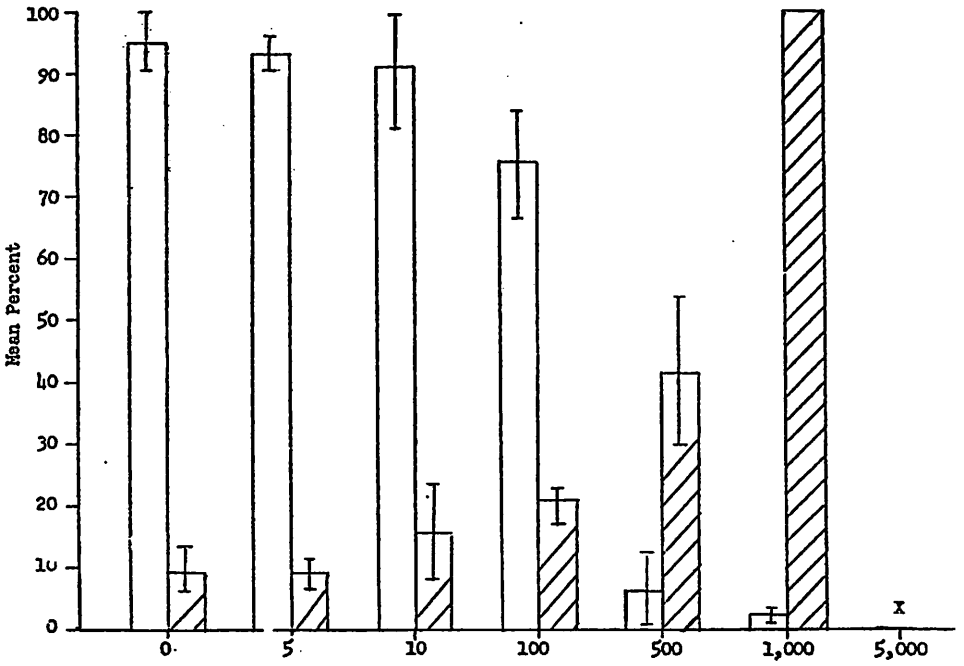

Figure 3. Mean percentage hatching and mean percentage abnormality in newly hatched grunion larvae exposed to various concentrations of benzo(a)pyrene. Empty bars: mean percentage hatching. Slashed bars: mean percentage abnormality in newly hatched grunion larvae. Standard deviations are represented as vertical lines.

X--There was 0% hatching and therefore no abnormalities.

other physiological or biological factors, such as hormones, have been shown to be necessary for the maintenance of chemically transformed cells. The comparison of hormonal characteristics between fish and mammals is currently under investigation at this laboratory.

Exposure of Grunion Eggs and Pregnant Guppies to BaP

Freshly spawned eggs of the grunion *(Leuresthes tenis)* were collected, artificially fertilized and immediately placed in specially constructed incubation chambers. During the incubation period of fourteen days the eggs were exposed to concentrations of BaP ranging from 2-5,000 ppb. Developing embryos and hatched larvae were examined for teratogenic effects. An equal number of eggs, maintained exactly as noted above except no BaP was added during incubation, served as controls. The total number of hatched eggs was recorded for each group.

It was found that percentage hatching declined rapidly for eggs exposed to BaP (Figure 3). In contrast, growth rate was reduced and percentage abnormality in embryos and larvae increased with BaP levels of 100 ppb or higher (Figure 3). The most prominent abnormality was malformation of caudal region. No observable caudal fin fold was present. Circulatory system abnormalities occurred with high concentrations of BaP.

Possible effects on fecundity in live bearing fish were studied using the common freshwater aquarium guppy. Two groups of guppies were chronically maintained for twelve months. Group one was housed in water saturated with BaP. Group two was housed under exactly the same conditions, however, no BaP was added to the water. Gravid fish were transferred to individual "birthing" aquaria to protect newborn fry. Fry were counted and observed for abnormalities.

No significant abnormalities were noted in control guppies or in guppies exposed to BaP or their fry. However, control guppies gave birth to three times as many live fry as did those exposed to BaP.

Conclusion

1. We have been unable to produce tumors in killifish or sandabs by chronic exposure to benzo(a)pyrene using concentrations which rapidly develop skin tumors in mice.

2. Metabolism of benzo(a)pyrene by fish may account for lack of tumor production.

3. Chronic exposure to benzo(a) pyrene has significant effects on fecundity of guppies and grunion.

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Uptake of Oxygen by Los Angeles and San Francisco Bay Sediments

Douglas E. Hammond

R/RD-3

The exchange of oxygen and dissolved nutrients across the sediment-water interface plays a major role in controlling the chemistry and biology of the overlying water column. This is particularly true in estuarine and coastal systems, where predictive models for the response of such systems to anthropogenic inputs cannot be developed without determining these benthic exchanges. The focus of this project has been to identify mechanisms responsible for benthic exchange and to develop models useful for calculating exchange rates.

San Francisco Bay and Los Angeles Harbor sediments are populated by diverse benthic faunas. These organisms irrigate the upper portion of sediments as they construct and move about in their burrows. One consequence of this activity is to accelerate the exchange of oxygen and other dissolved species across the sediment-water interface. A second consequence of irrigation is that it complicates estimation of exchange rates. One-dimensional models based on molecular diffusion are not applicable. Laboratory experiments will not reproduce *in situ* conditions.

We have used two approaches to this problem. One is to measure concentration vs. depth profiles of nutrients and radon-222 in interstitial waters of sediments. Radon serves as a naturally occurring radioactive tracer. Because it is a noble gas, radon distribution is controlled only by production (from radium-226 decay), decay, and physical transport. Thus, reaction kinetics for radon can be easily measured, and rates of physical transport for all dissolved species can be deduced from the observed radon distribution. By applying an appropriate model, calibrated with radon, fluxes of oxygen and nutrients may then be calculated. The second approach we have used is to directly measure oxygen and nutrient fluxes by placing a chamber on the sediment-water interface and monitoring concentration changes in the enclosed water as a function of time. These results serve as a test of the exchange rates calculated using the first approach.

1977-78 Goals

The primary goal for the past year was to develop and test models for calculating benthic exchange rates, using radon as a tracer. These models were to be used to estimate the importance of sediments to the overlying water column as a sink for oxygen and a source for nutrients. A second goal was to test the feasibility of utilizing cesium-137 and lead-210 to determine the rate of sediment accumulation in San Francisco Bay.

Results

A closed system will have a radon/radium activity ratio of one. Zones which have a ratio less than one are termed deficient and must be communicating with the overlying water.

The magnitude of the deficiency is a measure of the degree of communication. Figure 1 illustrates the impact of polychaete worms on nutrient profiles in gravity cores from two locations in San Francisco Bay. Cores from station 28C have generally included live specimens of the polychaete A. elongata, which builds tubes extending about 20 cm into the sediment. These tubes are conduits for irrigation of these sediments with overlying water, and the upper 25 cm of nutrient and radon profiles are strongly influenced by this process. Nutrient concentrations decrease or remain constant in this zone and radon shows a substantial deficiency. Below 25 cm, TCO_2 and NH_3 increase rapidly with depth and radon/radium ratios are in equilibrium within analytical uncertainty.

At station 28, nutrient profiles in the upper 10 cm again show evidence of irrigation and substantial radon deficiency. Cores from this station usually contain live specimens of *H. filaforma*. Between 10 cm and 45 cm, radon is slightly deficient, although $T\text{-}CO_2$ and NH_3 show little evidence of this. This is an important observation because it indicates that irrigation can occur at a significant rate, even when nutrient profiles show smooth increases. It also indicates that sediments as deep as 45 cm may communicate with the overlying water column on a time scale of $\sim$ ten days. Below 45 cm radon and radium are in equilibrium.

Figure 2 demonstrates that irrigation occurs throughout the year, even in the presence of an annual temperature variation of 10°C. It is also clear that the profiles of radon deficiency vs. depth vary in adjacent cores. This reflects variation in burrow structure and density over short distances.

Several types of models have been proposed to describe transport in the presence of irrigating organisms. These include modeling irrigation as an eddy diffusion process (Goldhaber *et al.*, 1977), an advective process (Hammond and Fuller, 1979), or as an increase in the surface area available for molecular diffusion (Aller and Yingst, 1978). Korosec (1979) has compared these types of models and found that all give similar results (within 30 percent) when applied to San Francisco Bay sediments, although the first model is not always appropriate. As a test of the accuracy of these models, a comparison can be made between fluxes calculated using the advective model (Hammond and Fuller, 1979) and fluxes measured directly with benthic chambers at stations in San Francisco Bay and Los Angeles Harbor (Table 1). The large standard deviation of measured fluxes is due to the heterogeneity of faunal density. This spatial variability among data collected at the same time is as large as the variation among data collected in different seasons (Korosec, 1979). The calculated fluxes are about 50 percent of the measured values, but are 2-10 times the fluxes predicted by one-dimensional diffusion models which neglect irrigation. Thus, the model utilized in this report represents a significant improvement in calculating fluxes, but needs further refinement. A more sophisticated model, emphasizing radial diffusion into benthic burrows has been formulated, but calculations are not yet completed (Hammond *et al.*, 1979). Preliminary calculations show it will be more satisfactory than the advective model.

The importance of sediments to the water column as a sink for oxygen and a source for nutrients in San

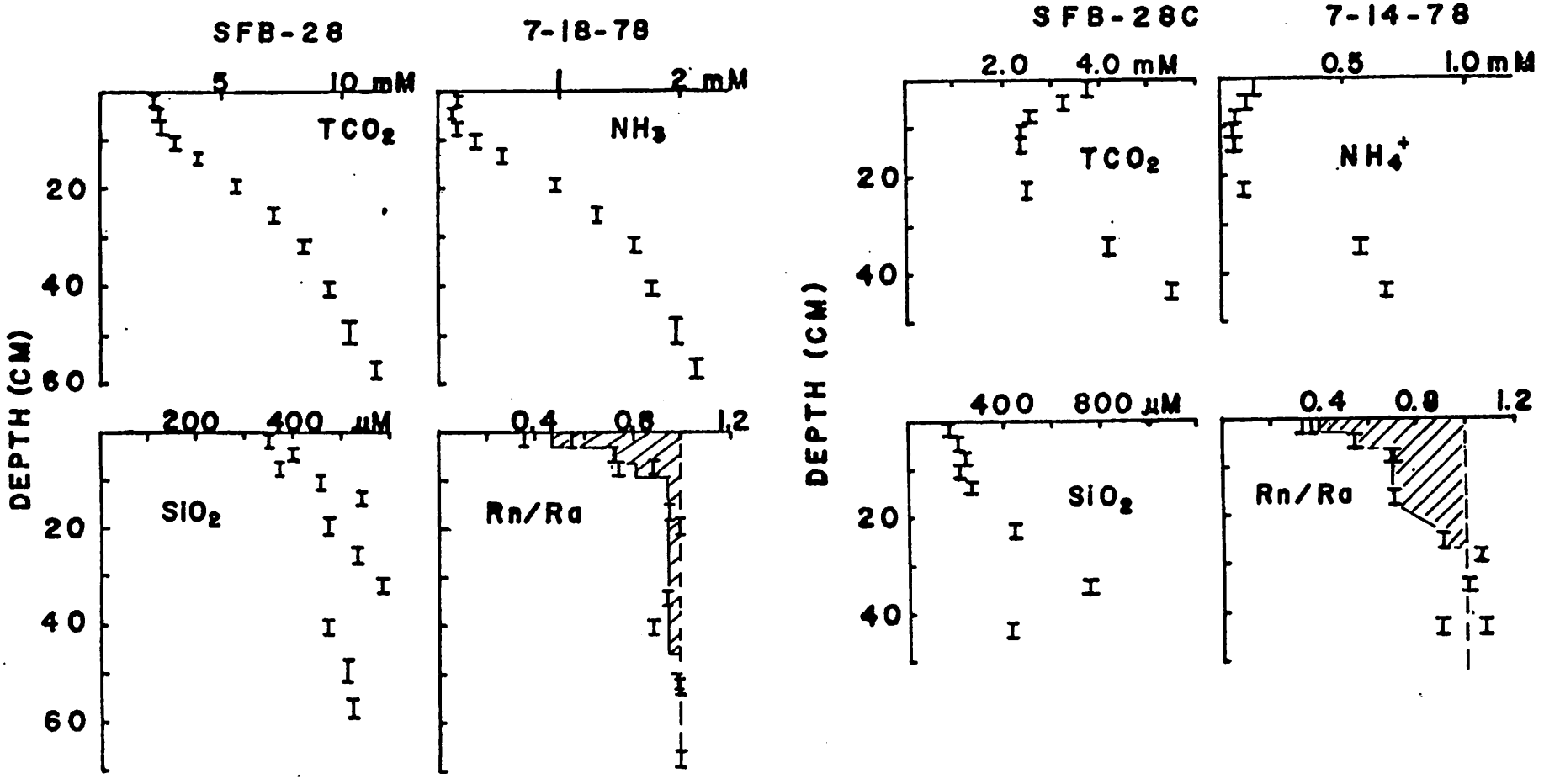

Figure 1. Interstitial water chemistry at two stations in South San Francisco Bay. Vertical bars show the length of the sample interval. Water depths at stations 28 and 28C are 14 and 1m, respectively.

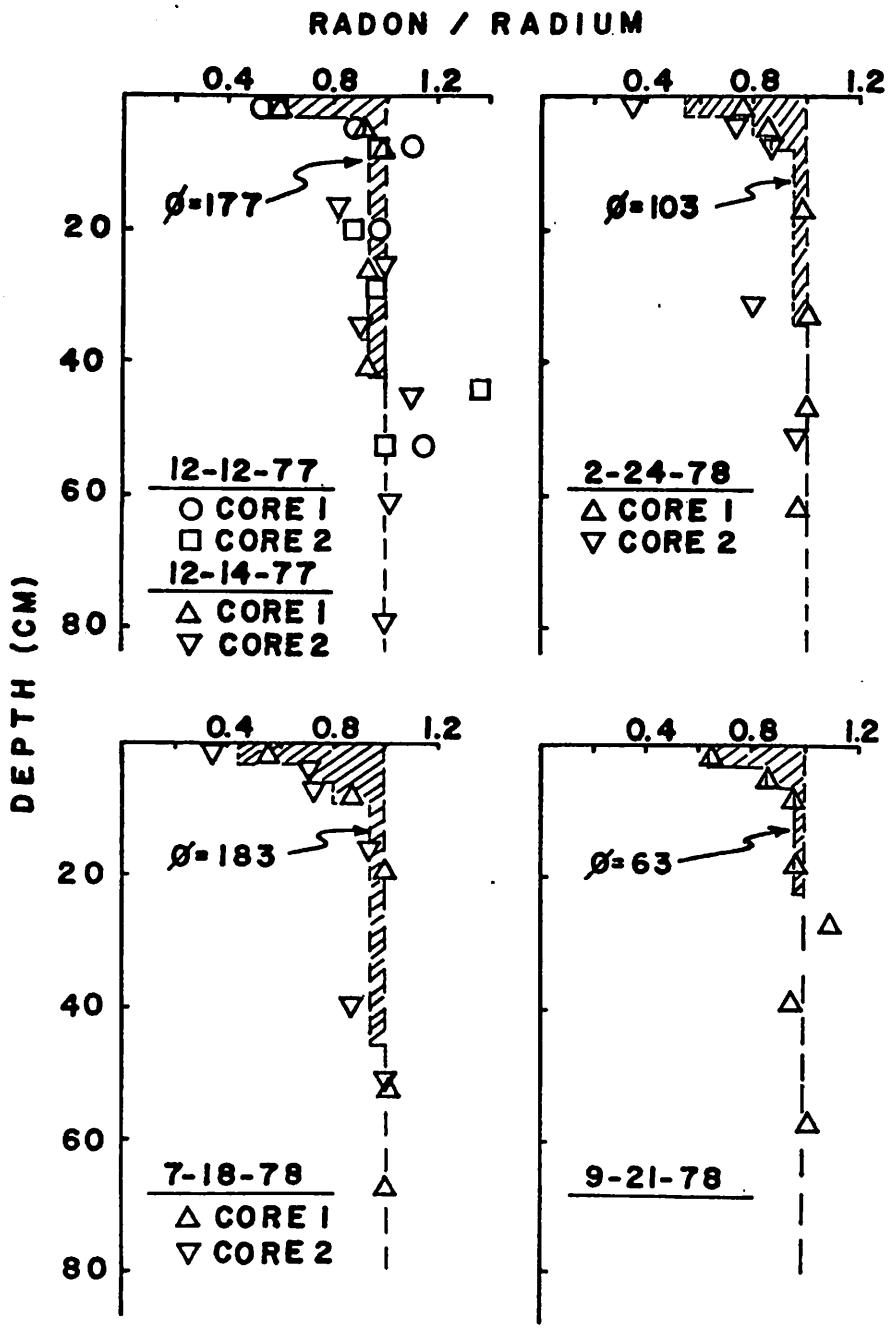

Figure 2. Radon/Radium activity ratios vs. depth at station 28 in South San Francisco Bay. The shaded area is the deficient zone and ϕ is the depth integrated radon deficiency in atoms/m^2sec. Note differences between cores collected on the same day. In the absence of irrigation, the deficiency would be confined to the upper 10 cm and ϕ would be 70 units. The low value observed on ^·21-78 may be due to the low sample density.

Table 1

Fluxes Across the Sediment-Water Interface[a]

	Radon[b]	O_2[c]	NH_3	NO_3	SiO_2
SFB-28C (October '77)					
Calculated	192	-8	0.5	--	2.3
Measured	251±53	-20±9	1.3±.8	-0.7±.4	5.7±1.2
LAH-1 (February '78)					
Calculated	114	-17	2.8	--	1.6
Measured	72±24	-30±30	--	--	--

[a]Units are atoms/m^2sec for radon, all others are mmol/m^2day. Positive values are releases from sediments, negative values are uptake.

[b]To improve accuracy, the calculated fluxes for radon are an average of integrated radon deficiencies from one core and chamber fluxes.

[c]Calculated fluxes are from CO_2 measurements assuming a 1:1 stoichiometry for CO_2:O_2. The measured fluxes represent an average of one-day experiments in which concentration changes were assumed linear with time.

Table 2

Oxygen and Nutrient Cycling for San Francisco Bay Water Column[a]

	CO_2	NH_3	SiO_2	O_2
Input from Sediments[b]	10	2	5	-10
Uptake in Water Column[c]	40	6	10	-40

[a]Units are mmol/m^2day. O_2 input was determined from CO_2 flux and is negative because it is taken up by sediments. Numbers are annual averages.

[b]Korosec (1979)

[c]Peterson (1979)

Francisco Bay has been discussed by Korosec (1979). Table 2 compares the benthic fluxes he determined to net uptake (or production) in the water column determined by Peterson (1979). Sediments account for 25-50 percent of the net cycling occurring in the water column. During periods of low river flow, however, sediments may become more important than indicated in this table.

A more detailed discussion of our work can be found in publications resulting from this project. The major conclusions are:

1. Irrigation by benthic organisms is of major importance in cycling oxygen and nutrients across the sediment-water interface.

2. Radon-222 can be used to estimate irrigation rates in sediments and calibrate exchange models.

3. Sediments are an important source for nutrients and a sink for oxygen in San Francisco Bay.

4. Preliminary work (not discussed here) has indicated that lead-210 and cesium-137 are useful for estimating sediment accumulation rates in San Francisco Bay. This is being pursued in a Sea Grant project funded for the 1978-79 year.

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Coastal Engineering

To develop a truly accurate representation of the environmental quality and resource potential of the southern California coastal zone, information must be gathered as to the behavior, force, location, and circulation pattern of currents and tides. Studies in this area are part of the broad category of "coastal hydrodynamics" or coastal engineering.

R/CE-2 was motivated by the need to have an efficient analytical/numerical tool for calculating the circulation patterns induced by tides in harbors or bays. The tools generated by this project will be used in other projects to evaluate the water quality effects related to any harbor improvement. The expected outcome could also be used to model pollutant and oil slick transport in marinas or harbors.

Tide-Induced Currents in Harbors of Arbitrary Shape

Jiin-Jen Lee and W. L. Chaing

R/CE-2

Water quality is strongly dependent on tidal circulation patterns within the harbor. For example, field measurements have shown that large scale tide-induced circulation gyres are very beneficial to the water quality and marine life (see Soule and Oguri, 1972; Robinson and Porath, 1974). Such gyres act as an aeration pond for continuous mixing and exchange with the neighboring environment. This is probably as important as the action of flooding and ebbing tides in a region which produces exchanges of water between the harbor and the open sea. However, hydraulic engineers have overlooked the importance of this type of circulation pattern and the mechanism for how the gyres are generated.

We know that flood and ebb tide in a harbor region produces slowly rising and falling water surface. The variation of water surface elevation within a harbor (usually a few miles) is very small compared with the length associated with a tide (usually in the order of several hundred miles). A closer look at the tidal flow, however, indicates that if there is enough open water surface, the large scale circulation pattern, or large circulation gyres, could develop. Clearly, therefore, the shape of the harbor is an important factor in whether or not the gyres develop. The goal of this project is to find an efficient and stable way of predicting the tide-induced current, or gyres, in a harbor of

arbitrary shape, which is representative of actual harbors.

Goals

1. To develop a stable and an efficient mathematical and numerical model for simulating the tide-induced current in a harbor of arbitrary shape and to demonstrate the use of the model by simulating the tide-induced current pattern in Los Angeles-Long Beach Harbor.

2. To predict the extent of the change in the current pattern if the harbor boundary is modified through construction of moles, fills, or piers within the harbor.

3. To verify the proposed numerical scheme by comparing with the data obtained from WES hydraulic models and the field data of USC Harbors Environmental Projects in the Los Angeles-Long Beach Harbor.

For numerical models, the fluid is considered incompressible, and the depthwise variation of velocity is neglected but the bottom friction is considered. The governing equations for vertically averaged flow are:

$$\frac{\partial E}{\partial t}+\frac{\partial (HU)}{\partial x}+\frac{\partial (HV)}{\partial y} = 0 \qquad (1)$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}-fV+g\frac{\partial E}{\partial x}=$$

$$\nu\left(\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right)+F_x+W_x \qquad (2)$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+fU+g\frac{\partial E}{\partial y}=$$

$$\nu\left(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}\right)+F_y+W_y \qquad (3)$$

where U and V are the averaged velocity along x- and y-axis, respectively.

f is the coefficient for the Coriolis force.

g is the acceleration of gravity.

ν is the kinematic viscosity of water.

W denotes the forcing function of wind stress and barometric pressure.

F denotes the bottom friction with

$$F_x = \frac{gU(U^2+V^2)^{1/2}}{C^2H} \qquad (4)$$

and $$F_y = \frac{gV(U^2+V^2)^{1/2}}{C^2H} \qquad (5)$$

Circulation Patterns

The results from one sample run are presented in this report. In this computer run, the tidal flow in the Los Angeles-Long Beach Harbor is simulated. Actual harbor geometry and bathymetry are used. A rectangular network of 108 x 69 grid points covers the whole harbor and a part of the outside ocean. The uniform grid spacing is 500 feet. The time step is 360 seconds. For the calculation of bottom friction, the Manning's coefficient is chosen to be 0.020. The internal friction and the wind stress are neglected. The only forcing function is the tidal elevation along the open boundary. This

tidal elevation is assumed to be a sinusoidal function with the amplitude of 5.6 feet, ranges from the maximum to the minimum, and the period of 12.5 hours. The simulation starts from ebb tide.

Shown in Figures 1 to 4 are the distribution of average velocity at time 103.2 hours, 106.3 hours, 109.4 hours, and 112.5 hours, after the beginning of the simulation. These four times correspond to the rising stage, flood tide, falling stage, and ebb tide, respectively, at the open boundary. These figures indicate that a large clockwise gyre appears in the Outer Harbor. The center of this large gyre is north-northeast of Angel's Gate and is midway between the Middle breakwater and the Navy Mole on the Los Angeles-Long Beach city boundary. During flood tide, currents from Angel's Gate and Queen's Gate joined together and form this strong gyre. During ebb tide, most of the water in this gyre flows toward Angel's Gate. The gyre persists in clockwise motion throughout the whole tidal cycle. Two smaller counterclockwise gyres appear to the west of Angel's Gate and to the west of Queen's Gate, respectively. They show their strongest motion when the water flows outward from the Main Channel and Cerritos Channel during the ebb tide. They disappear for awhile during the flood tide. A small clockwise gyre appears to the north of Queen's Gate when the current passing through the Gate is weak. The circulation pattern to the north of the Long Beach breakwater is quite complex due to the existance of four isles. Notice that there is higher recharge through Queen's Gate during the flood tide than discharge during the ebb tide.

During ebb tide, as shown in Figure 3, the current coming out of the Cerritos Channel flows toward the west of the Long Beach Outer Harbor and increases the discharge through the west of Long Beach breakwater.

These figures might have shown stronger circulation than what can be found in the field because the wind stress, internal friction, and subscale obstacles are not counted into the model. These may cancel, in some way, forces needed to sustain a circulating gyre.

Residual Velocity

The term "residual current" is defined here as that part of the current that is left after removal of the diurnal, semidiurnal and higher frequency signals.

The residual velocity can be considered as the mean velocity averaged over a long period. It is the net direction and amplitude of the motion of water particles. If the only forcing function in a model is a tide of which the integration over a cycle is zero, then the residual velocity at any point in the study area is the local velocity averaged over the tidal cycle.

The residual velocity in the Los Angeles-Long Beach Harbor is studied here to help understand the gyre structure in the Harbor. Figure 5 shows the residual velocity obtained from the aforementioned computer run. The water velocity at every grid point is averaged over the tidal cycle from 100.0 hours to 112.5 hours after the beginning of the simulation. The computer print-out appears to be quite similar to Figures 2 and 4.

All gyres mentioned in the previous section can be found clearly in this figure.

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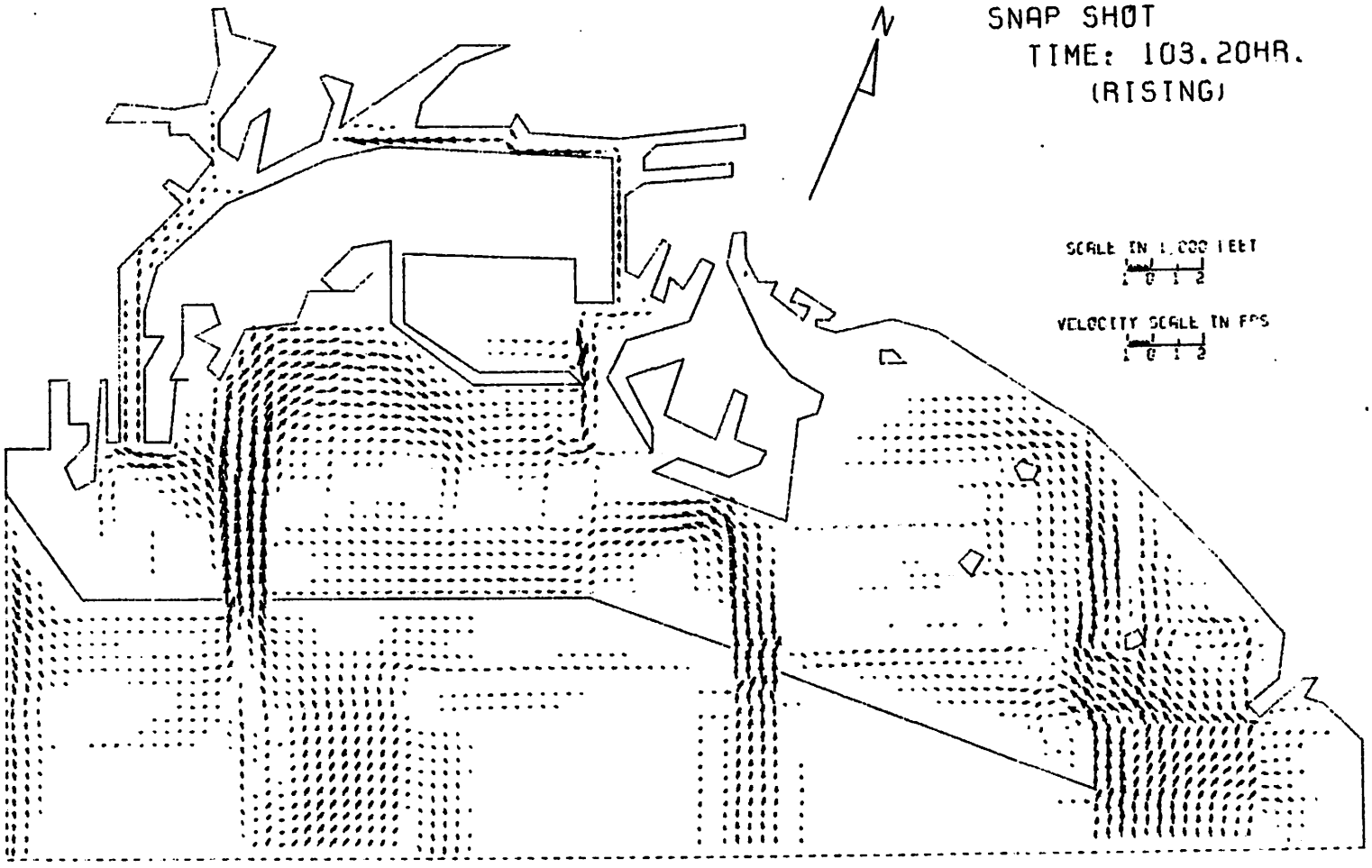

Figure 1. Circulation pattern in Los Angeles-Long Beach Harbor model at 103.2 hours (Rising tide).

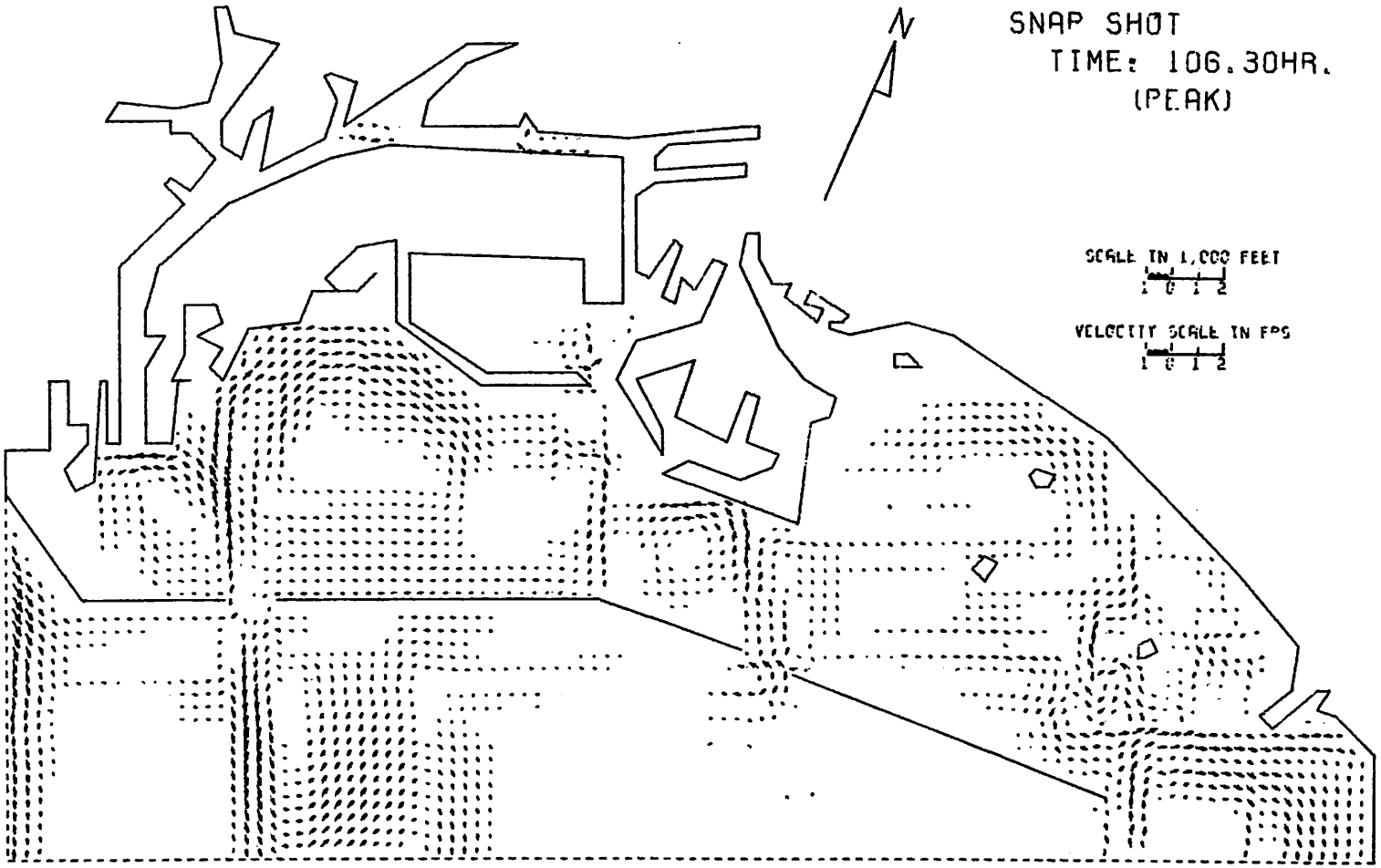

Figure 2. Circulation pattern in Los Angeles-Long Beach Harbor model at 106.3 hours (High tide).

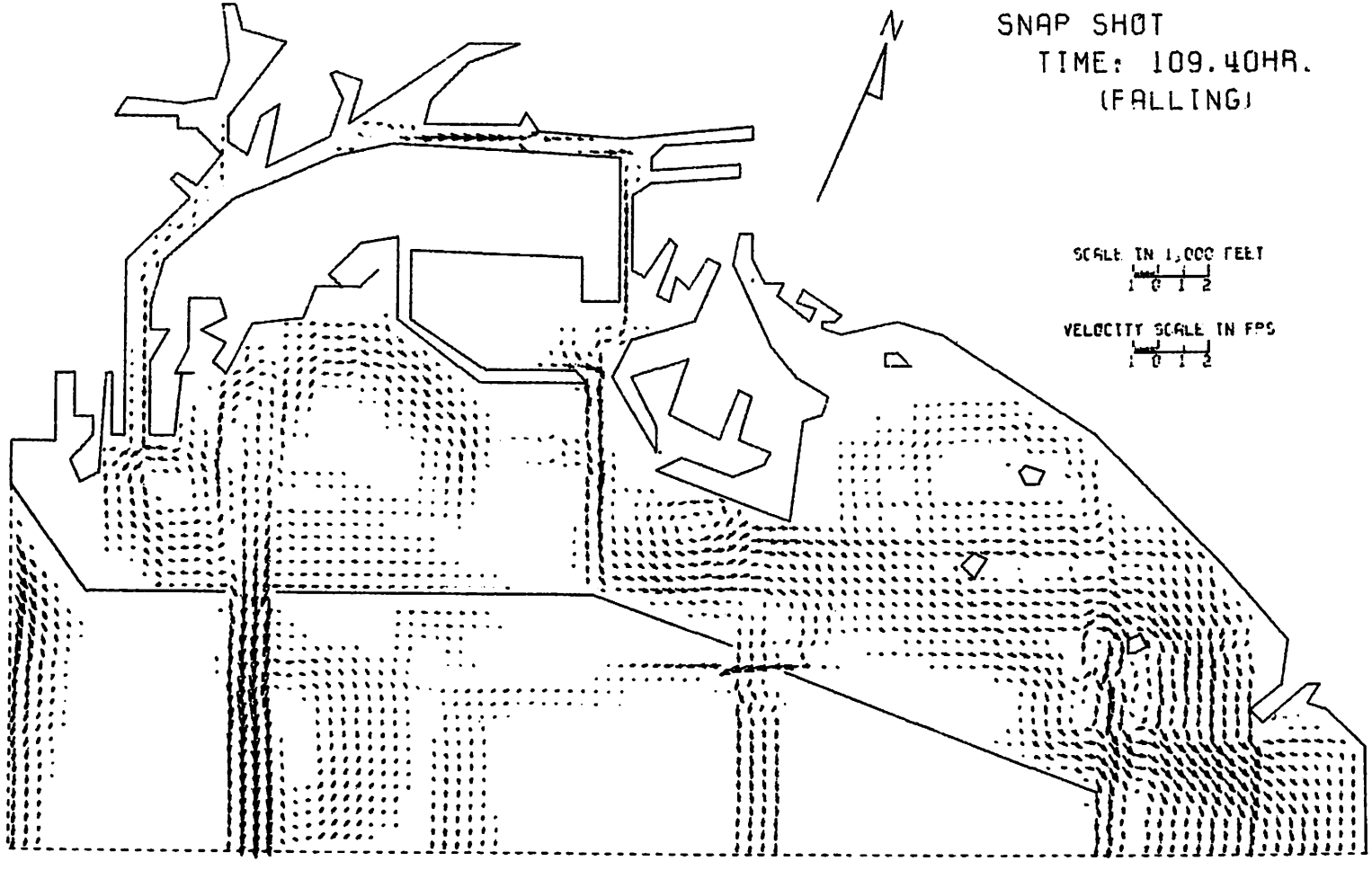

Figure 3. Circulation pattern in Los Angeles-Long Beach Harbor model at 109.4 hours (Falling tide).

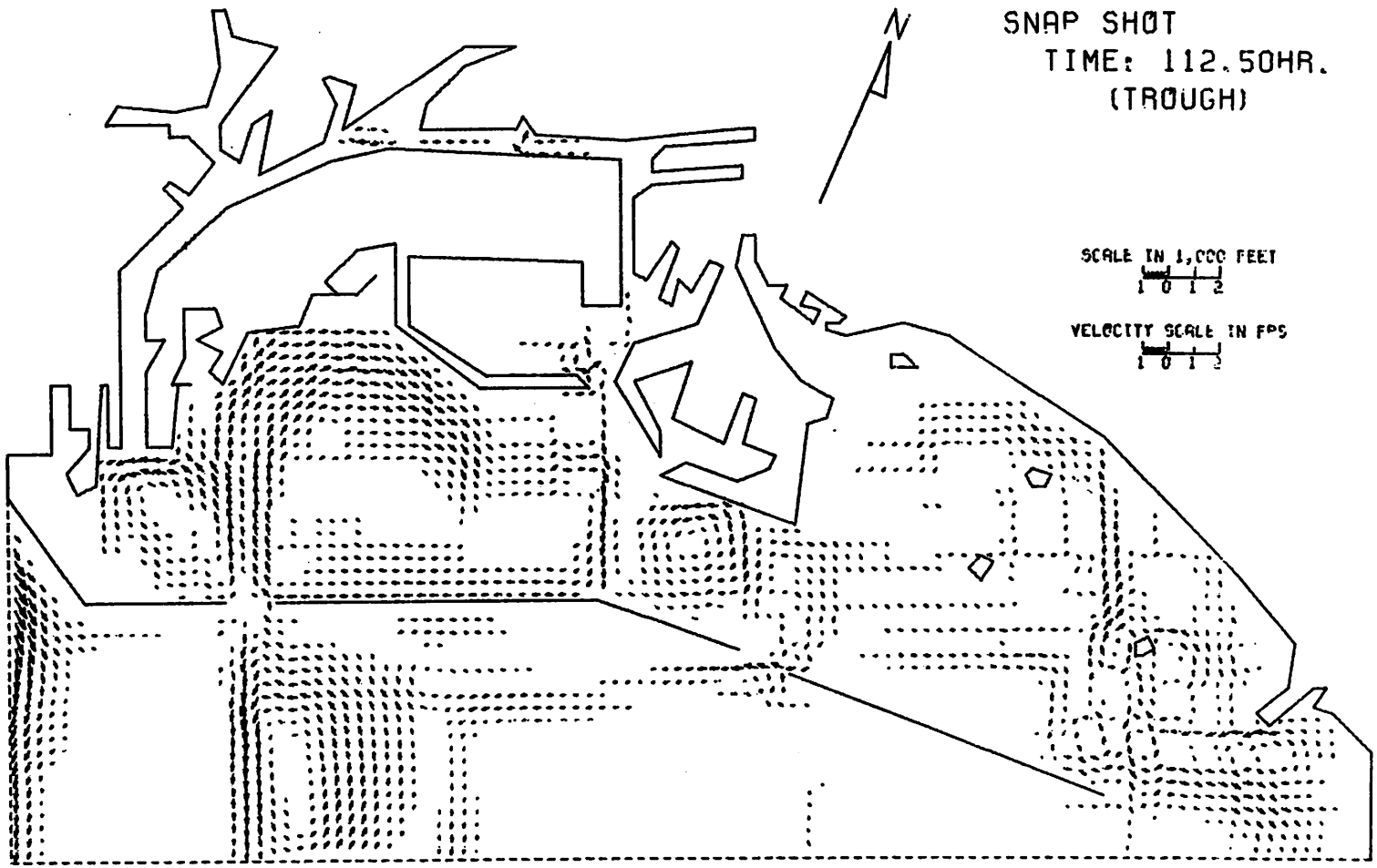

Figure 4. Circulation pattern in Los Angeles-Long Beach Harbor model at 112.5 hours (Low tide).

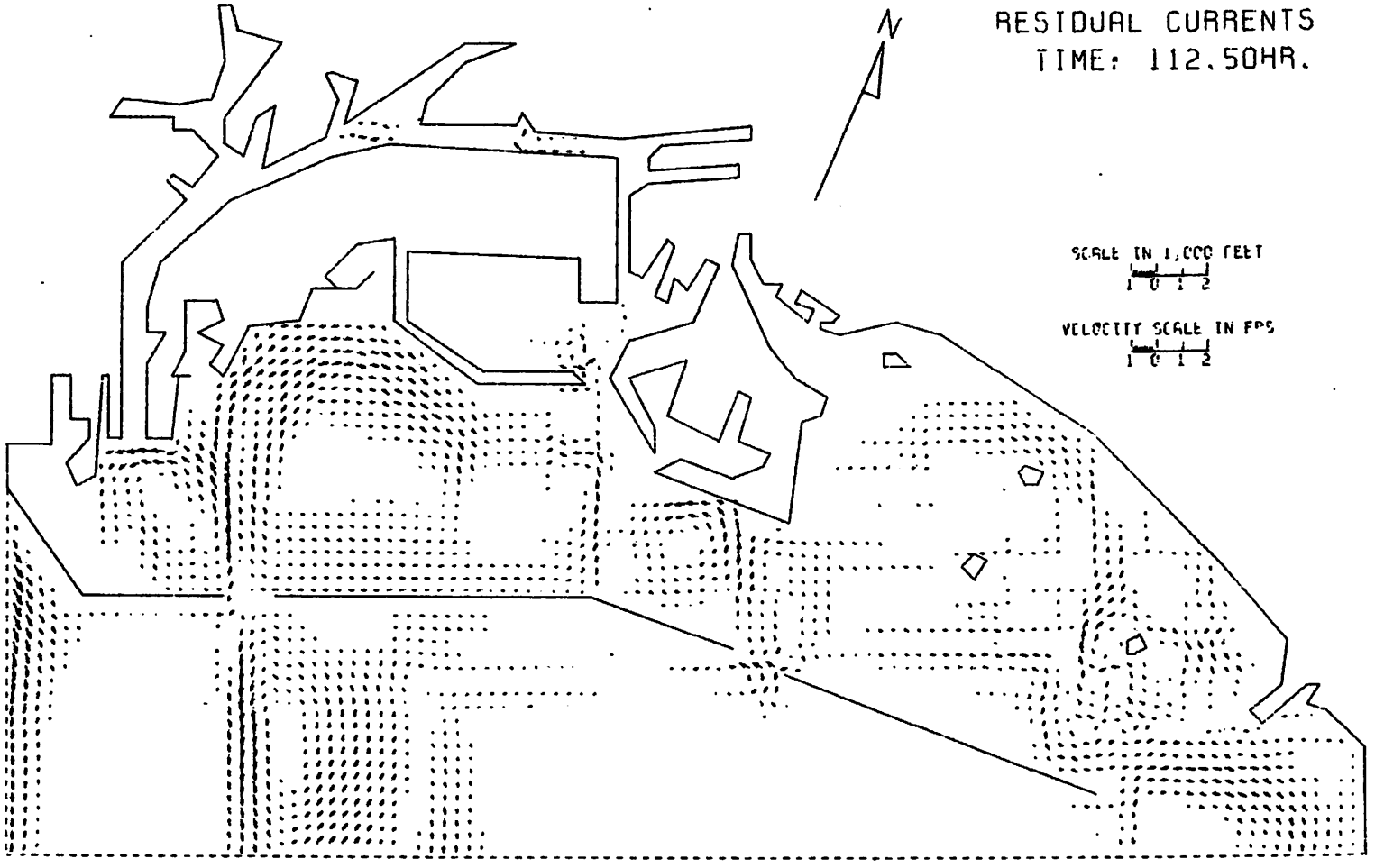

Figure 5. Residual velocity in Los Angeles-Long Beach Harbor model.

Marine Advisory Services

The goal of Marine Advisory Services is to deliver information and expertise needed to help people solve marine resource 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 researchers, and delivering the results of research to the appropriate users of that information.

Coastal Planning for Southern California

James A. Fawcett

During the past year I contacted and assisted a diverse clientele. The individuals, groups, and agencies assisted ranged from the California Coastal Commission to campus researchers, and from the general public to coordination with the University of California Marine Advisory Service, among others.

During the past year, six workshops have been planned and conducted by me in cooperation with other researchers and advisory service personnel. Four workshops were conducted for local government coastal planners in the Los Angeles and Orange County region to discuss matters related to the coastal planning process. Those four workshops were arranged in cooperation with Professors Kreditor and Bannerjee of the School of Urban and Regional Planning as a component of their Sea Grant funded project exploring coastal planning in urban areas. Approximately twenty local government planners attended each of the four workshops, and a previously unavailable opportunity was provided for them to discuss problems of mutual concern. Acting jointly, the University of California and USC Marine Advisory Services sponsored a workshop for approximately twenty-five coastal planners from throughout the state to discuss technical issues related to preparation of local coastal plans. This two-day technical workshop was designed to bring together representatives of cities who had made substantial progress in preparing local coastal plans. The purpose of the workshop was to allow an opportunity for representatives of communities with relatively advanced coastal plans to compare techniques for preparing those plans. A consensus report from that workshop was prepared and sent to the Coastal Commission for its consideration. At the present time (January, 1979) a large regional workshop on recreational access to the coastline is planned for spring, 1979. That workshop will be sponsored by the Pacific Area Sea Grant Advisory Programs and funding is anticipated from the Office of Coastal Zone Management. It is expected that approximately 200 planners will attend from the states of Alaska, Washington, Oregon, California, and Hawaii with representatives from other parts of the country being present to discuss in a two- to three-day format problems related to recreational access. This workshop is being planned in coordination with Andrew Manus and Barbara Katz of the University of California Sea Grant Marine Advisory Program.

Most of the assistance we provide is related to particular problems related to the coastline. As the services of MAS become more widely known, there is an increasing demand for advice from developers and individuals wishing to build within the coastal zone. During the past year I received approximately two requests per week for information related to this issue. Although demand for this type of service is unpredictable, the demand has increased during the past year.

With the decrease in size of the MAS staff during the past year, additional duties previously discharged by other staff members have fallen to me. One of those is the responsibility for conducting computer literature searches for on-campus researchers and others requesting this service. Using the System Development Corporation's ORBIT data base and Lockheed's DIALOG data base, I have been able to provide literature searches for a number of researchers during the past year. Although direct assistance has been rendered to a number of clients during the past year, the client most frequently assisted during that period has been the United Fishermen's Organization (UFO) of Southern California. UFO represents commercial marine fishermen in the southern half of California. Many of the members of the UFO are home ported in Los Angeles Harbor and I have been involved in assisting them to participate in the port planning process of Los Angeles Harbor. This has been an on-going project, and I will continue to assist and advise the UFO until such time as a plan is prepared for the harbor.

In the category of publications, Barbara Katz (UCMAS) and I have prepared a monograph on the coastal development permit process. That document is a detailed description of the legal requirements for obtaining a coastal development permit from the Coastal Commission, and is intended for use by researchers, attorneys, and developers proposing construction in the coastal zone. The monograph has been published by Sea Grant. A shorter and much less detailed description of that process has been prepared for use by the Coastal Commission as a hand-out to individuals requesting information regarding the permit process. Sea Grant has also published a paper written by myself, Barbara Katz, and Andrew Manus which was delivered to a recreation conference of the American Society of Civil Engineers in April. The paper proposes a land use planning tool for use in coastal recreational planning in an attempt to encourage a continuous type of planning and implementation process.

I maintain contacts with campus researchers who are now or could potentially obtain Sea Grant funding for research. As the preparation of LCP's progresses to the point of discussing the marine environment, additional work of campus researchers in that field can be delivered.

As faculty members, especially those in the fields of urban and regional planning and public administration, have become aware of my skills and background, I have been invited to lecture to classes and/or to assist in student research efforts having to do with coastal planning. Three times per year I arrange a two-day series of lectures and tours at the USC Catalina Marine Science Center and at Avalon for students of the School of Public Administration's Environment Management Institute. During those sessions, myself, scientific staff at the Marine Science Center and officials of the City of Avalon lecture to the class regarding coastal planning and coastal marine resources. Ongoing assistance has been given to the School of Urban and Regional Planning as a mentor to a small group of graduate planning students who have been researching the California coastal planning process. The MAS library, which is exceptionally strong in coastal planning materials, has been made available to these and other interested students.

Marine Information and Communications

Shirley J. Hudgins

The 1977-78 fiscal year was one of transition for the Communications Program. This was the first full year in which multi-media pilot programs were "tested." The results opened yet more avenues of possible programmatic concentration.

As with last year's program, the Communications Specialist concentrated her one-person resources on other avenues beside the "scientific report." The resultant output was a legitimate reflection of this choice.

Publicatic

There was one Advisory Services formal publication which has been quite an attraction. The document was entitled "Cooking With Offshore Oil," by Martin Chorich. The Harbors Environmental Project also produced another in their Harbors Studies Series.

Everything else produced was in the form of a scientific reprint or a thesis/dissertation.

Television

Our $2 million marine educational television series which was developed with KCET-TV (Public Broadcasting Station), has yet to be funded. KCET's Underwriting Department has assumed responsibility for assisting us in finding production monies.

In hopes of eliciting more than just the assured verbal support from NOAA for our series, a national proposal was submitted to the National Sea Grant Office, seeking monies to support the testing and evaluation of the series' pilot. The proposal's review was not completed by the end of the 1977-78 fiscal year.

1977-78 was the year in which California's now famous Proposition 13 was passed. In reaction to the pending loss of state tax dollars, certain governmental and educational programs were cut back. One of these was the regularly scheduled public summer school for kids.

In response to the parental outcry that arose from this misfortune, KCET-TV produced a live, half-hour magazine format show called "Summer Faire." Both Sea Grant's Communications Specialist and Education Director were asked to participate. We put together two, 6-minute segments on tide pool creatures. In the first segment, several live animals were used and we shared some interesting facts about them with the listening audience. The second segment involved teaching kids to cut out these animals from construction papers and placing them *correctly* in a prepared tidepool backdrop. If the series is continued, KCET wants Sea Grant to participate again.

This year also held a pleasing outcome to our efforts in encouraging marine programming on *Sesame Street*. The Communications Specialist was flown to New York to serve as informational consultant to Children's Television Workshop as they began formulating programming ideas

for a new science series for which test shows are now being developed.

Radio

The 1977-78 fiscal year was the first full year of the expanded "Marine Recreational Watch" weather reports on KNX (CBS) News Radio. Working in cooperation with the National Weather Service (NWS), we appended their full, coastal marine forecast to our hourly, site-specific reports.

The relationship has benefited both NOAA components. The NWS now reaches a far larger audience with the data it generates, and Sea Grant's on-air-time matching funds increased to over $100,000.

This longer, on-air exposure to KNX's listening audience of about 1.25 million Californians also stimulated a rather surprising side-effect...fan mail!

As a component of Marine Advisory Services, the Communications Specialist is naturally looking for ways to get identified-need information flowing to the public. Again, in cooperation with the NWS, this was made possible. The Los Angeles Office of the NWS has a phone number anyone can call to get their overall marine forecast. For some unknown reason, NWS decided to stop this service. When Sea Grant was alerted to this fact, we contacted them and explained that such action would be counter to the need. We had the line monitored and the final weekly count of the numbers of people accessing the service was quite an eye-opener to NWS. In fact, the line really needed to be expanded to a three-line rotary to accommodate all the calls.

Although NWS acknowledged this latter need, they felt that they could not afford such a set-up. After negotiations for a taped credit on the line, Sea Grant picked up the tab and now southern California has an adequate service being given to its millions of recreational enthusiasts.

One bit of disappointing news did take its toll on Communications' ability to produce its hoped-for radio series. The News Director at KUSC-FM, with whom we were working to generate programs, production and airing, left the station. No one replaced her, for KUSC wished to concentrate its limited staff in other production areas. This unfortunate incident left our one-person Communications shop without help to staff a solid radio programming effort. Hopes are that next year we will get a Sea Grant Trainee to assist in this venture.

Despite the loss of our KUSC associate, a preliminary proposal was sent to the National Science Foundation (NSF) to obtain monies for the hiring of some talented radio people to produce a coherent coastal zone environmental and science series. Of the 150 preliminary proposals nationwide that were received by the Office of the Public Understanding of Science, NSF, only five were asked to submit formal proposals... our's was one of these five. When our final proposal has been drafted, we'll send it off and hope for the best. Only time will tell.

Newspapers

As a satellite editor for the USC News Bureau, the Communications Specialist continued to work with this campus-based organization to make sure Sea Grant received proper community notice for its activities.

We completed our second successful year of bilingual, marine "filler" material to fifty-five local newspapers. These two- to-three-paragraph bits of information have appeared in newspapers from Laguna Beach to Malibu, including the largest Spanish publication in Los Angeles, *La Opinion*.

Covering topics from marine biomedical research to tidepooling hints, these articles have a confirmed readership of over 1.25 million southern Californians.

Other Avenues

The implementation of Proposition 13 and a change in Museum personnel slowed our efforts to establish a Marine Science and Technology exhibit at the Museum of Science and Industry for the Institute for Marine and Coastal Studies. The Communications Specialist has, however, doggedly kept in touch with the Museum, has located the new person, and has re-instituted the informal proposal for the exhibit. The proposal is to go before the Museum's Board of Directors early next fiscal year.

In addition to the Communications Specialist's participation in the Los Angeles Press Club, she has been asked to become a Board Member of the newly established Los Angeles Chapter of the Oceanic Society. Her function...public relations.

Marine Education and Training

> The Congress has recognized the need for a marine-literate public and has instructed the Sea Grant Office to place more emphasis on public education and public awareness than has been true in the past.

This statement, which was included in a memorandum mailed to Dr. Werner Baum from the National Advisory Committee on Oceans and Atmosphere, gives the marine educator an added incentive to accelerate the efforts now being made in the world of public marine education.

The need for a marine-literate public has been all too evident to those endeavoring to promote public awareness of the necessity for better understanding the marine environment. Decisions are now being made which will affect the lives of future generations, by decision-makers who are unaware of the impact the marine environment presents to their lives and to the lives of their children. It is our intent to not only disseminate scientific knowledge to the current decision-maker, but also to more carefully prepare the future voters--those children now attending our public schools--to become rational and knowledgeable decision-makers when their opportunity arises.

Now that concerted efforts have been initiated to broaden the categorization of the marine concepts from a strictly science orientation to a multidisciplinary focus, there is evidence that educators are beginning to accept this viewpoint as legitimate. The multidisciplinary supplementary curriculum materials developed during the past couple of years at USC have been instrumental in helping educators to more easily integrate the marine concepts into classroom situations.

Invitations to acquaint educators in other parts of the United States and in Latin America included participation in the Interciencia Conference in San Jose, Costa Rica, and a workshop put together by the University of Concepcion in Chile, South America. The reception to the marine education concepts as they have been developed within the USC Sea Grant Program were enthusiastically accepted. As a result of these meetings, an on-going correspondence has been established with these countries as well as with several

other Latin countries, and an International Marine Education Proposal was developed. Although funding has not been granted for funding of this complete program at this time, there is evidence that parts or all of it will be initiated soon within Central America.

The Graduate Student Trainee Program continues to be benefical to both the students participating in the program and to the Sea Grant Projects, which benefit from the students' research and from their enthusiasm for accepting new and worthwhile challenges. The long-term benefits of this program cannot be measured, but are in part evident as we observe these students moving into positions where their expertise is acknowledged and accepted by decision-makers.

Although during 1977-78 there were a limited number of programs developed for the adult citizen, this certainly does not imply that these programs are unimportant. This program was maintained at minimum outflow due to pressures of the K-12 curriculum program, and to the lack of sufficient staff to expand. The next fiscal year will see a renewed interest in expanding this facet of the marine education program.

In conclusion, the marine education program at USC is still in its stages of capable infancy. With the solid base that has been built during the past couple of years, with development of materials and contracts with state and local educators, a marine-literate public has begun to emerge. It is our intent to assist Sea Grant in its effort to meet the mandate expressed by Congress to place greater emphasis upon public education and awareness in marine education.

"California and the Oceans" — Statewide Marine Education Curriculum Development Program

Dorothy M. Bjur

E/M-1

The initial stages of developing marine education materials for grades K-12 has been completed. The final product was six volumes of a Supplementary Marine Education Curriculum Guide" and two "Marine Studies Idea Books." The curriculum guides are being edited and compiled into one book rather than the original six books. The Marine Studies Idea Books will remain with the original format and only need minimum editing.

Supplementary Curriculum Guides

The Marine Education Supplementary Curriculum Guides were disseminated to approximately forty teachers for evaluation. Of these forty, nineteen teachers actively participated in the evaluation. Their participation included using lesson plans in the six volumes; with each lesson used, they filled out an evaluation form and returned it to this office. The evaluations received were overwhelmingly positive and suggestions for change minimum.

From this evaluation we decided to try a more in-depth evaluation. Nancy Guenther, a teacher and a graduate student in the USC School of Education (finishing her Ph.D.), took on this as a term project.

Ms. Guenther structured her evaluation around interviews with six of the nineteen original evaluators. The purpose of her evaluation was threefold: 1) To determine if the objectives of the program as stated in the Sea Grant Proposal were being met through the use of the lessons developed for this purpose; 2) to determine if the format presented was the most useful to teachers; and 3) to improve the program by incorporating suggestions made by the teachers evaluating the program.

The instrument Ms. Guenther used to gather the data had to be developed due to the special nature of the program and the objectives stated. The instrument was written by the evaluator, critiqued in a university evaluation class, and then changed and improved with the assistance of Ms. Guenther's advisor and one of the teachers who had been involved in the program development.

There were three men and three women selected for this evaluation. Their experience ranged from four to thirty-two years, representing all grades. Two of the teachers had no background or experience in teaching marine education, two had a limited background, and two had some background or experience.

The results, in brief, were:

Objectives: All seven of the program objectives were met according to the six teachers. All of the teachers expressed their appreciation of the fact that marine education materials now existed in one format. They were pleased to find it was no longer necessary to search through general

science books and other sources of information to find materials related to the marine environment. The six teachers unanimously felt that the information presented within the introduction to each of the units, and in the lesson plans, allowed them to teach the lessons comfortably.

Format: All of the teachers expressed the opinion that the lessons themselves were presented in the most useful format. They also agreed that the materials needed for teaching each lesson were accurately listed, and, in general, easy to obtain. It was stated that the format was concise. Several of the teachers expressed their appreciation for the manner in which lessons for the lower and upper grade levels were printed side by side, allowing them the opportunity to refer to both when desired.

Suggestions: Most suggestions were concerned with the final printing and the type of book they could most easily use. They felt a looseleaf style would be excellent as it would allow them to both pull lessons when they so desired and also add to the repertoire when new lesson plans were discovered. They also recommended including more lessons for "mainstreaming" and a greater number with multicultural format.

In summary, the teachers found the materials met all their objectives and they unanimously suggested their dissemination to as many schools and teachers as possible. They concluded that the materials developed in this program will indeed help to fill the void that exists in marine education materials in California.

"California and the Oceans" Curriculum Guides are presently in the final stages of editing and preparing for printing.

Marine Studies Idea Books

The Marine Studies Idea Books have proven to be one of the most exciting examples of marine education materials developed. The author's ability to synthesize thoughts and graphically depict ideas has produced an Idea Book easily and enthusiastically used by the University student and the veteran public school teacher. Although the books were developed especially to be used within the inner-city schools, they are adaptable to any teaching situation.

During the 1977-78 school year, fifty-six USC students took part in the Marine Studies Program. The students were broken up into eighteen teams of 2-4 students in each team. They taught approximately 240 different lessons in eight inner-city schools. These schools included elementary, junior high schools, and high schools.

Participating departments on campus included Geology, Geography, Classics, Speech Communication, Sociology, Political Science, Education, and English.

The continued demand beyond which we can fill for this inner-city marine studies program is proof of its value to the teachers and the public school children. Rather than go into the evaluation made by the teachers and public school children, I would like to quote from the evaluation sheets submitted by the University students after having the opportunity to participate in the course.

The University students participating in the Marine Studies Program were given an evaluation sheet with eleven questions to answer. One of the questions asked "do you think

that you were able to apply your USC classroom experience to your Marine Studies experience?" I quote just a few of the answers:

> My experience with the Marine Studies program helped to enforce my classroom experience. Often working with this program gave me a better understanding than the classroom lectures.
>
> Yes, not only was Marine Studies an enjoyable subject but was fun to teach and show someone else. It was fun to transform the college level materials down to a second grade level and still see them enjoy and learn so easily.
>
> Yes, I had learned so much from my Oceanography and Geography classes at USC that it was fun putting them into lessons.

One student's comments about the program and his participation went as follows:

> This is a great program which is one of the best things USC could have opened up in their history. It gives the University student an opportunity to get a feeling for teaching before committing themselves to a degree. Also a great interaction of the different cultures in nearby communities is great exposure for all of us. There should be more programs like this in other Universities and schools.
>
> Also, it has given me more confidence in myself than a few lectures would. I have learned more about geography and oceanography by being able to teach and communicate about the subject matter in a more comprehensive way with the students.

Statewide Marine Education Conference

In cooperation with the Marine Technology Society and the Los Angeles County School District, a statewide Marine Education Conference was held on the ship "Queen Mary" in Long Beach, California. This two-day conference, held in May, was attended by over 200 educators from all over the state of California. The program focused on the multidisciplinary aspects of teaching marine education, with specific emphasis on the marine education materials developed during the past couple of years by the USC Sea Grant Program. The workshops during the entire conference extolled the advantages of teaching the marine concepts with a multidisciplinary approach and offered methodologies in which to integrate these concepts into the on-going mandatory curricula.

It was a major victory to have some participants in this conference who were not totally science-oriented. Many of those who had reluctantly included marine science in their classrooms returned to their schools ready to experiment with a new approach to this very important subject matter.

Workshops

One of the important aspects of the marine education materials is their ability to serve as an inspirational catalyst for educators to develop their own ideas from the materials they are working with. By integrating the marine concepts into the normal classroom routine the marine environment does not become a new subject matter but takes its rightful place as an integral part of the child's world.

There is a definite need, however,

for teachers to take time in a workshop situation to learn how best to accomplish this task. Through the workshops teachers are brought into contact with scientists, marine educators, and other teachers who are willing to share their ideas and thoughts for teaching marine education as a multidisciplinary subject.

Several types of workshops have been pursued. We have involved teachers in statewide conferences and a National Science Foundation funded program which brings some 130 teachers together each month for a three to four hour working session. Also we have produced workshops in the schools.

The cutback of educational funds due to Proposition 13 has made it more difficult for teachers to obtain permission for a substitute if they wish to attend a workshop during the week. Cutting to a minimum the opportunity for field trips and laboratory equipment has taken some of the incentive teachers might have had to try new programs. In spite of these problems we have found a large percentage of the teachers committed to improving the educational opportunities of their students by adding a new dimension to the classroom in marine education.

Cooperative Programs

Following the philosophy that our combined efforts produce a superior product, Sea Grant Program directors have endeavored to work cooperatively on as many projects as possible. During this past year the Advisory Services Communications Specialist and the Education Director have had the opportunity to join forces on several programs

1. We have worked closely with Shirley Hudgins (Communications) and KCET-TV in developing and promoting the Marine Awareness Film Program. Although funding has not yet been found, we continue to believe it will be funded.

2. With the Communication Specialist we participated in a Careers Day High School Program. The opportunity was given to present a program and interact with the students in presenting alternative career possibilities in the marine environment.

The Education Program continues to interact with educators, industry and counselors in producing a document in marine careers for the high school graduates.

3. The opportunity for public school students to attend a summer school was suspended for the time being because of Proposition 13. Without the opportunity of attending classes students were left with a lot of free time. KCET-TV attempted to at least partially meet the need through a TV production they called "Summer Faire." "Summer Faire" consisted of half-hour television classroom presentations on varied topics. The audience was advised ahead of time what types of materials they might need to participate in the televised activities. The Communication Specialist and the Director of the Education Program were asked to present two programs, both of which were televised live and then videotaped and presented the second time.

This program was so successful that KCET-TV is preparing a continuing program similar to the

summer program and have asked for our continued participation.

NSF Teacher Training Program

In cooperation with the USC School of Education, the Sea Grant Education Director developed a Teacher Training Marine Science Program which was funded through the National Science Foundation. The Program Director is under the auspices of the School of Education. Sea Grant was responsible for supplying the curriculum materials and the staff for the intensive week-long training of the Trainers. There were twenty-five Trainers prepared to become instructors in monthly training sessions which brought together 130 interested teachers. The materials used in the intensive course were those used during the monthly meetings by the Trainers. Each month the workshop used one of the six units of the supplementary curriculum materials developed by Sea Grant, thus over a six month period teachers touched on one of the six concepts developed in the supplementary materials: 1) The Physical Ocean, 2) the Economic Sea, 3) Ecology, 4) Biology, 5) Frontiers of Research, and 6) Ocean Management.

MGM Program

After we participated in two meetings of the Southern California coordinators for the mentally gifted minors (MGM), and explained our curriculum materials, the teachers decided to put together some materials for the MGM student. A group of teachers began meeting with the Sea Grant Staff to discuss methods and materials needs. Since Proposition 13 was passed this program has been suspended and most of the MGM teachers were forced to discontinue their program.

The World Futures Society invited us to make a formal presentation to a group of educators at a banquet in May, held at the University. Many of these teachers are now using our materials in marine education.

Extended Participation

Marine Technology Society: Oceans 77. With Dr. Walsh, Director of the Institute for Marine and Coastal Studies at USC, and the Science Director for the Los Angeles County Schools, we presented the first Education program of MTS's yearly conferences. Presentations at the workshops included K-12 education through graduate school, plus technical training and careers.

In cooperation with the University of California Sea Grant Program we developed a proposal to the State of California for a statewide Marine Education Coordinator. Although the proposal did not receive funding, the two Sea Grant Education Specialists continue to interact and exchange ideas. It is the desire of both groups to continue working together when possible in creating a marine literacy program that will have a lasting effect on Californians.

Extension Programs

A limited number of weekend learning experience programs were conducted at Catalina, plus several short symposia on campus.

One of the more spectacular extension programs was the Underwater Photography Festival which we helped sponsor in conjunction with the Underwater Photography Club in Los Angeles. More than 1,000 people attended the Festival.

Sea Grant Graduate Student Trainee Program

Dorothy M. Bjur

E/PE-1

With so many highly qualified graduate students it is difficult to select such a limited number for participation in the Graduate Student Trainee Program. USC Sea Grant has been fortunate in their selection of students who scholastically are highly qualified and at the same time have interests adaptable to the overall USC Sea Grant theme: "The Planning and Management of California's Coastal Resources."

Graduate students desiring to participate in the Trainee Program must first choose a Sea Grant Project relevant to their research needs and then with the approval of the Principal Investigator submit an application to Sea Grant. Once their applications have been reviewed and accepted by the Trainee Selection Committee, they work closely with their professor and the Principal Investigator of the chosen project.

Besides the opportunity to fulfill their research requirements for the desired University degree, there are numerous long-term benefits of the program. They are given the opportunity to work closely with professionals in their field of research and at the same time have the perfect environment for testing the validity of their research and their future job-related goals.

The enthusiasm and additional perspectives these graduate students bring to the Sea Grant program makes a substantive contribution to the research results. The symbiotic relationship of student-professional contributes to their professional growth and produces results applicable to the public needs.

In summary, this program:

1. Provides financial assistance which partially relieves the student to pursue his/her needed research for the University degree.

2. Prepares the students to fill leadership roles in research and development in marine-related fields.

3. Brings additional perspectives to each research team and makes substantive contributions to the research results.

4. Through interaction with other Trainees, they learn about other disciplines and thus become specialists who can deal effectively with a broad range of social, economic, and scientific problems.

5. They become familiar with the needs of the ultimate recipient of Sea Grant work, the public.

6. They are given additional opportunities of working closely with University professionals.

During 1977-78 there were eleven graduate students participating in the Trainee Program. Their names,

degrees sought, and project assignments were as follows:

Ms. Karin F. Berthelsen
M.P.L. in Urban and Regional Planning
"Planning Methods for Coastal Communities"

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

Mr. Robert Charest
Ph.D in Cellular and Molecular Biology
"The Energetic Role of Amino Acid and Protein Metabolism in the Kelp Bass *(Paralabrax Clathratus)*"

Mr. Wen-Li Chiang
Ph.D. in Civil Engineering
"Tide-Induced Currents in Harbors of Arbitrary Shape"

Mr. Keith L. Duncan
Ph.D. in Pathology, School of Medicine
"Benzo(A)Pyrene Induction of Tumors in Flatfish"

Mr. Andrew S. Harper
M.S. in Geological Sciences
"Offshore Sand and Gravel Resources, San Pedro and Santa Monica Bays, Southern California"

Mr. Blayne Hartman
Ph.D. in Oceanography
"Oil and Tar Contamination of Beaches in Santa Monica Bay, California"

Mr. Gregory Morey-Gaines
Ph.D. in Biology
"The Potential of Cannery Wastes to Enhance Receiving Water Nutrient Quality"

Mr. Richard Murphy
Ph.D. in Marine Biology
"California and the Oceans--Statewide Marine Education"

Mr. James Rabe
Ph.D. in Economics
"Onshore Impacts of the Development of Ocean Resources"

Ms. Sarah Swank
Ph.D. in Biology
"Intraspecific Variation in the Wooly Sculpin, Clinocattus Analis"

Program Information

Institutional Program Summary

		1975-76	1976-77	1977-78
Program Management				
M-1	Program Administration and Management	C	C	C
M-2	Program Development		N	C
Marine Resource Development				
R/RD-3	Offshore Sand and Gravel Resources, San Pedro and Santa Monica Bays, Southern California			N-C
Socio-Economic Program				
R/CM-1	Coastal Environmental Monitoring Data Base Inventory: Phase I			N-F
R/CM-3	The Impact Upon California of World Ocean Decisions			N-F
R/CM-10	Onshore Impacts of the Development of Ocean Resources		N	F
R/CM-7	Planning Methods for Coastal Communities			N-F
Marine Environmental Quality				
R/Eq-5	The Potential of Cannery Wastes to Enhance Receiving Water Nutrient Quality	N	C	F
R/EQ-3	The Energetic Role of Amino Acid and Protein Metabolism in the Kelp Bass *(Paralabrax clathratus)*	N	C	F
R/RD-5	The Environment and Living Resource Potential of Marina del Rey Harbor, California		N	F
R/EQ-2	Benzo(a)pyrene Induction of Tumors in Flatfish			N-F
R/EQ-16	Uptake of Oxygen by Los Angeles Harbor and San Francisco Bay Sediments		N	F
Coastal Engineering				
R/CE-2	Tide-Induced Currents in Harbors of Arbitrary Shape			N-C
Marine Advisory Services				
A/S-1	Coastal Planning in Southern California	C	C	C
	Marine Information and Communications	C	C	C
Marine Education and Training				
E/PE-1	California and the Oceans--Statewide Marine Education Curriculum Development Program	N	C	F
E/M-1	Sea Grant Graduate Student Trainee Program	C	C	C

C=Continuing
N=New
F=Completed
T=Terminated

Activity Budget Summary

		OSG	MATCH
Program Management			
M-1	Program Administration and Management	$ 77,936	$ 45,519
M-2	Program Development	27,000	14,795
Marine Resource Development			
R/RD-3	Offshore Sand and Gravel Resources, San Pedro and Santa Monica Bays, Southern California	6,100	18,894
Socio-Economic Program			
R/CM-1	Coastal Environmental Monitoring Data Base Inventory: Phase I	16,709	5,018
R/CM-3	The Impact Upon California of World Ocean Decisions	13,081	8,173
R/CM-10	Onshore Impacts of the Development of Ocean Resources	12,730	25,273
R/CM-7	Planning Methods for Coastal Communities	24,754	16,449
Marine Environmental Quality			
R/EQ-5	The Potential of Cannery Wastes to Enhance Receiving Water Quality	60,073	76,641
R/EQ-3	The Energetic Role of Amino Acid and Protein Metabolism in the Kelp Bass (Paralabrax clathratus)	11,521	4,278
R/RD-5	The Environment and Living Resource Potential of Marina del Rey Harbor, California	12,750	18,892
R/EQ-2	Benzo(a)pyrene Induction of Tumors in Flatfish	24,455	31,044
R/EQ-16	Uptake of Oxygen by Los Angeles Harbor and San Francisco Bay Sediments	20,315	7,002
Coastal Engineering			
R/CE-2	Tide-Induced Currents in Harbors of Arbitrary Shape	8,356	11,100
Marine Advisory Services		118,918	227,049
Marine Education and Training			
E/PE-1	"California and the Oceans"--Statewide Marine Education Curriculum Development Program	22,583	4,000
E/PE-2	Marine Education Mini Courses (K-12)	34,719	2,257
E/PE-3	The Journal of Marine Education	8,000	13,000
E/M-1	Sea Grant Student Trainee Program	50,000	2,500
	Total	$ 550,000	$ 531,884

USC Sea Grant Advisory Panel

Victor Adorian
Director
Department of Small Craft Harbors

Gary L. Bane
Manager
Ocean Engineering Department
Rockwell International

Richard A. Geyer
Chairman
Department of Oceanography
Texas A & M University

Col. Ted Gillenwaters
Ocean Research Institute

George Hatchett
Executive Vice President
Tetra Tech, Inc.

Robert Kleist
Director of Trade Development
Port of Los Angeles

Robert Krueger, Esquire
Nossaman, Krueger, and Marsh

Capt. William C. Lynch
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Naval Station, San Diego

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California Institute of Technology

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University of California at San Diego

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Ocean Technology Department
Naval Undersea Center

Captain T.K. Treadwell
Department of Oceanography
Texas A & M University

O.D. Waters, Jr.
Rear Admiral, USN (retired)

Elmer Wheaton
Vice President
Lockheed (retired)

Professor Donald E. Wilson
Professor and Chairman
Teacher Education, USC, and
Chairman
Southcoast Regional Coastal Commission

EX OFFICIO MEMBER

Don Walsh
Director
Institute for Marine and
Coastal Studies, USC

Sources of MATCH Funding

Ameron
Bumblebee Foods
California Coastal Commission
California Department of Fish and Game
California Department of Navigation and Ocean Development
California State Lands Commission
California State University, Northridge
California State Resources Agency
California State University, Long Beach
Center for Natural Areas
City of Avalon, Santa Catalina Island
City of Long Beach Harbor Commissioners
City of Los Angeles Department of Water and Power
City of Newport Beach
CHB Foods
Del Monte Foods
Radio Stations: KNX News Radio, KCET-TV, KUSC-FM Radio, Children's Television Workshop, NBC-TV, ABC-TV, KFOX Radio News, KMET Radio News, KHJ Radio News, ABC News Radio, KFWB Radio News, KIIS Radio News, KYMS Radio
Los Angeles Board of Harbor Commissioners
Los Angeles Department of Public Works
Marineland of the Pacific
Mobil Chemical
Newspapers: *New York Times, Los Angeles Times, Santa Monica Evening Outlook, Senior Citizen News, Burbank Daily Review, Long Beach Independent Press/Telegram*

Occidental College
Pacific Lighting Corporation
Port of Long Beach
Port of Los Angeles
South Coast Regional Coastal Commission
Southern California Gas Company
Starkist Foods
Sumitomo Foundation for Public Policy Studies
Tuna Research Foundation
University of Southern California
Van Camp Foods

Cooperating Institutions and Agencies

International
Federal Republic of Mexico
Costa Rica

U.S. Federal Government
Bureau of Land Management
Center for Naval Analysis
Economic Development Administration
Environmental Protection Agency
Federal Maritime Commission
Maritime Administration, Western Region
National Oceanic and Atmospheric Administration
  National Weather Service
  Office of Marine Minerals
  Office of Deepwater Ports
U.S. Army Corps of Engineers
U.S. Congress, Office of Technology Assessment
U.S. Customs Office
U.S. Geological Survey
U.S. Navy

State and Local Government
California Coastal Zone Commission
California Department of Fish and Game
California State Lands Division
California Department of Navigation and Ocean Development
California Department of Parks and Recreation
California Department of Transportation
California Assembly Office of Research
California Senate Committee on Maritime Affairs
California State Coastal Planning Commission
California State Department of Education
California State Department of Health
California State Division of Mines and Geology
CALTRANS (California Department of Transportation)
California Underwater Advisory Committee
California Crop and Livestock Reporting Agency
California Division of Oil and Gas Department of Human Resources Development
Harbormasters Association
Metropolitan Transportation Commission, Berkeley
Regional Water Quality Control Board
California Water Resources Board
Southern California Association of Governments
Southern California Coastal Water Research Project
South Coast Regional Conservation Commission

Los Angeles County
Board of Supervisors
Department of Beaches
Department of Harbors and Harbor Commission
Department of Parks and Recreation
Department of Small Craft Harbors
Diving Program
Flood Control District
Museum of Science and Industry
Office of Urban Affairs
Regional Planning Commission
School District

Orange County
Department of Harbors
Flood Control District
School District

San Diego County
Aquatic Division
School District

Ventura County
Department of Harbors
Flood Control 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
Port Traffic Management and Trade Development

Newport Beach
Marine Safety Division

Carlsbad
Planning Department

Long Beach
Harbor Department
Port Authority

San Francisco
Port

Avalon
City of

Academic Institutions
All Pacific Area Sea Grant Advisory Panel Member Institutions
Claremont College
California Institute of Technology
California State University, Long Beach
California State University, Los Angeles
California State University, Northridge
Center for Study of Democratic Institutions
Cerritos Community College
El Camino Junior College
Escuela Superior des Ciencias Marinas, Ensenada
Florida State University, Tallahassee
Fullerton Community College
Immaculate Heart College
Loyola University
Occidental College
Scripps Institution of Oceanography
Southern California Ocean Studies Consortium
Stanford University
University of British Columbia
University of California, Davis
University of California, Los Angeles
University of California, Santa Barbara
University of North Carolina
University of Oklahoma
Virginia Institute of Marine Science

Private Organizations
The Aegir Corporation
Air Catalina
American Assembly
American Association of University Women
American Cetacean Society
American Petroleum Institute
American Tunaboat Association
Ameron
Aqua-Contractors and Oceanographers
Atchison, Topeka, and Santa Fe Railway Company
Autoetics
Blue Diamond Materials
BOAT, Inc.
Bumblebee Foods
California Chamber of Commerce, Sacramento
California Parks and Harbor Association
Canners Steam Company
Catalina Island Company and Avalon Museum Society
Cedars-Sinai Research Medical Center
Charter Boat Owners Association
Clean Coastal Waters (formerly Price Co-op)
CHB Foods
Daniel, Mann, Mendenhall, and Johnson
DEMA (Diving Manufacturers Association)
Edison Power and Light
Eichhorn and Davis Company
League of Women Voters
Los Angeles Chamber of Commerce
Los Angeles Press Club
Malibu Chamber of Commerce

Marine Biological Consultants
Marine Ecological Institute
Marine Technology Society, Los Angeles Region
Marineland of the Pacific
Marriott Hotel
Mobil Chemical
Monterey Sand Company
National Association of Skin Diving Schools
National Association of Underwater Instructors
National Surf Life Saving Association
Newport Beach Chamber of Commerce
North American Sailing Association
Nossaman, Krueger, and Marsh at Law Office of International Trade for California
Oceanic Society, San Francisco
Pacific Container Terminal
Pacific Lighting Service Company
Pioneer Skippers and other boating associations
Professional Association of Diving Instructors
Rockwell Industries
Security Pacific Bank
Shell Oil
Scuba Schools International
Socio Economics Systems
SOHIO; Alaska Oil Pipeline Division, Long Beach
Soil International
Southern California Boating Safety Advisory Group
Southern California Gas Company
Southern California Marine Association
Southern California Marine Radio Council
Sportfishing Association of California
Star Kist Tuna
Swedlow, Incorporated
Tuna Research Foundation
Van Camp Food
Villa Marina Homeowners Association
Western Oil and Gas Association
Western Surfing Association
UMCA
The following radio and TV stations:
KNX News Radio, KCET-TV, KUSC-FM Radio, Children's Television Workshop, NBC-TV, ABC-TV, KFOX Radio News, KMET Radio News, KHJ Radio News, ABC News Radio, KFWB Radio News, KIIS Radio News, KYMS Radio
The following newspapers and publications:
Los Angeles Times, New York Times, Daily Sun Post, Palisadian Post, Post Newspapers, Pasadena Star-News, The Register, Santa Monica Evening Outlook, San Pedro News Pilot, South Bay Publishing Co., San Marino Tribune, The Daily Breeze, United Western Newspapers, Inc., 20 de Mayo, Valley News, Westminster Observer, Westminster Herald, Publications, Inc., News Enterprise, El Pueblo Mexican News, Senior Citizen News, Artesia News/Comm. Advocate, Herald American Newspapers, Associated Valley Publications, American Publishing Company, News Advertiser, The Argonaut, Beach Cities News, Bunker Hill News, Beverly Hills Courier, Burbank Daily Review, Evening Star News-Vanguard, Canyon Crier, Dean Newspapers, G.M. Publishing Co., Inc., Glendale News-Press, Huntington Beach Independent, Los Angeles Herald Examiner, Los Angeles Times--Westside Section, Los Angeles Times--Orange County, Los Angeles Times--South Bay Section, Golden Rain Leisure World News, La Opinion, Independent-Journal Newspapers, Laguna Hills Leisure World News, Laguna Beach News Post, Long Beach Independent Press/ Telegraph, Long Beach Marina News, Los Angeles News, Los Angeles Daily Journal, Los Angeles Sentinel, Metroplitan Gazette, Malibu Surf-side News, Malibu Times, Garden Valley News

Publications

Journal or Book Contributions

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. USCSG-R-05-78.

Friedman, Judith J. "Community action on water pollution." *Human Ecology* 5(4):329-353, 1977. USCSG-R-01-78.

Gordon, P. and H.W. Richardson. "Economic and Fiscal Impacts of Metropolitan Decentralization: The Southern California Case." (Submitted for publication).

Hammond, D. and C. Fuller. "The use of radon-222 to estimate benthic exchange and atmospheric exchange rates in San Francisco Bay." In Conomos, T.J., (ed.) *San Francisco Bay, The Urban Estuary,* AAAS (in press).

Hammond, D.E., C. Fuller, M. Korosec, L. Miller. "Radon-222, a tool to study irrigation and benthic exchange rates." (In preparation).

Nardin, Thomas R. and Thomas L. Henyey. "Pliocene-Pleistocene diastrophism of Santa Monica and San Pedro shelves, California continental borderland." *The American Assoc. Pet. Geol. Bul.* 62(2): 247-272, February 1978. USCSG-R-03-78.

Richardson, H.W. and P. Gordon. "A Note on Spatial Multipliers." *Economic Geography* 54 (1978) pp. 309-13.

Soule, Dorothy F. "Palau: native paradise or petroleum superport?" Proceedings of Oceans '77 Conference, pp. 5D-1 - 5D-6, 1977. USCSG-R-02-78.

Soule, Dorothy, et al. "You can tailor effluent BOD to fit the receiving-water ecosystem...and enhance the environment." *Bulletin of the California Water Pollution Control Association* 15(1):58-63, July 1978. USCSG-R-04-78.

Technical Reports

Soule, Dorothy F. and Mikihiko Oguri (eds). *Marine Studies of San Pedro, California; Part 13: The Marine Ecology of Marina del Rey Harbor, California...A Baseline Survey for the County of Los Angeles Department of Small Craft Harbors 1976-1977.* December 1977. 424 pp. USC-SG-2-77.

Chorich, Martin. *Cooking with Offshore Oil: A Handbook for California Local Government.* USC-SG-AS-01-78. August 7, 1978.

Coastal Data Inventory for the Los Angeles County Region. Social Science Research Institute - Program for Data Research, University of Southern California, March 1978.

Other Products

Korosec, M. "The Effects of Biological Activity on Transport of Dissolved Species Across the Sediment-Water Interface of San Francisco Bay." M.S. Thesis, University of Southern California, 1979.

Leneman, Michael. "Geomorphology and Oceanography of Topanga Beach, California, in Relation to a Small Boat Launching Facility." Masters Thesis, University of Southern California, February 1976. USC-SG-TD-01-78.