NOAA Technical Memorandum NOS/MEMD No. 23

Abstracts and Reports from

The Marine Environment of Santa Barbara & Its Coastal Waters

A Symposium/Workshop

January 26, 27, & 28, 1988
Santa Barbara, California

Cosponsored by:

Channel Islands National Marine Sanctuary
Marine Science Institute, University of California at Santa Barbara
Santa Barbara Museum of Natural History

Glen R. St. Amant, Editor

Channel Islands National Marine Sanctuary
735 State Street
Santa Barbara, CA 93101

November, 1988

This work is the result of a project sponsored by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Ocean and Coastal Resource Management, Marine and Estuarine Management Division, Under Contract No. NA87AA-H-CZ056.

NOAA TECHNICAL MEMORANDA

National Ocean Service Series

Marine and Estuarine Management Division

The National Ocean Service, through its Office of Ocean and Coastal Resource Management, conducts natural resource management related research in its National Marine Sanctuaries and National Estuarine Reserve Research System to provide data and information for natural resource managers and researchers. The National Ocean Service also conducts research on and monitoring of site- specific marine and estuarine resources to assess the impacts of human activities in its Sanctuaries and Research Reserves and provides the leadership and expertise at the Federal level required to identify compatible and potentially conflicting multiple uses of marine and estuarine resources while enhancing resource management decisionmaking policies.

The NOAA Technical Memoranda NOS MEMD subseries facilitates rapid distribution of material that may be preliminary in nature and may be published in other referreed journals at a later date.

MEMD 1 M.M. Littler, D.S. Littler and B.E. Lapointe. 1986. Baseline Studies of Herbivory and Eutrophication on Dominant Reef Communities of Looe Key National Marine Sanctuary.

MEMD 2 M.M. Croom and N. Stone, Eds. 1987. Current Research Topics in the Marine Environment.

MEMD 3 C.E. Birkeland, R.H. Randall, R.C. Wass, B. Smith, and S. Wilkens. 1987. Biological Resource Assessment of the Fagatele Bay National Marine Sanctuary

MEMD 4 H. Huber. 1987. Reproduction in Northern Sea Lions on Southeast Farallon Island, 1973-1985.

MEMD 5 J.A. Bohnsack, D.E. Harper, D.B. McClellan, D.L. Sutherland, and M.W. White. 1987. Resource Survey of Fishes within Looe Key National Marine Sanctuary.

MEMD 6 S.G. Allen, D.G. Ainley, L. Fancher, and D. Shuford. 1987. Movement Patterns of Harbor Seals (Phoca vitulina) from the Drakes Estero Population, California, 1985-86.

MEMD 7 S.G. Allen. 1987. Pinniped Assessment in Point Reyes, California, 1983 to 1984.

MEMD 8 G.H. Han, R.W. Calvert, J.O. Blanton. 1987. Current Velocity Measurements at Gray's Reef National Marine Sanctuary.

MEMD 9 B.E. Lapointe and N.P. Smith. 1987. A Preliminary Investigation of Upwelling as a Source of Nutrients to Looe Key National Marine Sanctuary.

MEMD 10 C.S. Nordby. 1987. Monitoring of Fishes and Invertebrates at Tijuana Estuary.

MEMD 11 R.T. Heath. 1987. Phosphorus Dynamics in the Old Woman Creek National Estuarine Research Reserve - A Preliminary Investigation.

MEMD 12 A.J.C. Woods. 1987. Fluvial Erosion, Sedimentation, and Hydraulic Geometry in the Contributing Watershed of Old Woman Creek National Estuarine Research Reserve.

MEMD 13 D.G. Ainley, L.B. Spear, J.F. Penniman, C.S. Strong, and I. Gaffney. 1987. Foraging Ecology of Seabirds in the Gulf of the Farallones.

MEMD 14 L.F. Wood and J.B. Zedler. 1987. Dune Vegetation Reestablishment at Tijuana Estuary: Interactions Between the Exotic Annual, Cakile maritima, and the Native Perennial, Abronia maritima.

MEMD 15 M.M. Littler, D.S. Littler, J.N. Norris, K.E. Bucher. 1987. Recolonization of Algal Communities Following the Grounding of the Freighter Wellwood on Molasses Reef, Key Largo National Marine Sanctuary.

MEMD 16 F.T. Short. 1988. Production, Nutrition, and Ecological Health of the Wells Salt Marshes.

MEMD 17 J.F. Donoghue. 1988. Evaluation of Sediment Loading Processes in the Apalachicola Bay Estuary.

MEMD 18 P. Dustan. 1988. Changes in the Reef-Coral Community of Carysfort Reef, Key Largo, Florida: 1975-1982-3.

MEMD 19 J.T. Rotenberry, E.E. Emmons, C.H. Hardman. 1988. Use of Backwater Marsh Areas by Fish Populations in Old Woman Creek and Surrounding Lake Erie Prior to Highway Construction.

MEMD 20 R.L. Vadas, P. Garwood, W. Wright. 1988. Gradients in Salt Marsh Productivity in the Wells National Estuarine Research Reserve.

MEMD 21 L.C. Anderson. 1988. Vascular Plants of the Apalachicola Bay Wetlands in Florida.

MEMD 22 R.B. Searles. 1988. An Illustrated Field and Laboratory Guide to the Seaweeds of Gray's Reef National Marine Sanctuary.

MEMD 23. G. St. Amant. 1988. The Marine Environment of Santa Barbara and its Coastal Waters - A Symposium Workshop.

National Marine Sanctuary Program
Marine and Estuarine Management Division
Office of Ocean and Coastal Resource Management
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NOTICE

TABLE OF CONTENTS

PART II. POSTERS

PART III. PAPERS

PREFACE

The Channel Islands National Marine Sanctuary and the Santa Barbara Channel is one of the most biologically diverse marine regions of the world. A geologically active coastal fault system bisects the region, paralleling the more notorious onshore San Andreas Fault. An east-west trending coastline, the uplifted Channel Islands, and basins as deep as 2,500 feet help deflect the southward California Current to create upwellings, the Southern California Counter Current, and the Santa Barbara Gyre. Fish and invertebrates make a rich transition zone between the species of both the northern, cold temperate and southern, warm temperate regions. Luxuriant forests of kelp are common. The area hosts six species of seals and sea lions and is the migration route for five species of large cetaceans, notably the gray whale. Twenty-seven species of whales and dolphins have been sighted in the region. Over 60 species of sea birds use the waters and 11 rely on the marine resources to nest and raise young. There are also a variety of archaeological, prehistoric, cultural and historic resources, such as Chumash Indian artifacts, mid-19th century shipwrecks and the remains of Spanish exploration.

All these factors make this region rich for research and present a management and resource protection challenge. The Marine Science Institute of the University of California at Santa Barbara, the Santa Barbara Museum of Natural History and the Channel Islands National Marine Sanctuary recognized this challenge. Through their cosponsored **Symposium/Workshop on the Marine Environment of Santa Barbara and its Coastal Waters**, scientists and policy makers were brought together for an interdisciplinary view of current activities and an opportunity to better define future regional needs.

The Symposium illustrated the immense diversity of effort in the Santa Barbara Channel region. Because almost every type of ocean use can be found in the Channel, it was described as a "natural laboratory" for managers and scientists to define research and policy needs in order to both protect and enhance the use of the marine environment.

The staff of the National Marine Sanctuary Program (NMSP), and particularly that of the Channel Islands National Marine Sanctuary (CINMS), are appreciative of the investment of time and effort of each workshop participant, and of the ideas and recommendaitons which were the result of such stimulating and productive discussions. The information and ideas produced by the Symposium and Workshop will be considered fully in the operation and management of the CINMS.

This Symposium/Workshop was a valuable experience that left us with a better understanding of the Santa Barbara Channel and Channel Islands National Marine Sanctuary. It also emphasized the level and magnitude of expertise available at the University, Santa Barbara Museum of Natural History and many other local, state and federal agencies. Due to the energy and enthusiasm generated from this meeting, we were also able to solicit some complete papers which can be found in Part III of this report. For those of you who could not attend, please enjoy these proceedings and feel free to continue discussion on the direction and roles for the Channel Islands National Marine Sanctuary.

Finally, a very special thank you for the support of Dr. James P. Kennett, Director of the Marine Science Institute, University of California at Santa Barbara, Dr. Dennis M. Power, Director of the Santa Barbara Museum of Natural History and the participants of the Symposium. It was only with their foresight that this Symposium/Workshop was possible. Thank you also to the Workshop Chairs: Dr. John A. Calder, National Science Foundation, Dr. Russell J. Schmitt and Mr. A. H. Schuyler, University of California at Santa Barbara, Mr. Peter C. Howorth, Howorth and Associates and Mr. Gary R. Robinson, Manager of the Sea Center. The success of our workshop is truly due to the inspirational leadership of these individuals. Lastly, but very importantly, thank you to Glen St. Amant, Coordinator for the Symposium/Workshop, whose tireless efforts in organizing and coordinating the myriad details made the event such a success.

Funding for this Symposium/Workshop was provided by NOAA Cooperative Agreement Number NA87AA-H-CZ056.

Francesca M. Cava
Lieutenant Commander, NOAA
Sanctuary Manager

<u>NOTE TO READER</u>: While relevant information and expert opinion are welcomed and frequently solicited, decisions concerning the NMSP and the site-specific management of each national marine sanctuary (*e.g.*, management roles/priorities, areas of research emphasis, education and interpretive projects) are solely the responsibility of the National Oceanic and Atmospheric Administration and the NMSP. Although many of the opinions and recommendations of the workshop participants are shared by NMSP and CINMS staff, the workshop participants' assessment of relative priority for CINMS attention/action and recommendations for CINMS implementation do not necessarily reflect the opinions or intentions of the NMSP or CINMS.

PART I. ABSTRACTS

Artificial Reefs Along the Santa Barbara Coast: What are the Benefits?

R. F. Ambrose
Marine Science Institute, University of California, Santa Barbara, CA 93106

Artificial reefs have been used for centuries as a means of increasing the catch of fish in a local area. The first reefs in the United States were constructed on the East Coast by sport fishing groups; in recent years, artificial reefs have become popular with resource management agencies. At present, most artificial reefs are constructed for increasing fishing success, enhancing fish populations, mariculture, mitigation, or disposing of oil platforms or other materials.

Artificial reefs have been demonstrated to be effective for some purposes. Studies have shown that fishing success is higher over artificial reefs than over surrounding areas. Artificial reefs are used extensively to grow abalones, urchins and algae in Japan. And the technical feasibility of constructing artificial reefs from obsolete oil platforms has been demonstrated (although the biological consequences have not been measured).

There is uncertainty about using artificial reefs for other purposes. Theoretically, artificial reefs could enhance fish populations by increasing recruitment, growth, and/or survival, thereby increasing the total biomass of fish in a population. Typically, high densities of fish occur on artificial reefs, and some species recruit to and feed on the reefs. However, many of the fish on an artificial reef may simply be attracted to the reef, redistributing biomass but not increasing it, and the survival of fish may actually be lower than on natural reefs because of high fishing pressure. Fish production may be increased for species such as gobies and blacksmith that are not economically important, but the net benefit of artificial reefs to economically important species is not known.

To mitigate environmental impacts, artificial reefs must be able to increase natural resources. Since increased fish production on an artificial reef has not been quantified (or even demonstrated), the use of artificial reefs to replace lost fish resources should be considered experimental. Similarly, artificial reefs could potentially be used to replace damaged kelp beds, but few artificial reefs have been able to support persistent kelp beds. In spite of these uncertainties, however, artificial reefs remain a promising technique for replacing natural reef resources, since they can be designed to mimic the physical structure of natural reefs. However, appropriate size and location are likely to be critical in determining how successfully an artificial reef can replace natural reef resources.

Observations on the Benthic Environment at Greater Depths in the Santa Barbara Basin

J. J. Childress
Department of Biological Sciences and Marine Science Institute,
University of California, Santa Barbara, CA 93106

My laboratory has used a variety of techniques to collect larger deep-living animals from the Santa Barbara Basin. These include otter trawls, midwater trawls, dredges, epibenthic trawls and deep submersibles. Although the purpose of these collections has been to obtain animals for physiological studies and not to describe the ecology of the Santa Barbara Basin, some generalizations can be drawn from these data. There is apparently no infauna in the central part of the basin although sablefish, cat sharks, other pelagic fishes and pelagic crustaceans are abundant immediately above the bottom. At a depth of about 280 fathoms, the infauna begins to appear. Three clam species with chemoautotrophic sulfur-oxidizing bacterial symbionts are found between 240 and 280 fathoms. These are *Lucinoma aequizonata*, *Calyptogena elongata*, and a *Solemya* species. The *Calypotogena elongata* may be associated with seeps but the other two do not appear to be so associated. At shallower depths the benthic fauna becomes more typical.

Multiple-Use Issues in the Santa Barbara Channel

B. Cicin-Sain
Dept. of Political Science, University of California, Santa Barbara, CA 93106

Marine social scientists study the two-legged creatures who use offshore resources and the complex of laws that governs the use of those resources. In order to address general management issues in the Santa Barbara Channel, it is important to have some understanding of broader world trends in ocean management. Around the world, in the last several decades, there have been significant increases in the use of ocean resources--both for development (extraction) purposes and for recreation and enjoyment. Similarly, we are witnessing a global increase in governmental involvement with marine affairs. Following the conclusion of the Law of the Sea agreement in 1982, a new era of ocean governance was established with the general worldwide acceptance of the principle of national control over 200-mile Exclusive Economic Zones (EEZ), bringing nearly 40% of the world's oceans under the control of specific nations. In 1983, the US enacted an EEZ proclamation establishing sovereign rights over all marine resources within 200-miles, with the sole exception of tuna. Increased governmental involvement in ocean resource exploitation is especially apparent in developing nations, where offshore zones are viewed as a prime avenue for economic development and improving the standard of living. Many view the development of offshore resources as the US viewed the taming of the American West--as virgin territory to be tamed, exploited, and, ultimately, managed.

US national ocean policy has gone through four distinctive periods: 1) the 1950s, when extensive conflicts between state and federal governments occurred as to who would own ocean resources such as oil and gas, 2) the 1960s, when significant new thrusts in ocean science were developed, 3) the 1970s, when increased governmental involvement in ocean activities developed, but on a sector-by-sector/use-by-use (i.e. non-integrated) basis, and 4) the 1980s, when there has been a retrenchment in federal ocean programs and when few ocean initiatives have occurred. The 1990s, we expect will be a period of new activism vis-a-vis the oceans. This will be a period of harmonizing and improving of the sector-by-sector governmental approach and of developing a second generation scheme of ocean governance.

The Santa Barbara Channel is an important arena of multiple-use activity; it is also a laboratory of multiple-use conflicts (just about every type of conflict that occurs, occurs here). Similarly, the Channel could provide a laboratory for exploring methods of resolving multiple-use conflicts. Data on many of the major activities in the Channel are presented.

Variations at Different Scales of Time and Space on Intertidal Shores

J. H. Connell[1], *S. Schroeter*[2], and *S. Swarbrick*[3]
[1]Dept. of Biological Sciences, University of California, Santa Barbara, CA 93106
[2]Dept. of Biological Sciences, University of Southern California
531 Encinitas Blvd., Suite 113, Los Angeles, CA 92024
[3]Marine Science Institute, University of California, Santa Barbara, CA 93106

For 14 years, populations of marine animals and plants have been studied at an intertidal boulder field west of UCSB. For the first 10 years, abundances were in large part determined by small-scale disturbances which killed local populations by boulder overturning. However occasional large-scale disturbances also played a major role. A major storm occurred in 1983 and killed virtually all invertebrates and plants in the entire boulder field. An invasion of a marine tube-building worm then occurred which cemented the boulders together and changed the physical and biological environment substantially. The boulders were no longer overturned by waves, and there was no water circulation beneath them. The sea urchins, starfish, octopuses and crabs that were common before 1983 have not recovered after the storm, probably because their shelter beneath boulders has been eliminated. As a result, the ecological community has completely changed and has remained in this different state for 4-1/2 years. This example illustrates the value of detailed long-term ecological studies to our understanding of marine ecosystems.

Ecological Monitoring as a Diagnostic Tool for Marine Resource Management

G. E. Davis
Channel Islands National Park, 1901 Spinnaker Dr., Ventura, CA 93001

One of the primary challenges in marine resource management is knowing when to take action and when resource conditions are changing in response to natural events beyond management control. A long-term ecological monitoring program was initiated in Channel Islands National Park, California to identify and define changes in plant and animal populations. The purpose of the program is to determine natural limits of variation and diagnose abnormal conditions to assist in making management decisions and in defining research questions. Population parameters, such as abundance, age structure, reproduction, recruitment, growth rates and phenology, are determined at least annually in the park for 75 taxa of marine mammals, seabirds, fish, invertebrates and algae.

Dramatic changes in many populations have been documented since monitoring began in 1982 which graphically demonstrate the dynamic nature of coastal marine ecosystems and the difficulty of determining normal conditions in them. Most of these changes appear to be related to the major El Niño event of 1982-1983, but the proximal causes of significant declines in abundance and recruitment of three abalone species, *Haliotis*, and two sea stars, *Patiria miniata* and *Pisaster giganteus*, are less clear.

Severe Storms, Sea Urchins, and Disturbance-Driven Kelp Forests

A. W. Ebeling, D. R. Laur, and R. J. Rowley
Department of Biological Sciences and Marine Science Institute
University of California, Santa Barbara, CA 93106

In some West Coast kelp forests, energy flows from kelp and other macroalgae that produce large amounts of detritus, through sea urchins and other herbivores that eat this detritus, to sea otters and other top consumers that eat the herbivores. Wherever sea otters are absent at the top trophic level, ineffective regulation of sea urchin numbers at the middle level may cause local extinctions of kelp at the bottom level. Off southern California, for example, large numbers of urchins may outstrip their detrital food supply and graze back the forest. Yet severe physical disturbance can either destroy kelp biomass and the principal detrital source for urchins, or decimate the urchin population and reduce the primary grazing pressure. Thus, severe storms can promote either overgrazing or forest recovery, depending on the previous history of the site; they can cause changeovers between

two quite different community forms by deleting the major biomass of functionally important species. Deleting kelp can transform the forest into a barrens dominated by grazing sea urchins; deleting sea urchins from a barrens may accomplish the reverse, given a proper "window" for kelp recruitment. This happens because the rate of biological disturbance by large numbers of urchins exceeds the rate of recolonization by kelp. The chronically high rate of biological disturbance is permitted because (1) urchins are long-lived and can exploit alternative marginal food supplies and (2) urchin numbers are not regulated by effective predation.

Oxygen Isotope Analysis of Marine Shells from an Archaeological Site on Santa Cruz Island: Implications for Holocene Paleoenvironmental Reconstruction

M. A. Glassow[1], *M. J. DeNiro*[2], *L. R. Wilcoxon*[1]
[1]Dept. of Anthropology, University of California, Santa Barbara, CA 93106
[2]Dept. of Earth and Space Sciences, University of California, Los Angeles, CA 90024

Valves of California mussel *(Mytilus californianus)* from an archaeological site on western Santa Cruz Island were subjected to oxygen isotope analysis with the intent of determining whether sea-surface temperatures were cooler than present at ca. 5000 B.P. As controls, modern mussel valves from the intertidal habitat near the site and from locations in central California and Washington were also subjected to oxygen isotope analysis. Although results of the analysis imply that sea-surface temperatures indeed may have been cooler than 5000 B.P., certain factors appear to be causing the results to be less dramatic than expected. The analysis nonetheless demonstrates that archaeological data can be an important source of information on paleoenvironmental conditions during the Holocene.

Physical Circulation Characteristics in the Santa Barbara Channel

J. T. Gunn and *G. S. E. Lagerloef*
Science Applications International Corp., 13400 B Northup Way #36
Bellevue, Washington 98005

Current and hydrographic measurements were made in Santa Barbara Channel between April 1983 and January 1985, concentrated primarily in a 3 and a 12 month sampling period. The principal upper layer flow feature was a warm westward current which entered the Channel via the eastern entrance, continued along the northern coast and exited the western entrance as a persistent jet with mean speeds of 25 cm/s but at times reaching 60 cm/s. A cool eastward counterflow was present in the southern part of the Channel extending at least one-third the

length of the southern island boundary. This flow recirculated in the Channel interior, forming a cyclonic gyre in the central and western portions of the Channel. A northwest-southeast orientated front in the central Channel was a persistent upper layer feature.

The synoptic fluctuations (2-10 days) were negatively correlated between the westward and eastward-flowing currents in the western Channel entrance. There was a minor seasonal modulation of current speeds at some locations, where current speeds increased during the summer by 15-30% over winter speeds. An observed increase in the along-channel surface temperature gradient and the consequent along-channel steric sea level gradient increase accounted for part of the slightly greater current speeds in summer.

Hydrographic observations included five CTD surveys and time series of temperature and salinity from the current meters with emphasis on the basin boundaries. The hydrography during the first survey (April 1983) showed much more variability than the others (during 1984). The time series T-S relationships during 1984 were consistent with the coincident CTD surveys but illustrated variability not evident from the synoptic surveys. Comparison of the data with satellite imagery showed remarkable agreement. Numerous small-scale eddies (40 km diameter) moved westward and showed good agreement with the measured currents.

Factors that Control Population Characteristics of Benthic Nearshore Fishes: The Importance of Life History Traits and Critical Resources

S. J. Holbrook, M. H. Carr, and R. J. Schmitt
Dept. of Biological Sciences, University of California, Santa Barbara, CA 93106

A goal of population ecologists is to understand how critical resources influence characteristics of local populations. Our studies of benthic fishes on temperate rocky reefs illustrate that the effect of variation in one environmental feature, giant kelp, on recruitment of fishes depends on the life history characteristics of individual species. Forests of giant kelp, *Macrocystis pyrifera,* can undergo substantial variation in time and space. Such variation can have a direct and profound influence on recruitment of fishes that require giant kelp as a nursery habitat. Some fishes such as kelp bass, *Paralabrax clathratus,* have a planktonic larval stage that preferentially settle on giant kelp; young kelp bass remain closely associated with kelp for much of their first year of life. For these types of species, local recruitment is influenced more strongly by availability of appropriate nursery sites than by local abundance of adults.

The presence of giant kelp can adversely influence recruitment and abundance of benthic fishes having non-dispersive young indirectly by reducing other critical resources. Giant kelp alters the composition and abundance of understory algae and the invertebrates associated with understory algae. Surfperch in the genus *Embiotoca* are viviparous and release young into the local parental population. The number of young produced is a direct function of local adult density, which in turn is set by the availability of understory algae containing their food. Because of its effect on understory algae, giant kelp can negatively effect both recruitment and local population density of surfperch.

Causes of Pinniped Strandings in Santa Barbara County, 1976-1987

P. C. Howorth
Marine Mammal Center, 3930 Harrold Ave., Santa Barbara, CA 93101

From 1976 through 1987, the Marine Mammal Center has taken in hundreds of pinnipeds to rehabilitate for eventual return to the wilds. Detailed records have been kept on each animal. By interpreting data from these records, it is possible, in the majority of cases, to determine the cause of each stranding. Disease, starvation, abandonment of pups by mothers, and trauma head the list of causes. Human-related problems, such as shootings, stabbings, clubbings, gillnet entanglements, and removal of pups from beaches are also indicated. By examining the numbers of strandings from various causes, inferences can be drawn as to human impacts on pinnipeds, natural limiting factors on populations, public health hazards (if any), and concerns for management.

Monitoring Potential Environmental Effects of Oil and Gas Development and Production in the Santa Maria Basin

J. L. Hyland
Battelle Ocean Sciences-Ventura, 1431 Spinnaker Dr., Ventura, CA 93001

This presentation will provide a summary of the California Outer Continental Shelf (OCS) Phase II Monitoring Program, which is being conducted by a team of investigators from Battelle Ocean Sciences, and a number of other marine research institutions, for the Pacific OCS Regional Office of the Minerals Management Service, U. S. Department of Interior. The program consists of a five-year, multidisciplinary study designed to monitor potential environmental changes resulting from oil and gas development and production in the Santa Maria Basin region of the California OCS. Specific goals of this presentation will be: (1) To provide a brief review of the overall objectives and design of the monitoring program; and (2) to highlight some of the important results and observations noted during the first year of study. Results of the study will be available for use in various decision-making steps of the California OCS Federal leasing program. Also, it is anticipated that these results will expand existing knowledge of basic

oceanographic processes and ecological conditions of the Central California OCS, and will provide information to help interpret results of future offshore monitoring programs conducted in other planning areas.

Upwelling at Point Conception and its Interaction with the Santa Barbara Channel

B. H. Jones
Alan Hancock Foundation, University of Southern California,
Los Angeles, CA 90089

The western entrance to the Santa Barbara Channel is bounded on the north by Point Conception, a region known for frequent and strong upwelling. This upwelling provides a large supply of nutrients to the euphotic zone of the entire southern California Bight, and especially to the Santa Barbara Channel. The Organization of Persistent Upwelling Systems (OPUS) program focused its effort on the Point Conception region during two field studies in 1981 and 1983. There are several time scales of importance to upwelling in this region. At seasonal time scales, the strongest and coldest upwelling occurs between April and July, following the spring transition. On shorter time scales upwelling is generally correlated with the local wind forcing. The current regime near Point Conception is complex, affected by both the circulation in the Santa Barbara Channel and by offshore features such as eddies. Upwelling of nutrients into the euphotic zone results in high levels of primary production and phytoplankton biomass within the Santa Barbara Channel. The circulation in the channel and its interaction with the upwelling near Point Conception apparently helps to maintain patches of phytoplankton for extended periods of time and these patches may provide a feedback to the upwelling by providing seed populations for successive upwelling events. The Santa Barbara Channel thus acts as a biological "reservoir" for the upwelled water at Point Conception and the physical dynamics provide a mechanism for the exchange between the upwelled water and the water within the Santa Barbara Channel. The time scales of physical variability appear to be similar enough to certain characteristic biological scales to permit biological exploitation of the upwelled water.

The Transport and Fate of Drilling Muds

W. Lick
Dept. of Mechanical and Environmental Engineering, University of California
Santa Barbara, CA 93106

At present, many people are concerned with the disposal of drilling muds from offshore platforms because of potential effects of pollution from these muds. The decision on how to safely dispose of these muds is being made on the basis of emotional and/or political considerations which have little to do with the fate and effects of the drilling muds themselves.

In order to make these decisions about disposal on a more rational basis, a quantitative understanding of the transport and fate of drilling muds in the water and in the bottom sediments is needed. For this purpose; a quantitative numerical model of the transport and fate of drilling muds has been developed and will be reviewed. However in order to make this model usable, basic information is needed on (1) particle sizes and flocculation of drilling muds, (2) settling speeds of the flocculated particles, and (3) resuspension properties of the bottom sediments. Our present knowledge in these areas will be discussed.

Application and Future Potential of NOAA Status and Trends Research in the Santa Barbara Region

E. Long and G. Shigenaka
Ocean Assessments Division, National Oceanic and Atmospheric Administration
7600 Sand Point Way, NE, Seattle, WA 98115

The National Status and Trends Program of NOAA monitors the occurrence and concentration of chemical contaminants in sediments, bivalves and bottom fish at sites nationwide. Some of those sites are located in the southern California Bight. There are three bivalve sampling sites located along the Santa Barbara Channel, including one on Santa Cruz Island in the Channel Islands National Marine Sanctuary. The objective of the program is to determine the status of and trends in marine environmental quality in the Nation's coastal and estuarine areas. Data from initial monitoring efforts of the Program are discussed with emphasis upon the southern California Bight. The future direction of the Program with regard to the addition of biological measures of effects are also discussed.

Pac Baroness Sinking: Preliminary Overview of Environmental and Oceanographic Impact on Santa Barbara Coastal Waters

S. V. Margolis[1], R. K. Zimmer-Faust[1], P. M. Stout[1], B. H. Robison[1], R. Haymon[1] B. Luyendyk[1], and J. L. Hyland[2]
[1]Marine Science Institute, University of California, Santa Barbara, CA 93106
[2]Battelle Ocean Sciences-Ventura, 1431 Spinnaker Dr., Ventura, CA 93001

Since the sinking of the 564 foot freighter *Pac Baroness* on September 21, 1987, 12 miles southwest of Point Conception in 1,500 feet of water, two research cruises have investigated the wreck and the impact of its cargo of finely powdered copper sulfide ore and fuel oil on the surrounding marine environment. During the mid-November 1987 cruise, side scanning sonar surveys determined that the *Pac Baroness* was lying on its keel on the seafloor, apparently split open in three places, with debris scattered over at least a 1 square km area of the shelf. Analyses of sediment cores taken have indicated that both the powdered copper ore and fuel oil have been spilled out from the wreck and mixed with bottom sediments. Preliminary analyses of seawater from the sinking site have shown that there are elevated levels of dissolved copper in the water column. A surface oil slick which is present above the wreck, also exhibits copper enrichment. Bottom dwelling organisms including fish and urchins which are abundant in this region are currently being investigated for evidence of copper or hydrocarbon uptake. The second cruise conducted mid-January, 1988 will concentrate on submersible operations, photography, fish and sample collections immediately adjacent to the wreck.

Oceanographic, Contaminant and Ecological Trends of the Santa Barbara Coast

A. J. Mearns and G. Shigenaka
Ocean Assessments Division, National Oceanic and Atmospheric Administration
7600 Sand Point Way, NE, Seattle, WA 98115

NOAA's Ocean Assessments Division is conducting several historical reviews of trends in resources and contamination in the Southern California Bight. The studies include: (1) A major review of chemical contaminant trends in fish, shellfish and sediments, (2) A statistical study to determine relationships between long-term fluctuations in stocks of pelagic fish (anchovy, sardine and mackerel) with trends in pollutant inputs and environmental conditions and (3) A review of long-term trends in occurrences of unusual organisms and mass invasions into the region. The contaminant-trend study has identified data on concentrations of PCBs,

pesticides and trace elements that extend back to the 1940's for fish and to the turn of the century for sediments and clearly identifies historical hot spots and reductions due to pollutant control. The statistical study, undertaken by NMFS' Southwest Fisheries Center (La Jolla) has compressed 40 or more years of egg and larval distribution data, and accompanying oceanographic and climatological data from the CalCOFI Program into a suite of time-series that will be statistically compared to pollutant input data. A key feature of the study is computation of confidence limits around stock size estimates so that our certainty or uncertainty about cause-effect relationships will be clearly defined.

Together, these historical reviews are yielding a fascinating history of human activity and marine environmental changes that have occurred in the Southern California Bight and in the Santa Barbara coastal area. For example, during the mid-1800's, the marine fish fauna of the region was much more tropical than in later years. Oil slicks were observed in the region long before drilling commenced on a large scale in the 1920's and 30's. During the 30's, the coastal area was swept by a multiyear invasion of tropical forms such as jumbo squid and puffers. Contamination of marine life and sediments by organic chemicals began in the late 1940's which was also the beginning of a cool period and the final days of the great sardine populations. This period terminated with the major 1957-59 El Niño event when contaminant levels were coincidentally approaching their maxima. By the 1970's, contamination by DDT, radionuclides and trace elements was declining to the levels found today.

Continued surveillance of ecological indicator species, oceanic conditions and trace contaminants is needed to deduce the interplay of these factors on the ecological health of the region. The absence of any one can lead to inappropriate management action

---

Oil Spill Response in the Santa Barbara Channel Focusing on the Recent Sinking of the *Pac Baroness*

L. A. "Skip" Onstad
Clean Seas, 1180 Eugenia Place #204, Carpenteria, CA 93013

Oil spill preparedness in California has evolved from something essentially non-existent in 1970 to that which is comparable to the most comprehensive of any place in the world. The approach taken to containment, recovery and mitigation is systematic, it is based upon a response capability matched to the seriousness of the problem and relies on cooperation between the spiller, industry sponsored oil spill cooperatives and the federal government.

The recent sinking of the M/V *Pac Baroness* provided an example of how the system can mobilize and respond to a potential serious spill. The response to this spill involved mechanical containment and recovery, the use of chemical dispersants and demonstrated the rapid dispersal action of surface oil caused by strong winds and high seas. Organizationally, it showed the willingness of the oil

industry to respond to spills of others as well as the federal government's role in ensuring an adequate response is made to any significant spill.

Dispersant Trials Using the *Pac Baroness* Event as a Spill of Opportunity

J. R. Payne and J. R. Clayton, Jr.
Science Applications International Corp., 10260 Campus Dr., San Diego, CA 92121

Oil released from the *Pac Baroness* was used as a target of opportunity to study dispersant application technology and to evaluate and (possibly) calibrate remote sensing methods used to track the treated and untreated portions of the slick to extinction. Forty-one gallons of the dispersant Corexit 9527 was applied by helicopter to a 100 m x 700 m portion of the slick on 29 September, 1987. Photographic (video tape and slide) documentation of the spill behavior was completed from a US Coast Guard H-3 helicopter, and the US Coast Guard AIREYE Falcon Jet was used for Side Looking Airborne Radar (SLAR) coverage from an altitude of 5000 feet and IR/UV scans from 400 feet. Continuous subsurface UV/Fluorescence measurements and ground truth water samples were obtained from a surface vessel before and after dispersant application. Unfortunately, the results of the tests were somewhat equivocal due to the limited aerial extents and very thin nature of the oil combined with 15-20 knot cross-winds which lead to considerable breakup of both treated and untreated control areas. Photographic documentation showed a subtle difference between the head of the slick (original subsurface source) and the treated area 200 m downcurrent, but the breakup due to the cross-wind as the slick moved further downcurrent precluded any differentiation between the treated area and the untreated control area 700 m from the source. The SLAR data were of limited value because of the extremely small area treated and the resolution of the technique at 5000 feet. The UV scans from 400 feet did suggest a change in the slick behavior in the treated area; however, the ground truth UV/Fluorescence measurements and later chemical analyses did not indicate enhanced subsurface concentrations of dispersed oil. Attempts to complete another series of tests on 1 and 2 October were thwarted by the weather (poor visibility, 200-foot ceilings and 20 to 30 knot winds) and the continuing decline in the amount of oil surfacing from the vessel.

The Minerals Management Service's Environmental Studies in the Santa Barbara Area

F. M. Piltz
Minerals Management Service, Pacific OCS Region, 1340 W. Sixth St. MS 300
Los Angeles, CA 90017

The Minerals Management Service (MMS) of the Department of the Interior conducts an Environmental Studies Program in the Pacific OCS Region addressing a wide variety of marine related topics. The Environmental Studies Program (ESP) began in 1974 under the Bureau of Land Management and as it evolved over the years has included studies in the Santa Barbara Channel and adjacent areas. The early years of the program were devoted to baseline studies of the fauna, chemistry, and sediments of the Channel. Measurements made by the studies during the years 1976-1978 were the first and in some cases remain the only measurements in some parts of the Channel and adjacent areas. Extensive marine mammal and seabird surveys sponsored by the ESP during the years 1975-1978 included censusing in the Channel and on the Channel Islands. The MMS has sponsored the most complete physical oceanographic study of the channel with *in situ* current measurements, hydrography, and computer modeling of the Channel system. Active research being sponsored by MMS includes the long-term monitoring of production platforms in the Point Conception and Point Sal areas to the north of the Channel.

Primary Productivity Across the Santa Barbara Coastal Front

B. B. Prezelin[1], R. C. Smith[2], R. R. Bidigare[3], and K. S. Baker[4]
[1]Dept. of Biological Sciences, University of California, Santa Barbara, CA 93106
[2]Center for Remote Sensing and Environmental Optics, UCMBO,
University of California, Santa Barbara, CA 93106
[3]Geochemical and Environmental Research Group, Texas A&M University
College Station, TX 77843
[4]UCMBO at Scripps Institute of Oceanography, University of California
San Diego, CA 92093

A 'quasi-synoptic' shipboard bio-optical sampling strategy was developed to generate time-corrected data for assessing phytoplankton production across a coastal front that is persistently present in the Southern California Bight off Santa Barbara. During July 1985, diurnal (=daytime) patterns of photosynthesis and pigmentation were characterized for whole water and size-fractioned phytoplankton communities, with samples being collected at 3 different light depths at 8 different stations transecting the frontal boundary. Plant biomass and depth-integrated daily

rates of primary productivity respectively were 25-fold and 15-fold greater on the cold water side, representing recently upwelled water flowing from the north off Pt. Conception. In the cold water mass, netplankton (>5um) diatoms dominated the mixed layer and accounted for 80% of total daily productivity. There was an abrupt transition to nanoplankton size (0.4 to 5 um) algal communities within the frontal boundary, where coccolithophorids dominated production. On the warm water side of the front, very low productivity algal communities were comprised of a mixture of chlorophytes, cyanobacteria and coccolithophorids. The horizontal gradients in floristic composition and production across the front were accompanied by a horizontal gradient in nutrient availability and water optical properties, especially ocean color. A physiologically-based bio-optical model was developed by linking primary production estimates to optical properties of the water column and spectral signatures of component algal groups. The model is capable of predicting vertical profiles of instantaneous, diel and integrated daily rates of *in situ* primary production in variable water masses sampled across the front. We have shown that the model can be used for shipboard observations and that is may be useful for predicting production rates from data provided by untended buoys and remotely-sensed measures of optical parameters.

Submersible Research in the Santa Barbara Basin

B. H. Robison
Monterey Bay Aquarium Research Institute, Monterey, CA, and
Marine Science Institute, University of California, Santa Barbara, CA 93106

Submersible-based research in the Santa Barbara Basin has focused chiefly on the biology and ecology of the animals of the water column. In the 1960's and -70's, extensive sampling with conventional equipment had determined the patterns of species composition and vertical distribution of micronektonic fishes and crustaceans, with real precision. In the 1980's *in situ* methodologies have been developed using modern submersibles and instrumentation.

The results of these new studies have considerably altered and greatly improved our understanding of ecological processes in midwater. They show that we had previously underestimated the abundance and diversity of the midwater fauna, and that we had also greatly underestimated the complexity of its organization into a functioning ecosystem.

Recent studies have revealed several important aspects of midwater ecology that could not have been determined by indirect research methods. These include: The role of behavior patterns in determining the dynamics of community metabolism; the role of substrate as a basis for spatial organization in midwater communities; the significance of gelatinous creatures to community structure; the importance of bioluminescence as a regulator of activity levels; the complexity of predator-prey interactions; and the degree of overlap between benthic and pelagic processes. These results are leading to a fundamental re-description of these important communities.

Remote Sensing of Oceanic Primary Production

R. C. Smith[1], B. B. Prezelin[2], R. R. Bidigare[3], and K. S. Baker[4]
[1]Center for Remote Sensing and Environmental Optics, UCMBO, University of California, Santa Barbara, CA 93106
[2]Dept. of Biological Sciences, University of California, Santa Barbara, CA 93106
[3]Geochemical and Environmental Research Group Texas A&M University College Station, TX 77843
[4]UCMBO, Scripps Institute of Oceanography, University of California San Diego, CA 92093

The quantitative assessment of ocean primary productivity and the potential of the oceans to store atmospheric CO_2 is increasingly important as humankind pursues the ability to modify the marine environment. Methods for the remote estimation of phytoplankton biomass and production rates using multiplatform sampling strategies are essential in order to span the range of space/time variability in the abundance and distribution of phytoplankton organisms. Recent developments utilizing contemporaneous buoy, ship, aircraft and satellite data, along with bio-optical models linking remotely sensed optical properties with important biological parameters, now make it possible to obtain synoptic and continuous oceanographic data which was previously not possible. Synoptic satellite estimates of phytoplankton biomass on global and regional scales is now available. Towards the goal of estimating primary productivity on these scales a spectrally dependent bio-optical model for the computation of *in situ* production is presented. This model can be used for both shipboard observations and may be especially useful for predicting production rates from data provided by untended buoys.

Trends and Abundance, Diets and Foraging Areas of Pinnipeds in the Southern California Bight

B. Stewart[1], R. L. Delong[2], G. Antonelis[2], and P. K. Yochem[1]
[1]Sea World Research Institute, Hubbs Marine Research Center
1700 South Shores Rd., San Diego, CA 92109
[2]National Marine Mammal Laboratory, National Marine Fisheries Service
7600 Sand Point Way, NE, Seattle, WA 98115

On the Southern California Channel Islands, four species of pinnipeds have increased rapidly in abundance during the past three decades. Evaluation of the impacts of these important predators on local marine resources is complex. Although there are some overlaps in diets, these pinnipeds feed on the common prey in varying proportions seasonally, in different geographic locations, and at different depths. Age-structured consumption rates for males and females of each species vary daily and seasonally. Furthermore, the local age and sex composition and abundance of each pinniped species vary greatly with season. Locally, California sea lions and northern fur seals eat Pacific whiting, northern anchovy, market squid, and other cephalopods, particularly in summer when metabolic requirements of lactating females increase greatly. In summer, California sea lions forage near the surface (< 150 m depth) within an average of 54 km of rookeries in relatively shallow, nearshore waters while northern fur seals forage further offshore and at greater distances from their rookeries at San Miguel Island. Harbor seals evidently feed near the bottom in shallow waters near island and mainland haul-outs. Some seals may move among the islands seasonally but the extent of these migrations as well as reproductive integrity of island colonies are poorly known. Locally, they eat juvenile rockfish, plainfin midshipman, spotted cusk-eel and octopus but the diet varies seasonally. Although elephant seals are quite abundant ashore on San Nicolas and San Miguel islands in winter and spring, they evidently do not feed in coastal Southern California waters to any extent. Little is known, however, of their distribution when they are at sea. Their diet consists primarily of squids and mesopelagic fishes.

References

Antonelis, G. A., C. H. Fiscus, and R. L. DeLong. 1984. Spring and summer prey of California sea lions, *Zalophus californianus*, at San Miguel Island, California, 1978-79. U. S. Fish. Bull. 82:67-76.

Antonelis, G. A., S. Leatherwood, and D. K. Odell. 1981. Population growth and censused of the northern elephant seal, *Mirounga angustirostris*, on the California Channel Islands, 1958-1978. U.S. Fish. Bull. 79:562-567.

Antonelis, G. A., M. S. Lowry, D. P. DeMaster, and C. H. Fiscus. 1987. Assessing northern elephant seal feeding habits by stomach lavage. Marine Mammal Science 34:308-322.

Antonelis, G. A., B. S. Stewart, and W. F. Perryman. (1988). Foraging characteristics of California sea lions (*Zalophus californianus)* and northern fur seals (*Callorhinus ursinus*) in the waters around San Miguel Island. In Review.

Cooper, C. F. and B. S. Stewart. 1983. Demography of northern elephant seals, 1911-1982. Science 210:969-971.

DeLong, R. L. 1982. Population biology of northern fur seals at San Miguel Island, California. Ph. D. thesis, University of California, Berkeley, CA. 185 pp.

Feldkamp, S. D. 1985. Swimming and diving in the California sea lion, *Zalophus californianus*. Ph. D. thesis, University of California, San Diego, CA. 176 pp.

Stewart, B. S. 1981. The Guadalupe fur seal (*Arctocephalus townsendi*) on San Nicolas Island, California. Bull. S. Calif. Acad. Sci. 80:134-136.

Stewart, B. S. 1981. Seasonal abundance, distribution,, and ecology of the harbor seal, *Phoca vitulina richardsi*, on San Miguel Island, California. M.S. Thesis, San Diego State University, San Diego, CA, 66 pp.

Stewart, B. S. 1984. Diurnal hauling patterns of harbor seals on San Miguel Island, California. J. Wildl. Manage. 48:1459-1461.

Stewart, B. S. 1988. The ecology and population biology of the northern elephant seal, *Mirounga angustirostris* Gill 1866, on the Southern California Channel Islands. Ph. D. dissertation, University of California, Los Angeles, CA.

Stewart, B. S., G. A. Antonelis, R. L. DeLong, and P. K. Yochem. 1987. Abundance of harbor seals at San Miguel Island, California, 1927 through 1985. Bull. S. Calif. Acad. Sci. 86:In Press.

Stewart, B. S. and P. K. Yochem. 1983. Radiotelemetry studies of hauling patterns, site fidelity, and movements of harbor seals on San Nicolas and San Miguel Islands. HSWRI Tech. Rept. 83-152.

Stewart, B. S. and P. K. Yochem. 1984. Seasonal abundance of pinnipeds at San Nicolas Island, California, 1980-1982. Bull. S. Calif. Acad. Sci. 83:121-132.

Stewart, B. S. and P. K. Yochem. 1985. Entanglement of pinnipeds in net and line fragments and other debris in the Southern California Bight. NOAA Tech. Memo., NMFS, NOAA-TMA-NMFS-SWFC- 54:315-325.

Stewart, B. S. and P. K. Yochem. 1986. Northern elephant seals breeding at Santa Rosa Island, California. J. Mammal. 67:402-403.

Stewart, B. S. and P. K. Yochem. 1987. Entanglement of pinnipeds in synthetic debris and fishing net and line fragments at San Nicolas and San Miguel islands, California, 1978-1986. Mar. Pollut. Bull. 18:336-339.

Stewart, B. S. and P. K. Yochem. (1988). Feeding habits of harbor seals (*Phoca vitulina richardsi*) at San Nicolas Island, California, 1980-1985. In Review.

Stewart, B. S. and P. K. Yochem. (1988). Diving behavior of harbor seals near San Nicolas Island, California. In Prep.

Stewart, B. S., P. K. Yochem, R. L. DeLong, and G. A. Antonelis. 1987. Interactions between Guadalupe fur seals and California sea lions at San Nicolas and San Miguel Islands, California. NOAA Tech. Rept. NMFS 51:103-106.

Stewart, B. S., P. K. Yochem, R. L. DeLong, and G. A. Antonelis. (1988). Status and trends in abundance of pinnipeds on the Southern California Channel Islands. In Review.

Yochem, P. K. and B. S. Stewart. 1985. Radiotelemetry studies of hauling patterns, movements, and site fidelity of harbor seals (*Phoca vitulina richardsi*) at San Nicolas Island, California, 1983. HMRI Tech. Rept. 86-189.

Yochem, P. K., B. S. Stewart, R. L. DeLong, and D. P. DeMaster. 1987. Diel hauling patterns and site fidelity of harbor seals (*Phoca vitulina richardsi*) at San Miguel Island, California, in autumn. Marine Mammal Science 3:323-332.

Crustaceans and Other Invertebrates as Indicators of Beach Pollution

A. M. Wenner
Marine Science Institute, University of California, Santa Barbara, CA 93106

Sandy beaches, because of their dynamic nature, provide a greater challenge than other habitats if one wishes to monitor any potential impact on the environment as a result of human activities. Traditional comparative ecological studies of distribution, abundance, and diversity can be supplemented or replaced by other approaches, including studies of growth, reproduction, population structure, or other topics important in population biology. In addition, an analysis of several factors, including comparisons of chemical analyses of tissues for metals and toxic organic compounds, egg production, size frequency distributions, growth rates, and parasite incidence, may reveal the existence of sublethal effects. Acceptable organisms (as alternatives to mussels on hard substrata) include meiofauna, molluscs (especially *Donax)*, polychaete worms, and crustaceans. Of those, crustaceans appear to be the most suitable. Sand crabs *(Emerita analoga)* have proven to be especially valuable as biomonitors along the Southern California sandy beach coastline. They possess several of the key attributes listed by Phillips in 1980 and have several other favorable characteristics as well. A full account appears in the following reference: Crustaceans and other invertebrates as indicators of beach pollution. Pp. 199-229 *in* D. Soule and G. Kleppel (eds), *Marine Organisms as Indicators*: Springer-Verlag, NY (1987?).

Marine Mammal Research at the Santa Barbara Museum of Natural History

C. D. Woodhouse
Santa Barbara Museum of Natural History, 2559 Puesta Del Sol Rd.
Santa Barbara, CA 93105

A marine mammal program was formulated at the Santa Barbara Museum of Natural History in the fall of 1974. The program is based on information from two general sources. One involves the documentation of live marine mammals, particularly cetaceans, and the other involves salvage of beach cast marine mammals of all species. The region of focus incorporates the coasts of southern San Luis Obispo, Santa Barbara and Ventura Counties including the Northern Channel Islands. 1987 marks the program's 13th year. As a result, a long term data base has been established which provides a measure of variability of the region's marine mammal species. Prior to the program's start, the nature of the region's cetacean fauna was speculative. To date, 23 cetacean species have been documented. Among pinnipeds and cetaceans, little was known of mortality rates and causes in the area prior to 1975. In the 13 year period, over 500 beach cast specimens representing 21 species have been recorded. The data base of beach cast animals provides an important measure of "normal" mortality. The salvage effort has allowed the accumulation of a significant west coast museum study collection of marine mammals.

New Methods in Aquatic Chemoreception with Applications to Environmental Pollution

R. K. Zimmer-Faust[1], *L. Martinez*[2], *and G. Smyth*[3]
[1]Marine Science Institute
[2]Neurosciences Research Program, IES
[3]Dept. of Applied Probability and Statistics
University of California, Santa Barbara, CA 93106

Pollutants in marine environments have the potential of interfering with chemoreception in marine organisms--a sensory modality that is essential to foraging, mating, larval settlement, etc. Here we report the first determination of a marine organism's behavioral threshold for a chemical attractant (glycine) that takes into account the chemical's natural background level (as measured by high pressure liquid chromatography). We also report the suppression of chemoattractant responses by ammonia, a substance excreted by heterotrophic organisms during nitrogen metabolism, and a major pollutant of produce and process water created during gas treatment. Dilution associated with stimulus introduction was monitored by injecting fluorescent dyes, and recording fluorescence using optical fiber probes attached to olfactory and gustatory appendages of unrestrained spiny lobsters *(Panulirus interruptus)*. Recorded fluorescence was converted to an analog voltage signal, digitized, and stored on a microprocessor at 10 msec intervals. This time course is nearly identical to latencies of chemoreceptor responses. Dose-response functions for behavior were then modelled using maximum likelihood procedures and logistic regression. For these conditions, we find that: (1) lobsters detect glycine at concentrations $\leq$ 5% greater than ambient, (2) lobsters begin feeding at glycine concentrations two to five times greater than ambient, and (3) ammonia suppresses lobster responses to glycine at concentrations 2.5 to 5 times greater than ambient. The difference threshold for chemical detection in lobsters is lower than those reported for terrestrial animals. In its ability to discriminate among stimulus intensities, lobster olfaction appears to compare favorably with the vertebrate senses of vision and hearing. The inhibitory concentrations of ammonia are substantially lower than those causing lethality, and they are an order of magnitude below the concentration set as standard for State marine water quality. Our results demonstrate that chemosensory-mediated behavior of marine organisms is a highly sensitive assay for ecologically relevant pollutant effects.

PART II. POSTER SESSIONS

Underwater Photography: Techniques and Equipment

G. B. Allen
Brooks Institute, 12-B East Cota St., Santa Barbara, CA 93101

Audio/visual support (slides) plays an important role in research documentation and presentation. Techniques and applications of underwater photography will be discussed, including a brief history of underwater photography. Equipment will be exhibited and options or applications of this equipment demonstrated. Included in this equipment demonstration will be: Underwater sensitometry and optics; lighting systems (natural and artificial); strobe techniques and calibration; macro (close-up) photography; specialized diving techniques; and, the Nikonos system - an industry standard.

Handouts will be available on related equipment information and topic treatments and methods to enhance skills and evaluate equipment.

Use of Deepwater ROV'S and Manned Submersibles in the Santa Barbara Channel and Coastal Waters

D. Barthelmess
International Underwater Contractors, Inc, 4835-B Colt St., Ventura, CA 93003

The use of Remotely Operated Vehicles (ROV's) in addition to manned submersibles have proved to be useful tools for data collection during the research projects being conducted along the Santa Barbara Channel and coastal waters.

Over the past few years, many commercial marine contractors have seen an increasing demand for their equipment and services to provide cost effective means in assisting local research laboratories and universities in conducting environmental impact studies.

This new demand has created a new market for local contractors to focus upon and gear their efforts toward providing equipment and services to facilitate effective marine science research and exploration in the Channel.

Computer Aided Management of Emergency Operations (CAMEO) Demonstration

D. S. Chan
Hazardous Materials Response Branch, Ocean Assessments Division
National Oceanic and Atmospheric Administration
Coast Guard Island, Bldg. 14, Alameda, CA 94501

NOAA has developed a unique computer tool for emergency response and resource management. This tool, called CAMEO (Computer Aided Management of Emergency Operations), has been used extensively in NOAA's response capacity as the federal scientific coordinator at major oil and chemical spills nation-wide. Two demonstrations will be given during this poster session. First, how the CAMEO package is used to help during a spill response, including its use during the *Pac Baroness* incident. And secondly, how it has been modified for local use as a education and resource management tool. It is, for example, an innovative, interactive computer exhibit on display at the Sea Center that allows the public to access and learn about the Channel Islands National Marine Sanctuary and its resources.

New computer software developments, especially with the availability of the computer software known as HYPERCARD have increased the opportunity to utilize computers in resource management. Examples of new developments and the future potential of these types of computer aides will also be discussed. Limited hands-on availability and printed information will also be available.

Establishment of a West Coast Undersea Program

M. DeLuca
National Undersea Research Program
National Oceanic and Atmospheric Administration
6010 Executive Blvd., Rockville, MD 20852

In 1987, NOAA began to evaluate the scientific interest in a dedicated undersea program for the west coast. As a result of several meetings with representatives from west coast institutions, strong justification emerged for the establishment of such a program. NOAA is now conducting a national solicitation for the establishment of one and perhaps two undersea programs on the west coast. Opportunities for support of future undersea activities will be discussed for the west coast.

Growth Studies of Abalone at the Channel Islands

K. Henderson, P. Haaker, and D. Parker
California Department of Fish and Game
1301 West 12th Street, Long Beach, CA 90813

A five year study of red abalone, *Haliotis rufescens*, at Johnsons Lee, Santa Rosa Island, has provided growth data for fishery management. Sport size is attained in about eight years, and commercial size took significantly longer. Similar studies, in conjunction with the National Park Service, have been initiated on black abalone, *Haliotis cracherodii*, at Santa Rosa and San Miguel Islands.

Geochemical and Geological Investigations of the *Pac Baroness* Wreck Site Off Point Conception, California

S. V. Margolis[1], R. Haymon[1], B. Luyendyk[1], P. Stout[1], J. P. Kennett[1], E. Doehne[2] and P. Claeys[2]
[1]Marine Science Institute, University of California, Santa Barbara, CA 93106
[2]Dept. of Geology, University of California, Davis, CA 95616

We present detailed geochemical and geological analyses of data and samples collected during oceanographic expeditions to the site of the *Pac Baroness* wreck. High resolution side scanning sonar records indicate that the ship struck the sea-floor with significant force, generating a plume of sediment, ore and fuel oil which radiated out for a distance of at least 1 km to the east and west of the wreck. Microtopographic features on the sea floor indicate the location and trajectory of debris from the ship, as well as modification by possible bottom current activity. The originally flat, soft bottom in this area has been significantly disturbed by the impact of the wreck. T.V. images obtained by ROV submersible operations show that the area away from the wreck is typified by high sediment fluxes and highly productive benthic communities with abundant mounds, trails and fish. X-ray fluorescence, diffraction, scanning electron microscopic and electron microprobe analyses of sediments recovered by box coring near the wreck indicate that the fine grained chalcopyrite ore is present in bottom sediments to a distance of 1 km. Visual inspection revealed that these cores were also saturated with hydrocarbons. A control station 8.5 km to the north did not contain copper ore or hydrocarbons. There is evidence that the copper ore is undergoing oxidation and dissolution in the sediment, which may be responsible for the elevated levels of Cu found in the overlying water column.

Analysis of Mussel *(Mytilus edulis)* Growth in the Santa Barbara Channel: Field Measurements and a Physiological Model

M. Page and Y. Ricard
Marine Science Institute, University of California, Santa Barbara, CA 93106

This research addresses the general question: Can data on regional variation in phytoplankton biomass from remote sensing or other sources be used to predict the potential for growth of mussels (or other suspension feeding bivalves)? The answer requires an understanding of the factors influencing bivalve growth in the field. Using measurements of growth rate, water temperature, chlorophyll *a* and POM concentrations, and a physiological model, derived from data in the literature, we established a link between the availability of suspended particulate food and patterns of shell growth rate in mussels, *Mytilus edulis,* at an offshore platform in the Santa Barbara Channel.

Small (20 mm shell-length) individually numbered mussels were caged approximately monthly for 20 months at a depth of 2 m. Shell-length was measured initially and thereafter at 3-4 week intervals. Measurements of water temperature, chlorophyll *a* and POM (9 months) concentrations were made weekly. Published physiological rates of particle clearance and ingestion, oxygen concentration, an assimilation efficiency were reviewed and synthesized to estimate the "scope for growth", the potential production of soft tissue based on the energy equation:

P (scope for growth, J/h)=A (assimilated particulate food, J/h) -R (oxygen consumption, J/h).

The length-specific growth rate of *M. edulis* ranged from lows of 5-6 mm/mo to highs of 9-10 mm/mo. Growth rate correlated with chlorophyll *a* concentration at time lags of 2-4 weeks. Scope for growth ranged from lows of <7 J/h in November-January to >15 J/h in May and June and correlated with shell growth at time lags of 2-3 weeks. Changes in scope for growth were most sensitive to changes in the concentration of POM. Neither shell growth rate or scope for growth were associated with water temperature. We conclude that phytoplankton are a major component of the diet of mussels offshore. Regional variability in particulate food, particularly phytoplankton, may thus contribute to variability in mussel growth rate.

Volatile Liquid Hydrocarbon (VLH) Levels Off Goleta Point: A Long-Term Monitoring Study

R. L. Petty
Marine Science Institute, University of California, Santa Barbara, CA 93106

Petroleum related hydrocarbons are naturally present at parts per trillion levels (or greater) in the Santa Barbara Channel. The levels would be expected to be impacted by offshore oil development and production. The UCSB seawater system obtains its supply from an intake pipe at Goleta Point, about 100 m offshore. A project to determine the ambient, "background" levels of specific hydrocarbons in the campus seawater system, and to monitor any changes which might occur during or after nearby offshore development, was initiated in 1984.

After developing a routine sampling and analysis procedure, measurements of benzene, toluene, and C2-benzenes were initiated. Samples have been taken on a daily basis at either the seawater intake well or the inlet to the system's sand filter for over two years. Occasional intensive (hourly) sampling has been performed at several locations in the system, including the offshore intake point, to determine short term variability and to correlate levels at different points along the flow path. Results of the daily and intensive analysis programs will be presented.

PART III. PAPERS

Use of Deepwater ROV'S and Manned Submersibles in the Santa Barbara Channel and Coastal Waters

Don Barthelmess
International Underwater Contractors, Pacific Division
4835-B Colt St., Ventura, CA 93003

Introduction:

When Remotely Operated Vehicles (ROVs) first appeared in the underwater service market in the 1970's, they were designed chiefly to support offshore oil and gas operations, which were at the time quite active and numerous.

Consequently, much funding for research and development of these vehicles was available for the manufacturers and operators to outfit them to suit the needs of the industry. Today, this funding has since all but vanished since the cut backs in exploration, not only here in Santa Barbara Channel but worldwide as well. Many ROV/Submersible diving contractors have "gone under" as a result. Survivors have cut back and are now aiming at other work, to compensate for the current state.

Manned submersibles have seen a less drastic evolvement throughout the past two decades, mostly due to the higher costs associated with their operations. Most manned submersibles were however originally designed to support scientific research operations rather than specific support of offshore oil/gas operations.

ROV Adaptations:

It was with this thought in mind that International Underwater Contractors (IUC) started a gradual shift of focusing on developing our 2300' ROV Recon IV into a more useful tool for research.

Traditionally, Recon has always been installed onboard our 143' R/V *ALOHA* for all of our manned submersible research projects for the purpose of a safety backup should entrapment ever occur.

Not until several years ago did the thought arise to combine existing sampling/surveys techniques already in use with Mermaid and apply them to the ROV as an additional research tool. The results have been very successful, the

Recon has now become a primary research tool for IUC here on the West Coast.

Adaptations and developments that have occurred throughout local research projects and federally funded ones have included:

- Water Sampling, remotely triggered
- Manipulator Systems for rock sampling
- High Resolution Color Sonar for site identification
- 70 mm Photographic Systems
- 35 mm Photographic Systems
- Laser Systems for precision photo analysis
- Fish Collection
- Macro Photography
- High Resolution Color Video
- Broadcast Quality Video Recordings
- Larger Payload for sampling

This is an ongoing process as constant adaptations are being made to meet the many research ideas and requirements of various clientele.

The goal of our technical staff is currently to standardize sampling packages that are proven successful in the field and make them available as the job dictates. Prior planning and direct contact with the operational team has proven to result in effective research utilizing existing in house technology between contractors and researchers,

Types of Research:

CAMP:

Recon IV A and the 1000' three-man Mermaid II have been used primarily on photographic sampling, transect site surveys and biological reconnaissance here in the Santa Barbara Channel.

Recon has played a major role performing hard bottom studies in the ongoing California Monitoring Program (CAMP) locally. Mermaid is scheduled to participate in dives during the latter portion of this five year project.

PACBARONESS:

The *PACBARONESS* shipwreck was one of the more exciting projects conducted this past year with the ROV following up an initial side-scan search for the 564' frieghter with detailed photo survey of the wreck and surrounding areas. The ship sank in 1500' of water, September 21, 1987, carrying potentially harmful copper cargo.

Having an existing ROV spread with 2300' depth range installed on the R/V *ALOHA* made a very cost effective package for federal funding agencies to utilize on a "rapid response" investigation. ROV and vessel mobilization costs were cut since Aloha is berthed in Ventura, only 6 hours from the site.

The Tether Management System (TMS) for the ROV allowed Recon to maneuver free of effects from surface vessel movements, heave, pitch and roll.

By comparison of direct tether systems the possibility of fouling would have been greatly increased. The positively buoyant Recon 400' flying tether allowed the vehicle cage to be positioned above the major debris from the superstructure, eliminating fouling of the cage in the wreck.

Flying ROV's around major shipwrecks is not a common occurrence. Precision navigation and subsea-vehicle tracking interfacing with proper live-boating techniques were the key to the successful wreck study. The biggest advantage was having an operational team that is used to enclosure ROV flying, given the fact that much of their early experience was flying inside mazes of steel members during oil platform inspections in the boom years.

Detailed photo analysis of the shipwreck was completed in four (4) dives along with in site sampling.

NURP Projects:

Mermaid and Recon have participated in several projects sponsored by National Undersea Research Program (NURP) over the past few years, outside of work in the Santa Barbara Channel.

These cruises have extended from Sitka, Alaska, in 1983, with the Mermaid running longlines with baited hooks for a study on their effectiveness, to the Gulf of Maine in 1984, where the two completed Benthic survey studies at dredged material sites.

In 1987 *ALOHA* traveled to the Bering Sea where grey whale feeding pits were studied, and detailed CTD fluorometer analysis of the water column was carried out using an onboard computer in the Mermaid, combining a new technique developed by the University of Alaska for use on manned submersibles.

Later that year Mermaid/Recon completed studies of Rockfish near Heceta Bank area in 1000 FSW and also hydrothermal vent studies Astoria and Newport, Oregon, for Oregon State University.

In September 1987, Mermaid again brought scientists to the Monterey Canyon area for study of the Pacific hagfish in 1000 FSW.

All of these projects utilized proven research methods as well as developing many new methods for sampling such as:

- Water Rosette sampler for capping hydrothermal vents
- Deployment of Chemical agents for drugging rockfish for collection
- Collection of Multiple Box Cores and Tube Cores using submersibles

The addition of a third person to the Mermaid enabled scientists to collect more data on each dive since both a biologist and geologist could participate along with the pilot.

Conclusion:

In summary, local research activities are generally limited by the lack of funding for projects in the Channel. Growth and new technology will not advance without the revenues and funding for R & D of new tools/techniques that provided for the birth of the ROV and manned submersible.

By comparison of federal budget allocations for undersea research vs space program expenditures, it would seem that we really know more about outer space than inner space. This should not be.

The majority of the work has been funded or paid for directly from Federal and State agencies governing local oil and gas leasing.

"Side spins" off of existing monitoring projects such as the *PACBARONESS* survey were only made possible through cooperation of private industry, Federal agencies and local contractors. This in the past has been a rarity; it is encouraging for the future, but leaves little hope in development of new technology.

The establishment of a West Coast NOAA research program facility is the most promising source of future funding for higher level research here in the Channel.

In the future, further expansion of IUC's West Coast submersible fleet will see three Recon ROV systems and possibly the addition of a 3000 meter three-man submersible to assist in the deeper canyon areas yet to be explored.

It is important to note that throughout the continued development of our existing local oil and gas industry and the inevitable controlled expansions which will take place, our underwater environment can be monitored and researched at the very same time. The capabilities for achieving such are here locally and proven effective and useful.

Severe Storms, Sea Urchins, and Disturbance-Driven Kelp Forests

A. W. Ebeling, D. R. Laur, and R. J. Rowley
Department of Biological Sciences and Marine Science Institute
University of California , Santa Barbara, CA 93106

In some West Coast kelp forests, energy flows from kelp and other macroalgae that produce large amounts of detached algal drift, through sea urchins and other herbivores that eat this drift when it is available but living plants when it is not, to sea otters and other top consumers that eat the herbivores. Wherever sea otters are absent at the top trophic level, ineffective regulation of sea urchin numbers at the middle level may cause local extinctions of kelp at the bottom level. Off southern California, for example, large numbers of urchins may outstrip their supply of drift and graze back the living forest. Here a severe storm disturbance can either destroy kelp biomass and the source of drift, or decimate the urchin population and reduce the grazing pressure. Thus, severe storms can promote either overgrazing or forest recovery, depending on the previous history of the site. Deleting kelp transforms the forest into a barrens dominated by grazing sea urchins; deleting sea urchins from a barrens does the reverse, given proper conditions for kelp recruitment. This happens because the rate of grazing by large numbers of urchins exceeds the rate of recolonization by kelp. The high rate of grazing continues because (1) urchins are long-lived and can exploit marginal food supplies and (2) their numbers are not regulated by effective predation.

Introduction: alternative subtidal reef communities

Off southern California, subtidal reef communities can occur in two very different forms (North 1971; Dean *et al.* 1984; Harrold and Reed 1985; Ebeling *et al.* 1985). The forested form is dominated by dense, lush stands of large seaweeds. Fronds of giant kelp *Macrocystis pyrifera* rise from holdfasts on the reef bottom to spread out at the water surface and create a dense canopy of enormous biomass. Where enough sunlight penetrates, a subsurface canopy of understory kelp grows to a height of about 1 m. Finally a dense "turf," mostly of red algae requiring even less sunlight, carpets the reef bottom. The algal turf often overgrows a thin, tough pavement of crustose coralline algae, which can be exposed by the grazing of sea urchins. In contrast, the barren-ground ("barrens") form of the community has little foliage other than the crustose algae and is dominated by large echinoderms (Lawrence 1975), especially the sea urchins *Strongylocentrotus franciscanus* and *S. purpuratus*.

There has been public concern over the periodic transformation of forested reefs into urchin-dominated barrens. Currently, a popular notion is that periodic El Niños are harmful to kelp forests. Episodes such as the recent major El Niño of 1982-83 are accompanied by warm, nutrient-depleted water occurring to greater depths than usual (Dayton and Tegner 1984a; Tegner and Dayton 1987). This stresses the kelp plants and makes them more vulnerable to mechanical damage from severe winter storms that often accompany El Niños (Gerard 1984). Such storms, however, can also rejuvenate kelp forests. Strong wave action thins the canopy and increases available light and space, thereby enhancing conditions for recruitment of new plants (Cowen *et al.* 1982; Ebeling *et al.* 1985). In addition, winter storms may also promote the dispersal of kelp propagules and, given proper environmental conditions, the recruitment of kelp to previously barren reefs (Harris *et al.* 1984; D. C. Reed, D. R. Laur, and A. W. Ebeling, manuscript).

Our purpose is to describe the mechanisms by which severe winter storms, which tend to rejuvenate the community elsewhere (Cowen et al. 1982; Reed and Foster 1984), can trigger the transformation of a southern Californian kelp forest into an urchin-dominated barrens, or vice versa (Ebeling et al. 1985). We argue that the forest is least stable in localities without effective predators of sea urchins.

Community structure and regulation

Thus, the process of storm-triggered transformation involves the trophic structure of kelp-bed communities and the regulation of their species populations. To explain this, we'll use the familiar Hairston-Smith-Slobodkin (1960) three-level model (HSS) of community structure and regulation in terrestrial communities. These authors assumed that the earth appears green in a zone of suitable climate and rainfall because the land supports a large standing crop of plants for an excess of plant production by photosynthesis over plant consumption by herbivores. Energy flows from plants at the bottom level through herbivores at the middle level to carnivores at the top level. Now, assuming that no higher-order predators eat the carnivores and that the system is unperturbed by major disturbances such as fires and floods, the carnivores become very abundant and compete for food resources (the herbivores). Consequently, the herbivores are reduced below numbers that can effectively regulate plant abundances. As a result, plants increase in abundance and compete among themselves for limiting resources of space, sunlight, water and nutrients. In effect, the top and bottom levels are regulated by competition while the middle level is controlled by predation from the top level. Of course the model is oversimplified, in that food webs are more complex and physical disturbances often intervene (Connell 1978).

Nonetheless, this simple model can be applied to an important food chain in some kelp-bed communities. Substituting, respectively, for terrestrial plants, herbivores and carnivores, energy flows from macroalgae--especially kelp--at the bottom level through urchins--the most destructive grazers of kelp--at the middle level to sea otters *(Enhydra lutris)*--the most effective predator of urchins --at the top level (Fig. 1).

This pattern of energy flow may differ from the simple HSS model because sea urchins are not strictly herbivores: they eat detached drift kelp as well as many other things (Lawrence 1975). As in the terrestrial model, the kelp (plant) biomass is very large and there is usually an excess of kelp production over consumption by herbivores (Mann 1973; Gerard 1976). The mature stand replaces itself by supplying young plants (Fig. 2: "recruits") and by vegetative regrowth of broken and senescent fronds in the canopy. Much of the excess production breaks off from the canopy to accumulate on the bottom as drift algae (Gerard 1976). Under these circumstances, urchins tend to remain hidden in cracks and crevices where they expend relatively little food energy for maintenance metabolism (Vadas 1977). In this inactive or "hidden" behavioral mode, they snag and hold drift instead of eating living plants (e.g. Lowry and Pearse 1973; Rosenthal *et al.* 1974). If a severe winter storm destroys the canopy and source of drift, the urchins become hungry and emerge to graze living plants from the reef surface (Ebeling *et al.* 1985; Harrold and Reed 1985). Hunger seems to stimulate urchins into a more active or "exposed" behavioral mode (Mattison *et al.* 1977). If present, however, sea otters eat the more vulnerable exposed urchins, thereby preventing urchins from overgrazing plant recruits and other new plant growth (Laur *et al.* 1988). Wherever otters are present then, storm disturbance has only regenerative effects by clearing out old plants and promoting recolonization and vigorous new growth (Reed and Foster 1984). Thus, otters play the role of "keystone predator" (sensu Paine 1969) because they prevent local extinction of plants at the bottom trophic level by controlling numbers of exposed urchins at the middle level (e.g. Estes *et al.* 1978).

The rub is that sea otters no longer occur in substantial numbers off southern California (except for a recent introduction of a few individuals to San Nicolas Island). After being driven to near extinction by fur traders in the 19th century, the sea otter now ranges abundantly only along central California, Alaska, the Aleutian Islands, and the Kamchatka region (Riedman and Estes 1988). Thus there is often ineffective predator control of urchin numbers off southern California (review in Ebeling and Laur 1988). Other natural predators such as the California sheephead fish *Semicossyphus pulcher*, spiny lobster *Panulirus interruptus*, and starfish *Pycnopodia helianthoides* (Tegner and Dayton 1981) are usually less effective than otters. Humans are less effective predators because they harvest only large gravid red urchins; urchin fishermen leave behind the juveniles, other species, and all barrens urchins, which have small gonads and are not marketable.

A case history

Even in the absence of effective predator regulation of urchins, however, kelp beds persist locally off southern California for long periods of time (Foster and Schiel 1988). Since 1970, for example, we have been monitoring an area of reef and kelp (Naples Reef) located 23 km west of Santa Barbara (Ebeling *et al.* 1980). A dense canopy of giant kelp covered the reef and environs continuously throughout the 1970s despite large populations of sea urchins (Ebeling and Laur 1988). Weather was benign to the extent that no winter storms were severe enough to destroy the entire kelp canopy. Kelp biomass was sufficiently large that production exceeded consumption and there was enough detached drift kelp to satisfy sea urchins in the "hidden" mode (Fig. 3a). Due perhaps to limited numbers of young urchins recruiting into the Naples populations (see Leighton *et al.* 1966; but also Tegner and Dayton 1981), sea urchin populations never grew so large that they overexploited the supply of drift, and living plants were generally spared.

In February 1980 the most powerful storm swell in more than a decade struck the Santa Barbara Channel and destroyed not only the canopy of giant kelp over Naples Reef, but all those within about 1.6 km (Ebeling *et al.* 1985). Most urchins survived because they had been inactive and hidden. The source of drift kelp was eliminated when most of the biomass of the mature kelp stand was destroyed (Fig. 3b). Consequently, urchins grew hungry, more active, and emerged in the absence of effective predation to destroy the large kelp recruitment that often follows the period of winter storm disturbances. Within a year, most urchins of both species had assembled into grazing fronts (see Leighton 1971), destroyed mot foliose algae in their path, and transformed the community generally into a barrens (Ebeling *et al.* 1985; Laur *et al.* 1986).

In the barrens, only exposed sea urchins remained among the elements in our simple food chain (Fig. 3c). Even without their primary food resources of drift kelp and living macroalgae, however, urchins can subsist in a semi-starved condition because they can exploit marginal supplies of alternative foods (e.g. Lang and Mann 1976; Tegner and Levin 1982). Urchins are long-lived, with maximum life spans of more than 10 (Ebert 1967) or even 20 years (Estes *et al.* 1978). Like cattle, they harbor gut bacteria that digest plant cell walls and provide nitrogen (Fong and Mann 1980). Sea urchins may even be able to absorb organic molecules directly from seawater (Pearse and Pearse 1973). The barrens may thus persist indefinitely in the absence of any external population control (Mann 1977) such as disease (Pearse *et al.* 1977) or physical disturbance (Ebeling *et al.* 1985).

Three years later in February 1983, large swells from a second major winter storm, associated with the strong 1982-84 El Niño, decimated the population of exposed urchins on Naples Reef (Ebeling *et al.* 1985). Even without drift kelp, this urchin mortality reduced grazing pressure to the point where the heavy post-storm kelp recruitment survived to cover the reef with algae (Fig. 3d). Within a year, the young forest had differentiated into a thick subsurface canopy of *Pterygophora californica*, through which rose fronds of *Macrocystis*. In two years, a large biomass of mature kelp was producing accumulations of drift (Fig. 3a). Consequently, individuals in the growing urchin population remained inactive and generally hidden, snagging and holding drift instead of actively grazing live plants.

Conclusions

We have now gone full cycle with a disturbance-driven kelp forest: Severe storms can promote either over grazing or forest recovery by deleting the major biomass of functionally important species. Deleting the mature kelp canopy transforms the forest into a barrens if large numbers of sea urchins are present.

Deleting sea urchins permits recovery, given proper conditions for kelp recruitment. The barrens persist because the rate of grazing by sea urchins exceeds the recovery rate. The chronically high grazing is sustained by two factors: (1) urchin numbers are not regulated by predation or disease, and (2) urchins are long-lived and can exploit marginal food supplies at low metabolic cost. That severe storms may trigger kelp-forest degeneration as well as rejuvenation may help explain what North (1971) called "irregular changes" in southern California kelp forests. Whenever and wherever predators or other agencies control urchin numbers, storm effects tend to be rejuvenating, much like the effects of forest fires and other terrestrial disturbances that clear areas in which vigorous new growth can occur (Dayton and Tegner 1984b). But where local populations of exposed urchins go unchecked, the outcome depends on what form the community happens to be in. Locally, therefore, sea otters may tend to preserve the kelp-forest community. In fact, this has prompted several researchers to refer to the sea otter--the most effective predator of sea urchins--as a "keystone species" and not "just another brick in the wall" (Foster and Schiel 1988).

Acknowledgments--We thank D. Reed for reviewing the manuscript. A. DuBois, C. Ebeling, J. Jenkins, T. Miller, and T. Pearsons helped with field work. S. Anderson provided technical assistance with equipment and boating operations. We appreciate the encouragement of officials with the Channel Islands National Marine Sanctuary, Santa Barbara National History Museum, and UCSB Marine Science Institute for their encouragement and good administrative services. The work was supported by NSF grants OCE79-25008 and OCE82-08183.

REFERENCES

Cowen, R. K., C. R. Agegian and M. S. Foster. 1982. The maintenance of community structure in a central California giant kelp forest. J. Exp. Mar. Biol. Ecol. 64:189-201.

Dayton, P. K. and M. J. Tegner. 1984a. Catastrophic storms, El Niño, and patch stability in a southern California kelp community. Science 224:283-285.

Dayton, P. K. and M. J. Tegner. 1984b. The importance of scale in community ecology: a kelp forest example with terrestrial analogs. In: Price, P. W., C. N. Slobodchikoff and W. S. Gaud (eds.), Novel approaches to interactive systems, Wiley, New York, pp. 457-481.

Connell, J. H. 1978. Diversity in tropical rain forests and coral reefs. Science 199:1302-1310.

Dean, T. A., S. C. Schroeter, and J. D. Dixon. 1984. Effects of grazing by two species of sea urchins (*Strongylocentrotus franciscanus* and *Lytechinus anamesus*) on recruitment and survival of two species of kelp (*Macrocystis pyrifera* and

Pterygophora californica). Mar. Biol. 78:301-313.

Ebeling, A. W. and D. R. Laur. 1988. Fish populations in kelp forests without sea otters: effects of severe storm damage and destructive sea urchin grazing. In: VanBlaricom, G. R. and J. A. Estes (eds.), The community ecology of sea otters, Springer-Verlag, Berlin Heidelberg, pp. 169-191.

Ebeling, A. W., R. J. Larson, W. W. Alevizon, and R. N. Bray. 1980. Annual variability of reef-fish assemblages in kelp forests off Santa Barbara, California. Fish. Bull., U.S. 78:361-377.

Ebeling, A. W., D. R. Laur, and R. J. Rowley. 1985. Severe storm disturbances and reversal of community structure in a southern California kelp forest. Mar. Biol. 84:287-294.

Ebert, T. A. 1967. Negative growth and longevity in the purple sea urchin *Strongylocentrotus purpuratus* (Stimpson). Science 157:557-558.

Estes, J. A., N. S. Smith, and J. F. Palmisano. 1978. Sea otter predation and community organization in the western Aleutian Islands, Alaska. Ecology 59:822-833.

Fong, W. and K. H. Mann. 1980. Role of gut flora in the transfer of amino acids through a marine food chain. Can. J. Fish. Aquat. Sci. 37:88-96.

Foster, M. S. and D. R. Schiel. 1988. Kelp communities and sea otters: keystone species or just another brick in the wall. In: VanBlaricom, G. R and J. A. Estes (eds.), The community sea otters, Springer-Verlag, Berlin Heidelberg, pp. 92-115.

Gerard, V. A. 1976. Some aspects of material dynamics and energy flow in a kelp forest in Monterey Bay, California. Dissertation, University of California, Santa Cruz.

Hairston, N. G., F. E. Smith, and L. B. Slobodkin. 1960. Community structure, population control, and competition. Am. Nat. 94:421-425.

Harris, L. G., A. W. Ebeling, D. R. Laur, and R. J. Rowley. 1984. Community recovery following storm damage: a case of facilitation in primary succession. Science 224:1336-1338.

Harrold, C. and D. C. Reed. 1985. Food availability, sea urchin grazing, and kelp forest community structure. Ecology 66:1160-1169.

Lang, C. and K. H. Mann. Changes in sea urchin populations after the destruction of kelp beds. Mar. Biol. 36:321-326.

Laur, D. R., A. W. Ebeling, and D. C. Reed. 1986. Experimental evaluations of substrate types as barriers to sea urchin (*Strongylocentrotus* spp.) movement. Mar. Biol. 93:209-215.

Laur, D. R., A. W. Ebeling, and D. A. Coon. 1988. Effects of sea otter foraging on subtidal reef communities off central California. In: VanBlaricom, G. R. and J. S. Estes (eds.), The community ecology of sea otters, Springer-Verlag, Berlin Heidelberg, pp. 151-168.

Lawrence, J. M. 1975. On the relationships between marine plants and sea urchins. Ocenogr. Mar. Biol. Ann. Rev. 13:213-286.

Leighton, D. L. 1971. Grazing activities of benthic invertebrates in southern California kelp beds. Nova Hedwigina 32:421-453.

Leighton, D. L., L. G. Jones, and W. J. North. 1966. Ecological relationships between giant kelp and sea urchins in southern California. In: E. G. Young and J. L. Mclachlan (eds.), Proceedings of the fifth annual seaweed symposium. Pergammon Press, Oxford, pp. 141-153.

Lowry, L. F. and J. S. Pearse. 1973. Abalones and urchins in an area inhabited by sea otters. Mar. Biol. 23:213-228.

Mann, K. H. 1973. Seaweeds: their productivity and strategy for growth. Science 182:975-981.

Mann, K. H. 1977. Destruction of kelp-beds by sea-urchins: a cyclical phenomenon or irreversible degradation? Helgolander wiss. Merresunters. 30:455-467.

Mattison, J. E., J. D. Trent, Å. L. Shanks, T. B. Akin and J. S. Pearse. 1977. Movement and feeding activity of red sea urchins (*Strongylocentrotus franciscanus*) adjacent to a kelp forest. Mar. Biol. 39:25-30.

North, W. J. 1971. Introduction and background. In: The biology of giant kelp beds (*Macrosystis*) in California. Nova Hedwigia 32:1-97.

Paine, R. T. 1969. A note on trophic complexity and community stability. Am. Nat. 103:91-93.

Pearse, J. S. and V. B. Pearse. 1973. Removal of glycine from solution by the sea urchin *Strongylocentrotus purpuratus*. Mar. Biol. 19:281-284.

Pearse, J. S., D. P. Costa, M. B. Yellin and C. R. Agegian. 1977. Localized mass mortality of red sea urchin, *Strongylocentrotus franciscanus*, near Santa Cruz, California. Fish. Bull., U.S. 75:645-648.

Reed, D. C. and M. S. Foster. 1984. The effects of canopy shading on algal recruitment and growth in a giant kelp forest. Ecology 65:937-948.

Reidman, M. L. and J. A. Estes. 1988. A review of the history, distribution and foraging ecology of sea otters. In: VanBlaricom, G. R. and J. A. Estes (eds.), The community ecology of sea otters, Springer-Verlag, Berlin Heidelberg, pp. 4-21.

Rosenthal, R. J., W. D. Clarke, and P. K. Dayton. 1974. Ecology and natural history of a stand of giant kelp, *Macrocystis pyrifera,* off Del Mar, California. Fish. Bull. U. S. 72:670-684.

Tegner, M. J. and P. K. Dayton. 1981. Population structure, recruitment and mortality of two sea urchins (*Strongylocentrotus franciscanus* and *S.purpuratus)* in a kelp forest. Mar. Ecol. Prog. Ser. 5:255-268.

Tegner, M. J. and P. K. Dayton. 1987. El Niño effects on southern California kelp forest communities. In: Adv. Ecol. Res. 17:243-279.

Tegner, M. J. and L. A. Levin. 1982. Do sea urchins and abalones compete in California kelp forest communities? In: Lawrence, J. M. (ed), Proceedings international echinoderms conference, Tampa Bay. A. A. Balkema, Rotterdam, pp. 265-271.

Vadas, R. L. 1977. Preferential feeding: an optimization strategy in sea urchins. Ecol. Monogr. 47:337-371.

FIGURE LEGENDS

Figure 1. The Hairston-Smith-Slobodkin three-level model of trophic structure and regulation of terrestrial communities applied to an important kelp-bed food chain. Arrows denote energy flow.

Figure 2. Transfers of energy and materials (arrows) in a simplified three-level kelp-bed system where sea otters are absent. An "X" indicates the absence or elimination of a component.

Figure 3. Storm-triggered transformations of a kelp bed community represented by the three-level food chain but without sea otters or other effective predators of sea urchins. See Fig. 2.

Figure 1.

HSS MODEL APPLIED TO A KELP-BED FOOD CHAIN

TOP LEVEL	Carnivores = sea otters
	↑
MIDDLE LEVEL	Herbivores = sea urchins
	↑
BOTTOM LEVEL	Plants = kelp

Figure 2.

SIMPLIFIED FOOD CHAIN IN A KELP BED COMMUNITY WITH SEA OTTERS

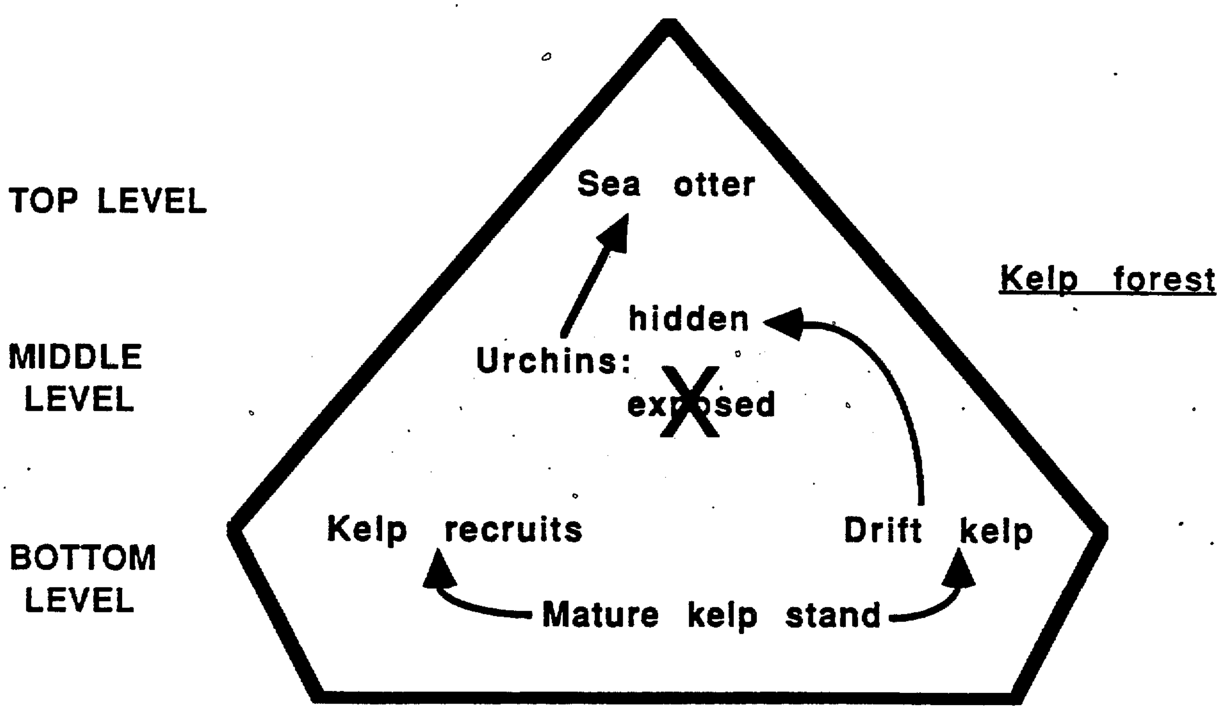
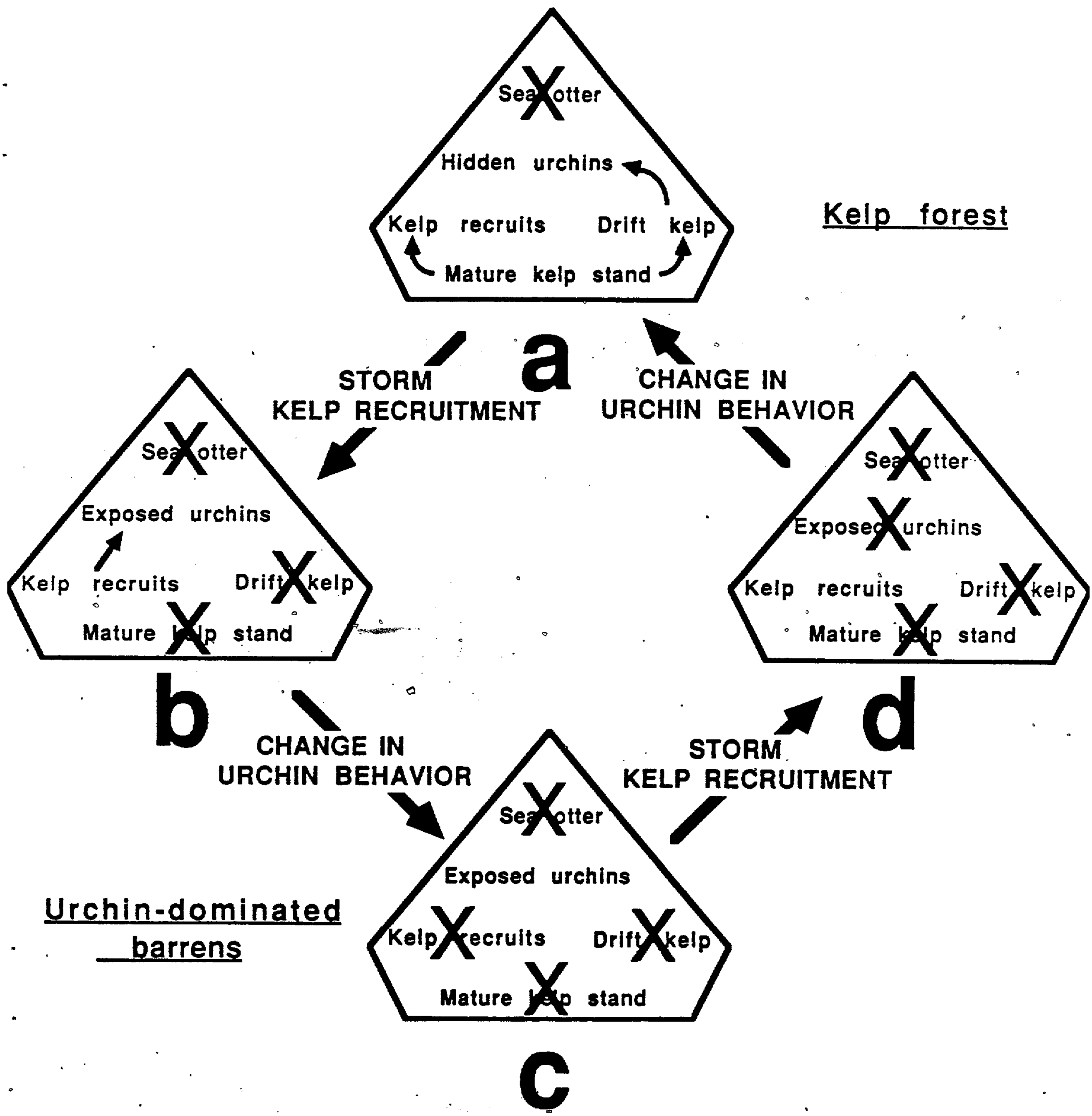


Figure 3.

TRANSFORMATIONS OF OTTER-LESS KELP BED COMMUNITY



Monitoring Potential Environmental Effects of Oil and Gas Development and Production in the Santa Maria Basin

Dr. Jeffrey L. Hyland
Battelle Ocean Sciences, 1431 Spinnaker Drive, Ventura, CA 93001

1. Introduction

This paper provides a summary of a presentation on the California Outer Continental Shelf (OCS) Phase II Monitoring Program, sponsored by the Minerals Management Service (MMS) Pacific OCS Office. Goals of the presentation were: (1) to provide a brief review of the background, objectives and design of the Monitoring Program; and (2) to highlight some of the important results and observations noted during the first year of study.

2. Background and Purpose of the Program

The California OCS Phase II Monitoring Program is a five-year, multidisciplinary study designed to monitor potential environmental changes resulting from oil and gas development in the Santa Maria Basin region of the California OCS (Figure 1). This ongoing monitoring study extends the predrilling baseline sampling conducted in the same study area during the earlier 1983-1984 Phase I Reconnaissance Survey (SAIC, 1986)

The Phase II Monitoring Program was initiated in response to requirements under the 1978 OCS Lands Act Amendments (43 U.S.C.-1346) for MMS (then BLM) to implement studies designed to evaluate environmental impacts of oil and gas development activities on human, marine, and coastal resources of the U.S. OCS. Three additional factors have contributed to the decision to implement this particular study. These factors are: (1) the great potential for extensive production of oil and gas from this region of the California OCS; (2) the concern that development of, and production from, a major new oil field on the U.S. OCS may result in cumulative, long-term adverse impacts on the marine environment; and (3) the lack of previous oil and gas production activities, or other major anthropogenic influences in the area.

3. Study Objectives and Design

Specific objectives of the program are: (1) to detect and measure potential long-term (or short-term) changes in the marine environment in the vicinity of OCS oil and gas development and production activities; and (2) to determine whether changes observed in the marine environment during the monitoring period are caused by drilling and production-related activities or are the result of natural processes. Program objectives are being addressed through time-series monitoring of a number of environmental parameters before and after initiation of

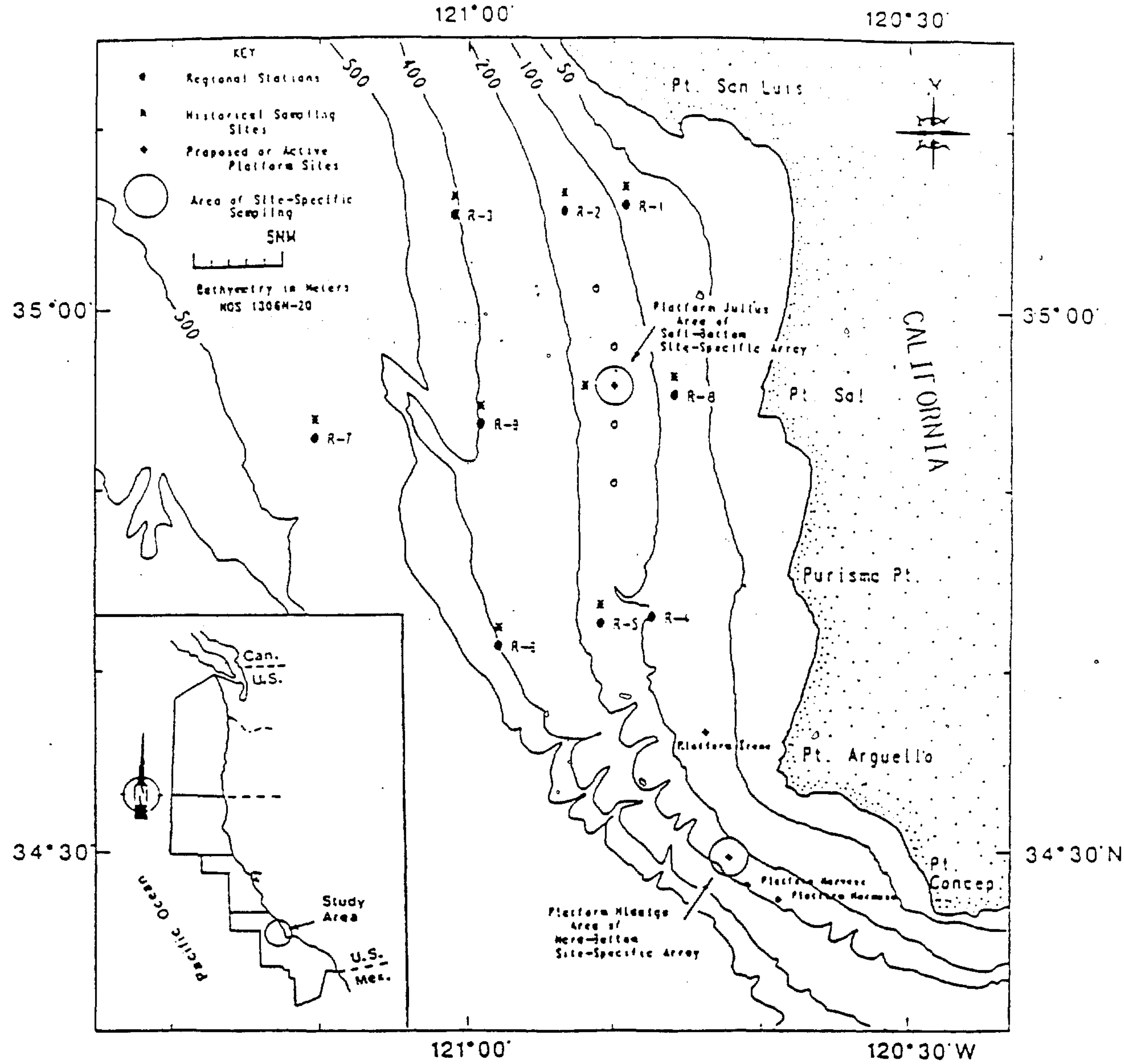


Figure 1. Area of Study and Station Locations for MMS California OCS Phase II Monitoring Program

drilling at various monitoring sites throughout the study area, including control sites and sites where environmental impacts are more likely to occur. An optimal-impact study design (Green, 1979) and *a priori* hypothesis testing are being applied in the process of addressing these objectives, so that any conclusions regarding environmental changes can be stated within established levels of statistical confidence. The long-term nature of this program will help to achieve the objective of separating natural background variation from actual environmental impacts caused by oil and gas production activities.

Specific parameters being addressed as part of the time-series monitoring effort consist of biological community indices and species abundances for hard-bottom and soft-bottom benthic assemblages; levels and distributions of trace metals and hydrocarbons in bottom sediments, suspended particulates, animal tissues, and pore waters; water currents and other physical oceanographic features; and various sedimentological properties (e.g., sediment grain size, total organic carbon and carbonate content, sediment shear strength, distribution of minerals types, and redox conditions). Synoptic measurements of these various parameters are taken to permit examination of biological changes in relation to concomitant chemical or physical changes linked to specific drilling events. Additional companion studies focus on benthic sediment-transport processes and animal-sediment-pollutant interactions.

The station design (Figure 1) consists of a series of regional stations and two additional arrays of site-specific stations located in the vicinity of two existing, or planned, oil development/production platforms. Regional stations consist of three cross-shelf transects of three stations each and an additional station located approximately 50 km west of Point Sal in a suspected offshore depositional area. Regional stations provide an opportunity to compare ecological conditions and potential responses to drilling-related impacts over broad regional areas and bathymetric zones. The two site-specific sampling arrays provide an opportunity to examine potential nearfield impacts and possible impact gradients extending outward from point sources of platform discharge. One array is located in unconsolidated substrates offshore of Point Sal at the future site for Cities Service's (now Shell's) Platform Julius. The second array is located offshore of Point Arguello, within a region of hard-bottom features, in the vicinity of Chevron's Platform Hidalgo. Both arrays consist of a series of platform and comparison stations.

Sampling began in October, 1986 and is scheduled to continue on a seasonal basis throughout the next five years.

4. Summary of Results from the First Year of Study

Soft-bottom macrofaunal and meiofaunal assemblages occurring at different stations, at approximately the same depths, usually have similar faunal compositions. This relative constancy of community structure at a given depth is important in the context of the present monitoring program because it allows comparisons of impacts over broad regional areas and in relation to anticipated patterns of along-shelf current flows and sediment transport. Cluster analysis of soft-bottom benthic communities (both macrofauna and meiofauna) clearly show a high degree of faunal homogeneity among stations within the Platform Julius site-specific array. These data indicate that this sampling array is located in an appropriate region for monitoring short and long-term impacts of oil development and production activities on the benthos.

The Santa Maria Basin supports a very rich and highly diverse benthic infauna. Numbers of species and abundances of both the macrofauna and meiofauna exceed previously reported values for the area. Both the macrofauna and meiofauna exhibit an apparent pattern of decreasing species abundance and diversity with increasing water depth. These patterns were reported earlier in same general area during Phase I Reconnaissance Survey; however, the pattern of species diversity is at variance with results of other studies conducted along the Atlantic continental shelf and slope.

Several species of attached epifauna identified on low-relief and high-relief substrates at stations around Platform Hidalgo appear to have high enough abundances to permit repeated sampling and statistical assessment of drilling and production impacts. Species suitable for monitoring at low-relief stations are the corals *Paracyathus stearnsii* and *Caryophyllia* sp.(p.), the crinoid *Florometra serratissima*, and the ophiuroid *Ophiocantha diplasia*. Species suitable for monitoring at high-relief stations are the unidentified Anemone No. 25, and the corals *Desmophyllum crista-galli* and *Lophelia californica*. Occurrences of these species are not necessarily restricted to a single type of relief. Depth appears to be a strong determinant of the distribution and abundance of many of these attached hard-bottom species. However, within a given depth range, the presence of substrate relief appears to interact with the effects of depth. *Lophelia californica*, a suspension-feeding coral found predominantly on deeper, high-relief substrates, might be a particularly good indicator of stress caused by unnaturally high suspended sediment loads linked to drilling discharges.

Hydrocarbon and trace-metal distributions generally are uniformly low in sediments throughout the study area, and background levels do not reflect anthropogenic sources of contamination; therefore, the ability to detect drilling-related changes is good. Examination of hydrocarbon compositions and diagnostic ratios, however, has shown that sediments from 3 stations near Platform Hidalgo contain very small but detectable amounts of petroleum hydrocarbons, which might be linked to earlier exploration activities in the area. Particles resembling tar balls have been discovered in infaunal samples from all soft-bottom regional stations. Chemical analysis shows that this material is highly refractory and not characteristic of production oil. The source might be very old, weathered seep oil. The chemical composition of the material is very distinguishable from drilling-related sources of hydrocarbon contamination; therefore, its presence should not interfere with the ability to detect potential hydrocarbon signals associated with drilling activities.

Pb-210 dating of sediment cores indicates that sediments in the study area are actively accumulating suspended particulate matter from the overlying water column, thus, they can be expected to accumulate solids from platform discharges. Estimated sedimentation rates at the Platform Julius site, based on PB-210 dating, are in the range of 0.2 to 0.3 cm/year.

Pb-210 profiles show a mixed surface sediment layer that extends to a depth of about 8 to 10 cm, indicating substantial vertical mixing of sediments. These data are consistent with several other chemical and biological results: (1) uniform concentrations of metals throughout surface (0-2 cm) and subsurface (2-10 cm) sediments during both seasons sampled (October 1986 and January 1987); (2) uniform concentrations and compositions of all hydrocarbon parameters throughout surface and subsurface sediments during the January 1987 sampling; and (3) signs of strong disturbances of sediment features seen in core radiographs, as a result of the influence of deep-burrowing organisms. These combined data support the hypothesis that contaminants associated with drilling discharges that settle to the bottom may become mixed with subsurface sediments as a result of extensive bioturbation.

Current-meter records confirm predictions of a mean along-shelf current flow in both an upcoast and downcoast direction. These patterns are interrupted periodically by cross-shelf flows, of up to several days duration, that are associated with traveling eddies seen in satellite images. These variations in the direction of mean current flow support earlier decisions to select a semi-radial station design with a greater concentration of stations along isobaths both deeper and shallower locations to allow detection of possible contaminant movement across the shelf.

Several biological, physical and chemical parameters show clear signs of temporal variation between cruises. These results demonstrate the importance of conducting seasonal sampling before and after initiation of drilling activities, to provide the basis for differentiating between natural temporal variations in benthic community parameters and impacts due to drilling and production activities.

Companion laboratory studies (flume studies and substrate-choice experiments) on settling of larval invertebrates, performed on two species with contrasting life-history characteristics (*Capitella* sp. I and *Mercenaria mercenaria),* demonstrated differences in sediment preferences and selection capabilities. Presence of a layer of barite on sediment surfaces was also tested and found to have no effect on settlement of *Mercenaria* larvae. Initial experiments on settlement of these 2 species, and future work on settlement of other species, will be used to help interpret causes of potential drilling-related impacts on benthic communities observed during the time-series monitoring effort. In addition, studies will be performed to examine the degree to which activities of benthic organisms influence sediment and pollutant-transport processes.

Additional field measurements from side-scan sonar observations and moored instruments are being obtained and will provide data on near-bottom current flows and sediment movements in different sedimentary environments of the study area.

5. Conclusions

Results obtained during the first year of study provide a basis for beginning to understand environmental processes and relations that will be important in detecting and interpreting any subsequent impacts caused by oil and gas development and production activities in this region of the California OCS. Much of the predrilling chemical, physical, and biological data generated to date on this program demonstrate that impacts of discharges from oil and gas operations should be detectable, if they occur, and should be distinguishable from natural environmental variability.

Results of this study will be available for use in various decision-making steps of the California OCS Federal leasing program. Also, it is anticipated that these results will expand existing knowledge of basic oceanographic processes and ecological conditions of the central California OCS, and will provide information to help interpret results of future offshore monitoring programs conducted in other planning areas.

6. References

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley & Sons, New York, 257 p.

Science Applications International Corporation (SAIC). 1986. Assessment of long-term changes in biological communities in the Santa Maria Basin and Western Santa Barbara Channel - Phase I. Final Report Prepared for U. S. Minerals Management Service, Pacific OCS Region, Los Angeles, CA. Contract No. 14-12-0001-30032. Two volumes.

The National Status and Trends Program in Southern California: Some Recent Data and Potential Future Direction

Edward R. Long and Gary Shigenaka
Ocean Assessments Division, National Ocean Service
National Oceanic and Atmospheric Administration
United States Department of Commerce
7600 Sand Point Way N.E., Seattle, WA 98115

The National Status and Trends Program of NOAA was initiated in 1984 to provide information relevant to assessment of the current status of and recent trends in marine environmental quality in the nation's coastal and estuarine areas. Thus far, the Program has focused primarily upon measurement of toxic chemicals. Samples of sediments, bottomfish, and bivalves are annually collected and analyzed from selected sites in each coastal state around the country. A number of trace metals and organic compounds are measured in these samples.

There are currently six major projects supported by the National Status and Trends Program. The *Benthic Surveillance Project* is conducted by the National Marine Fisheries Service of NOAA and involves analyses of sediments and bottomfish at 50 sites nationwide, six of which are located in southern California. These six sites are shown in Figure 1. The *Mussel Watch Project* is conducted by Battelle Ocean Sciences laboratories, Science Applications International Corporation, and Texas A&M University at 150 sites around the country, 16 in southern California. The 16 sites are shown in Figure 2. Mussel Watch includes chemical analyses of both sediments and bivalves (mussels and oysters). A *Quality Assurance Project*, coordinated by the National Bureau of Standards, ensures that state-of-the-art and consistent methods are used throughout the Status and Trends Program. A *Specimen Bank Project*, or environmental sample archive, has been established at the National Bureau of Standards in Gaithersburg, Maryland, for long-term storage of sediment and tissue. This project will facilitate future analyses of Status and Trends Program samples using new methodologies, and provides temporal reference materials to compare subsequent measurements. A *Testing and Evaluation Project*, which is an ongoing effort to encourage and evaluate new measures of environmental quality, currently is focusing upon prospective measures of biological effects in a study being conducted in San Francisco Bay. Finally, a *Historical Trends Project* examines archived and newly acquired data from a wide variety of sources to evaluate spatial and temporal trends in contamination.

Three of the above activities have involved major efforts in southern California. The Benthic Surveillance Project has repetitively sampled most of the same six sites in southern California on an annual basis from 1984 through 1987. In addition, a prospective location in the Channel Islands Marine Sanctuary was sampled during 1987. Results of the first year (1984) of Benthic Surveillance have been published (NOAA, 1987a). The Mussel Watch Project began sampling a suite of southern California sites in 1986, with subsequent annual collections in 1987 and 1988. A new site on San Miguel Island was sampled in only 1988 to increase the level of effort within the Channel Islands Marine Sanctuary. The first year (1986) of Mussel Watch results have also been published (NOAA, 1987b). An evaluation of historical geographic and temporal trends in southern California marine environmental contamination is underway (see accompanying paper by Mearns and Shigenaka), and a NOAA Technical Memorandum on the subject will be available in the latter part of 1988.

Examination of available results from the Benthic Surveillance and Mussel Watch Projects yields consistent observations of some regional trends. For example, sediments and biota in the southern California region show a high degree of contamination by DDT, with the highest levels occurring near the Palos Verdes Peninsula. Results of measurement of DDT in southern California resident mussels in 1986 are illustrated in Figure 3. Concentrations were highest in the Los Angeles area sites and decreased with increased distance from that area. Mean concentrations measured by the 1984 Benthic Surveillance Project in sediment and in liver tissue of bottomfish collected offshore from Palos Verdes ranked among the highest obtained nationwide by the Project for that year. The source of the contamination has been identified by several authors (see, for example, Smokler *et al.*, 1979) and the County Sanitation District of Los Angeles County as a chemical manufacturing facility located in Torrance, California. The plant discharged DDT production wastes into the LA County treatment system until 1970. Despite cessation of direct inputs, the persistence of DDT in the environment means that the pesticide and its derivatives will continue to be measured in relatively large, but decreasing amounts, in subsequent years of Status and Trends sampling.

Concentrations of polychlorinated biphenyls (PCBs) measured in 1986 in mussels in southern California by the National Status and Trends Program are illustrated in Figure 4. PCBs were found in high concentrations in San Diego Harbor by the Mussel Watch Project. Much lower concentrations were found in mussels from coastal and island sites away from San Diego and Los Angeles. In 1984, Benthic Surveillance found elevated PCB concentrations in both sediments and bottomfish livers in San Diego Harbor, thus corroborating the findings with mussels. Investigations by the San Diego Regional Water Quality Control Board in 1984 and 1985 traced the source of the PCB contamination to an aeronautical facility adjacent to San Diego International Airport. Remedial actions have been proposed to control and/or remove PCB contaminated sediments; however, because of the chemical stability of PCBs, these compounds, like DDT in the Palos Verdes region, can be expected to remain in the environment for some time into the future.

Examination of analytical results for concentrations of trace metals in mussels offers general insights into sources and distribution in southern California. Selected results from Mussel Watch Project analyses are shown as Figures 5 and 6. Lead was elevated in concentration at sites in Anaheim Bay and Marina del Rey, and lowest at Santa Cruz Island (Figure 5). Sites at which mussels contained elevated levels of lead were generally associated with heavily urbanized areas and regions receiving large amounts of stormwater runoff. Coastal locations removed from major population centers and offshore islands showed relatively lower concentrations of lead in resident mussels. Silver concentrations were highest in mussels from Point Dume, Point La Jolla, and Royal Palms and lowest at San Pedro (Figure 6). Silver is known as a constituent of sewage effluent, which may account for higher levels in mussels collected near outfall systems. However, the elevated concentration encountered at Point Dume is not as easily explained and may warrant closer examination if it persists in the future.

The National Status and Trends Program intends to add a selection of biological tests to its activities, in order to further assess the impacts of environmental contamination on living resources in coastal and estuarine waters. Based upon results from the San Francisco Bay experiment presently under evaluation, measures of sediment toxicity, and fish and mussel health, may be incorporated regionally or nationally into the Program. Such measures could be used for more detailed assessments of locations shown by recent Program data to be most contaminated, such as the areas in and around Long Beach Harbor or San Diego Harbor. The Channel Islands represent prospective reference sites in such assessments.

In summary, the National Status and Trends Program encompasses a wide range of activities in the southern California region and around the country. In addition to ongoing monitoring projects, the Program also supports new research into indicators of environmental health, and the means to evaluate past collections of data. Continuing refinement of the National Status and Trends Program will improve the reliability, relevance, and usefulness of information made available for scientists, decision makers, and members of the public with an interest in marine environmental quality of the nation's coastal and estuarine areas.

References

National Oceanic and Atmospheric Administration. 1987a. National Status and Trends Program for Marine Environmental Quality: Progress report and preliminary assessment of findings of the Benthic Surveillance Project - 1984. Rockville, Maryland: Ocean Assessments Division, NOS/NOAA. 81 pp.

National Oceanic and Atmospheric Administration. 1987b. National Status and Trends Program for Marine Environmental Quality progress report: A summary of selected data on chemical contaminants in tissues collected during 1984, 1985, and 1986. NOAA Technical Memorandum NOS OMA 38. Rockville, Maryland: Ocean Assessments Division, NOS/NOAA. 23 pp. and appendices.

Smokler, P.E., D.R. Young, and K.L. Gard. 1979. DDTs in marine fishes following termination of dominant California input: 1970-1977. *Marine Pollution Bulletin* 10: 331-334.

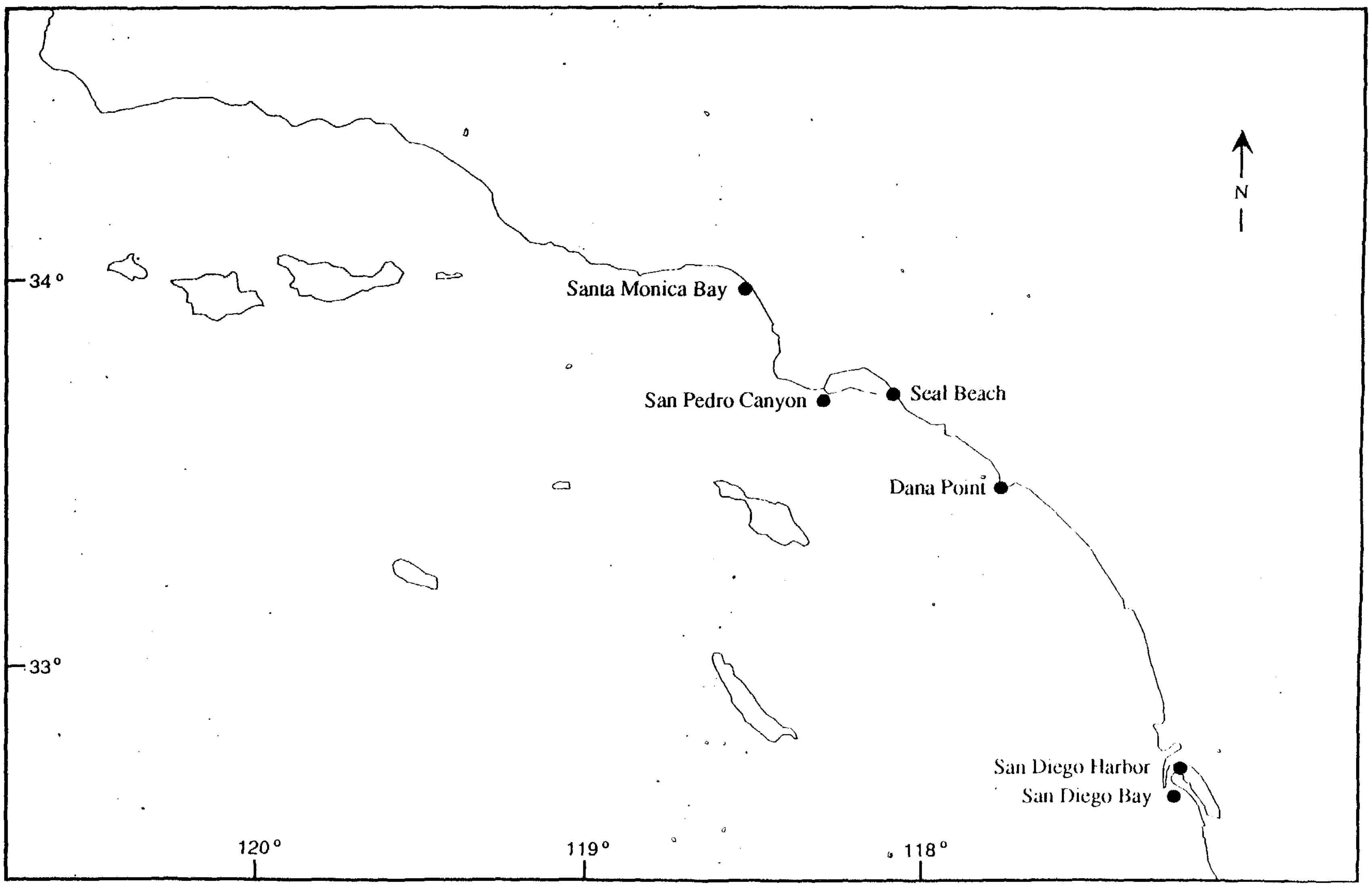


Figure 1. Location of 1984 National Status and Trends Program Benthic Surveillance Project site locations in the Southern California Bight. Source: NOAA, National Status and Trends Program.

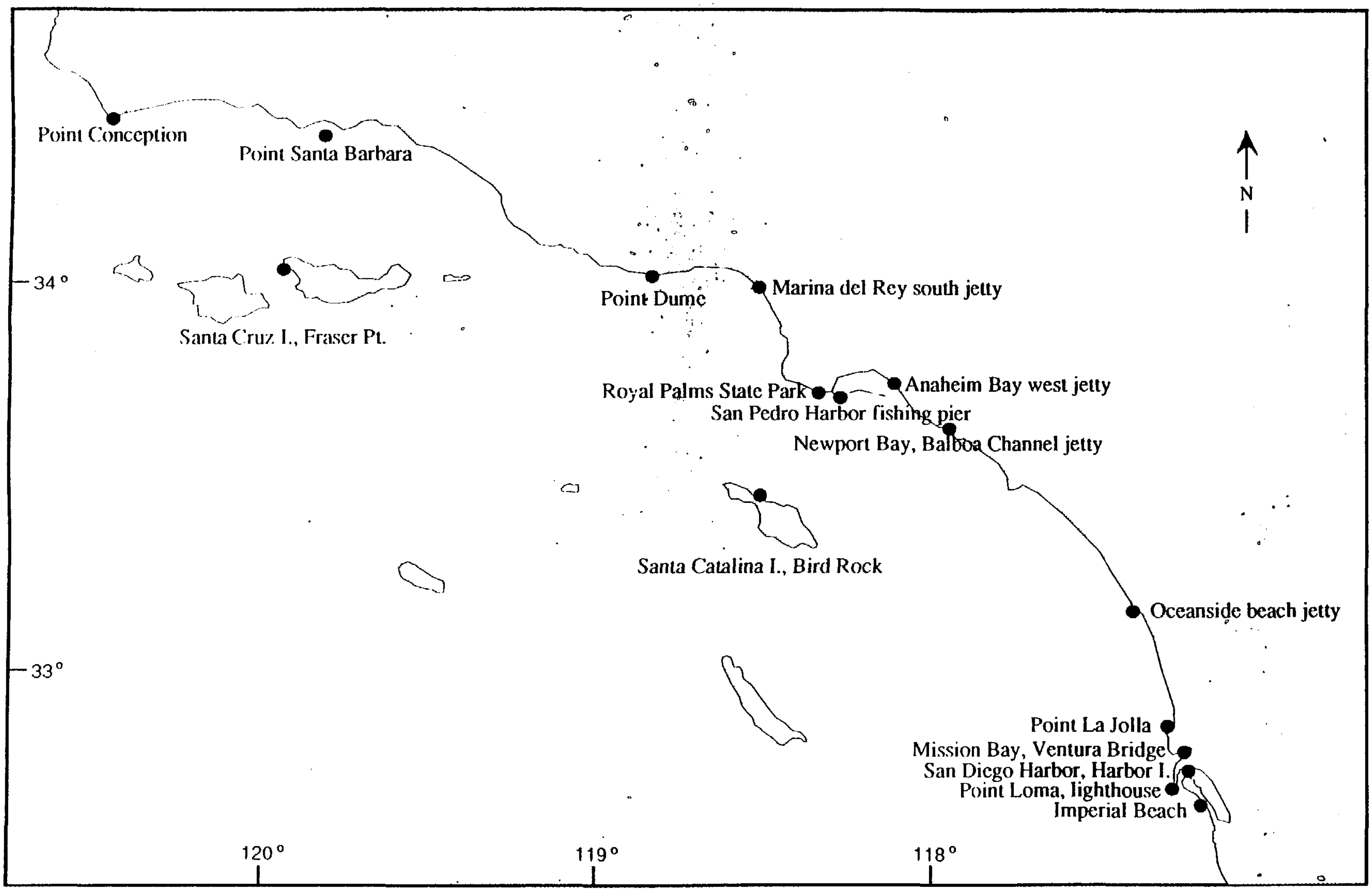


Figure 2. Location of 1986 National Status and Trends Program Mussel Watch Project site locations in the Southern California Bight. Source: NOAA, National Status and Trends Program.

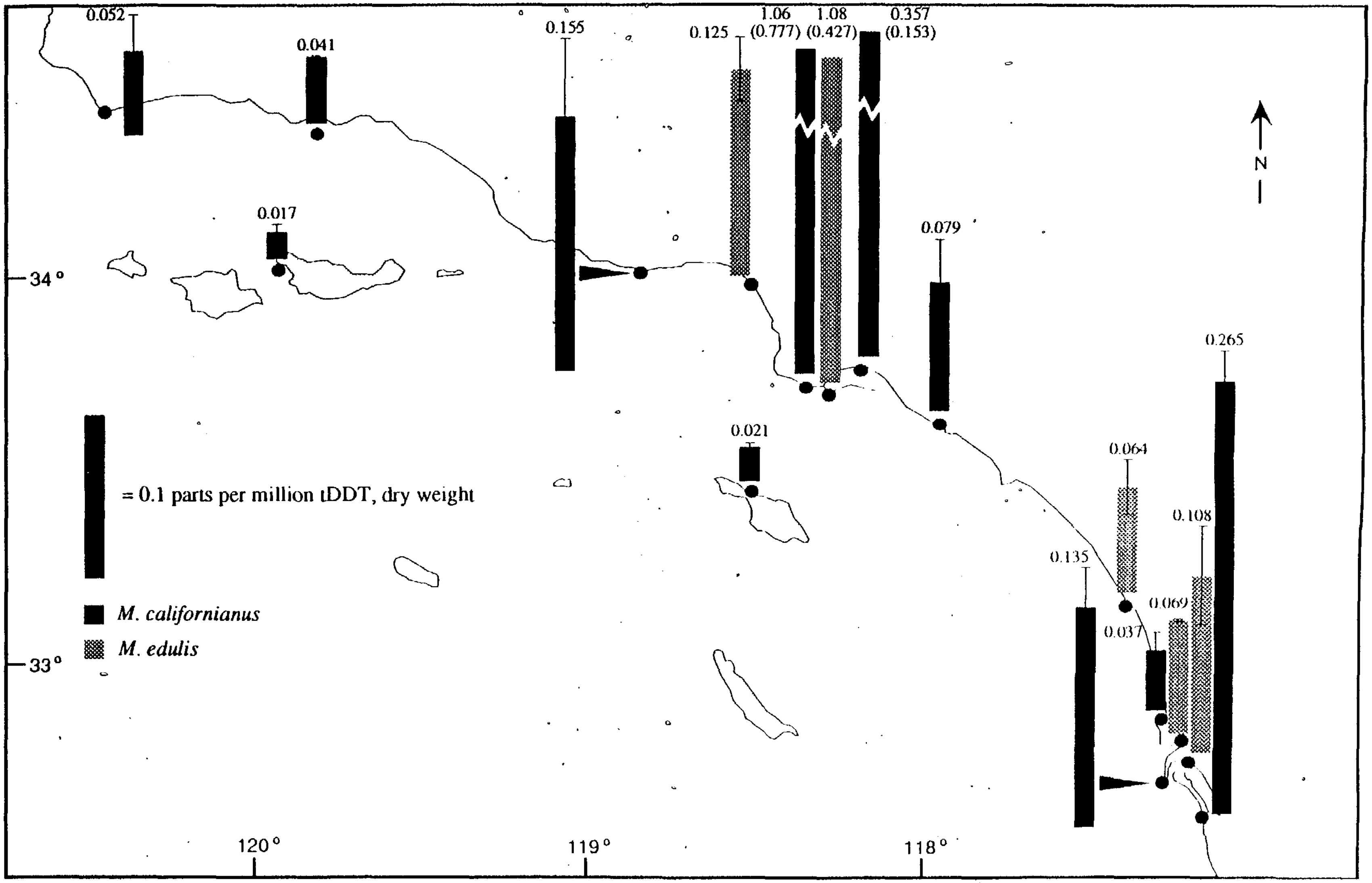


Figure 3. Concentrations of total DDT measured in M. californianus and M. edulis mussels collected in the Southern California Bight in 1986. Source: NOAA, National Status and Trends Program.

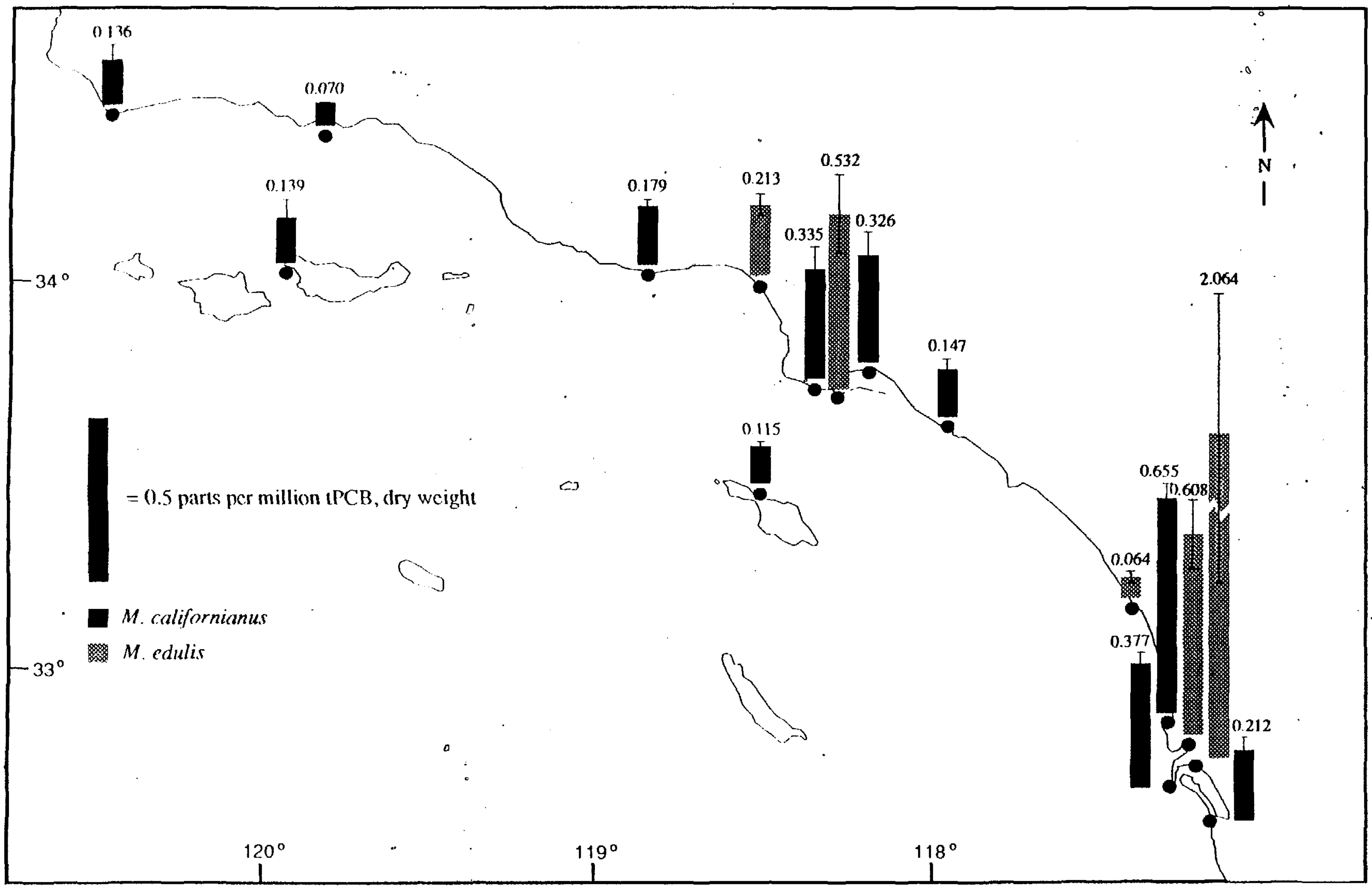


Figure 4. Concentrations of total PCB measured in M. californianus and M. edulis mussels collected in the Southern California Bight in 1986. Source: NOAA, National Status and Trends Program.

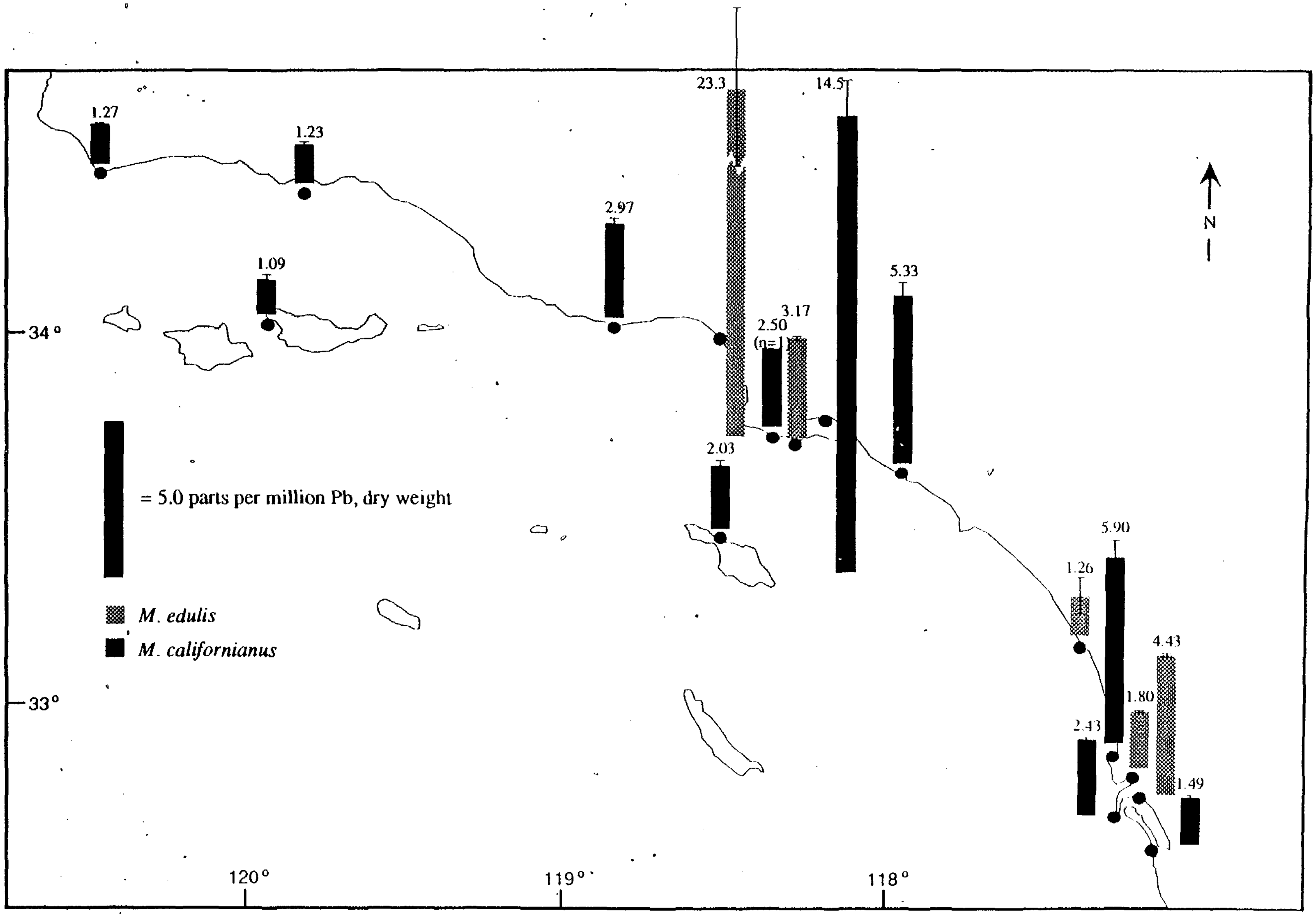


Figure 5. Concentrations of lead measured in M. californianus and M. edulis mussels collected in the Southern California Bight in 1986. Source: NOAA, National Status and Trends Program.

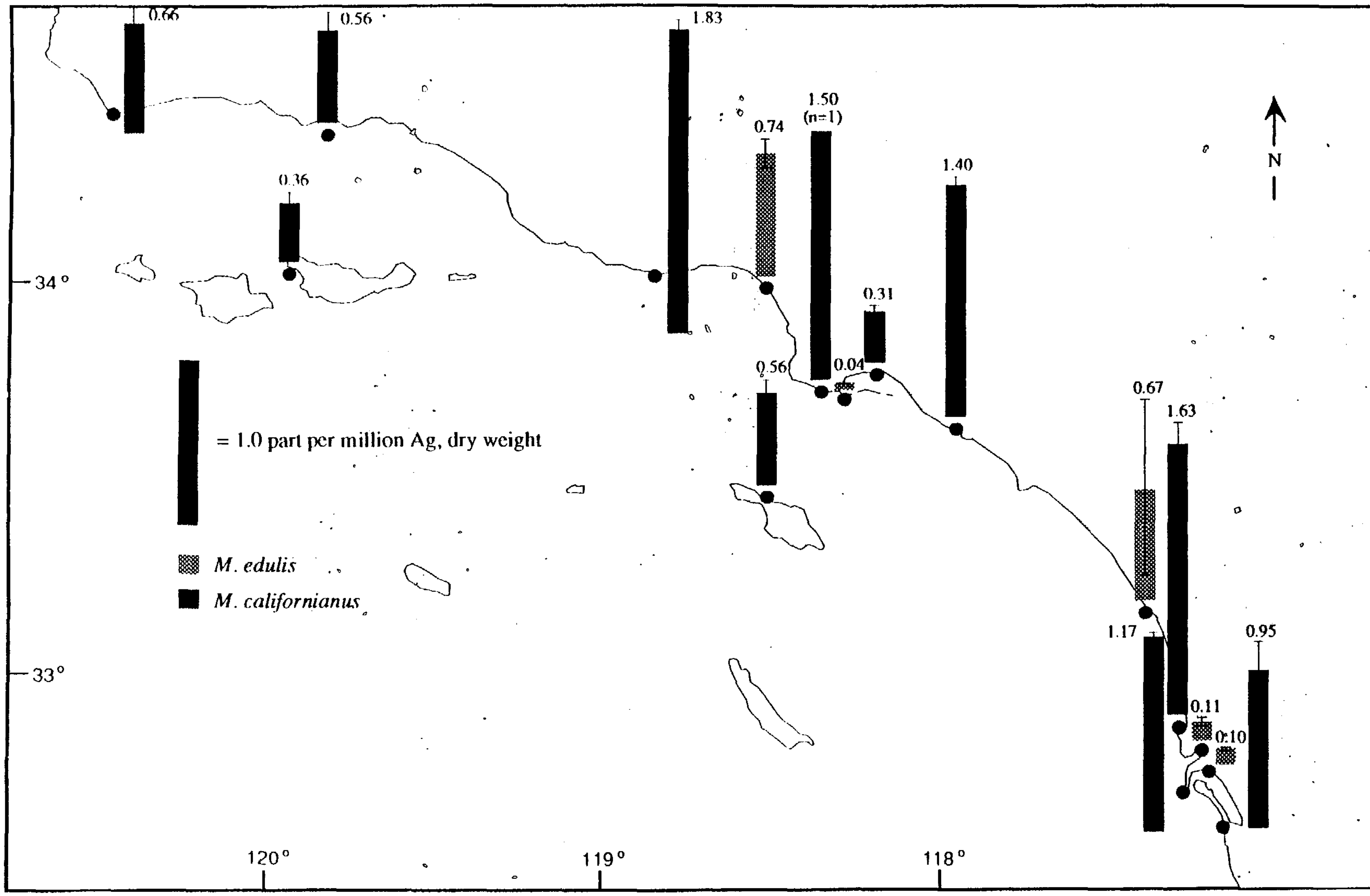


Figure 6. Concentrations of silver measured in M. californianus and M. edulis mussels collected in the Southern California Bight in 1986. Source: NOAA, National Status and Trends Program.

Oceanographic, Contaminant and Ecological Trends of the Santa Barbara Coast

Alan J. Mearns and Gary Shigenaka
Pacific Office, Ocean Assessments Division
National Oceanic and Atmospheric Administration
7600 Sand Point Way, N.E., Seattle, Washington 98115

Introduction

The Channel Islands and adjacent areas of the Southern California Bight (Figure 1) have been the subject of marine research and exploration since Juan Cabrillo first visited the region in 1500s. Richard Dana was a careful observer of marine life when he explored the area in 1836 (Dana, 1840). When the U.S. Fish Commission steamer *Albatross* pulled into the Channel Islands area in 1890, the staff was amazed at the extent of oil slicks in the area, took numerous samples of sediment and marine life and feasted on rockfish using lobster as bait (Rathbun, 1894). Since then, southern California marine scientists have explored the region in detail, providing much of our general understanding of the oceans and how they work.

Indeed, some of our most fundamental understanding of the coastal seas, fisheries and pollution come from recent research and monitoring investigations in this area. For example, the Channel Islands themselves are nearly in the center of the extensive surveillance grid of the California Cooperative Oceanic Fisheries Investigations (CalCOFI), which has been surveying the area for over 30 years. Due to anoxic conditions below sill depth in the Santa Barbara basin, scientists have been able to document and date with great accuracy over 2000 years of history of California Current fish stocks (Soutar and Isaacs, 1969), plankton dynamics and climatological events, and nearly 100 years of pollution history including trends in metals, pesticides and other contaminants.

This vast fund of knowledge should give us pretty good clues about how man and nature have responded to one another in this major coastal zone. NOAA is contributing to this knowledge in several ways. Most notable is the leading role of the National Marine Fisheries Service in the CalCOFI program, the most extensive and longest running marine fisheries investigation in the U.S. Next, the entire region is currently included in NOAA's National Status and Trends (NS&T) Program, as outlined by Ed Long in this Symposium. In addition, however, NOAA's Ocean Assessments Division (OAD) has been conducting several studies in an attempt to understand pollutant trends and their possible impact on fisheries and marine life of the Southern California Bight.

This report presents examples of some of the trends, patterns and effects of marine pollution currently under investigation in the Southern California Bight in general, and the Santa Barbara area in particular, by OAD staff and funded scientists. For convenience, the information is organized by type of study. The principal studies include: (1) a major review of chemical contaminant trends in fish, shellfish and sediments of the Southern California Bight; (2) a statistical study to determine relationships between longterm fluctuations in stocks of pelagic fish (anchovy, mackerel and sardine) with trends in pollution inputs and environmental conditions; (3) a study to determine the extent to which reproduction in nearshore fish may be impacted by pollutants; and, (4) a review of longterm trends in occurrences of unusual organisms, mass invasions and episodic events along the coast.

Contaminant Trends

The Bight in general, and the Santa Barbara/Channel Islands area in particular, is world-famous as an area of contamination by the pesticide DDT. However, DDT is just one of the many contaminants that have entered these coastal waters for decades through sewage, runoff and direct aerial fallout. Through the California Mussel Watch Program, the state has monitored contaminant trends for over a decade, and now the NOAA NS&T Program is doing so as well, with the added benefit that these data can be placed in a national context.

In addition, there is a considerable history of contaminant monitoring by other agencies and covering several decades prior to these ongoing programs. Our office in Seattle is attempting to collate these historical surveys and place current patterns and trends of contamination into a historical perspective.

We can identify over 5000 samples of plankton, seaweeds, shellfish, sharks, rays, finfish, birds and mammals that have been collected throughout the Southern California Bight since 1940 and analyzed for chlorinated pesticides, polychlorinated biphenyls (PCBs), radionuclides and trace metals in over 50 research and/or monitoring survey efforts. To get some idea how data are distributed, we present in Figure 2 a breakdown of the distribution of DDT and PCB data by species for the U.S. west coast. Assessments already completed (Matta *et al.*, 1986; Mearns and O'Connor, 1985) clearly demonstrate that DDT contamination of marine life in the Bight and the Santa Barbara area increased during the 1950s, reached a peak in the late 1960s and has since declined (Figure 3). Contamination occurred throughout the Bight and through the entire food web. Many species of commercially important fishes in and around the Santa Barbara area were once contaminated at concentrations that far exceed current regulatory action levels. Some of these older data are shown in a national context in Figure 4. Although DDT has declined on a national as well as local scale, coastal fish and mussels of the Southern California Bight remain among the most contaminated in the nation (Figures 5 and 6).

Marine life also apparently accumulated measurable concentrations of radionuclides from nuclear bomb testing in the 1950s and early 1960s; by 1971, however, levels in resurveyed mussels had dropped below detection (Young and Folsom, 1973).

Levels of lead and several other trace elements in mussels have also declined during the past decade (Figure 7).

In addition to defining spatial and temporal trends, these contaminant data have been and continue to be used to explore basic processes of contamination, including biomagnification, *i.e.*, the successive build-up of contaminants through food chains. It is now clear from existing assessments that pollutant biomagnification may be the exception rather than the rule: of 10 trace elements investigated in coastal and pelagic food webs of the Bight, Young *et al.* (1987) demonstrated that only one -- mercury -- clearly increased in concentration through regional food chains; several did not, and others actually decreased with increasing trophic level (Figure 8)!

Much has yet to be done to pull together existing data, especially for PCBs, metals and petroleum hydrocarbons. In our Southern California Bight report, due in late spring, we do not isolate out the Santa Barbara area for specific study, but rather let the data fall where they may. This will help others identify where gaps exist and need to be filled.

Oceanographic Trends and Marine Life

Dana related how the climate of southern California improved between 1835-37 and his revisit in 1859. Scientists and government agencies have been monitoring oceanographic and climatological trends on a steady basis in the Southern California Bight since tide gages were first installed at San Diego and Los Angeles near the turn of the century. Indeed, the oceanography of the Bight is perhaps better known than in most other ocean areas of comparable size. A key feature of the region's oceanography that is now clearly understood to drive fishery stock fluctuations is the occurrence and persistence of longterm, low frequency events such as El Niño. This and other episodic events occur several times a decade and affect everything from sea surface temperature, salinity, transparency and runoff volumes, to production of plankton, kelp, fish and bird populations. During the past several years, the senior author attempted to add to this knowledge by looking at impacts of climate and oceanographic changes on occurrences of unusual organisms, mass strandings and mass invasions. It is clear that the Bight, as well as much of the west coast, has experienced major changes in marine life in association with episodic low-frequency increases and decreases in sea surface temperature and sea level (Figure 9). During the 1850s and 1860s, marine life in the region was decidedly more tropical than in subsequent decades. The cooling that followed, and a subsequent warming since 1976, was punctuated by more than a dozen events that brought in tropical or sub-arctic organisms. Many of these events and occurrences took place in the Santa Barbara area. In short, the region is not at all insured of a constant and predictable fauna. The appearances of unusual species, if closely monitored, can signal the onset of unusual oceanographic conditions.

Fishery Stocks and Pollution

What has been the impact, if any, of pollution on fishery stocks of the Bight and the Santa Barbara area?

Several years ago, OAD sponsored a statistical study of historical trends in fish stocks and pollution indicators in five northeast U.S. estuaries. Stock indices were developed for nearly 50 species of fish and invertebrates and compared with indices of pollution and development over a 4 to 6 decade period. The results suggested that certain species which were highly dependent on estuarine conditions suffered stock declines and increases in concert with changes in organic loading and development of estuaries, while other less estuarine dependent species were not affected by other than climatological variations.

We wanted to know if this approach would work for coastal fisheries stocks. The best longterm data for stocks, climatology and pollution inputs was from the Southern California Bight. The NMFS Southwest Fisheries Center at La Jolla agreed to take on the task of assembling the pieces and testing for trend associations.

Although that work is now nearing completion, the final answer is yet to come. In the interim, the project has several major accomplishments to its credit. Foremost among these is the extensive collation and use of CalCOFI egg, larval, juvenile and environmental data that have now been assembled for a four-decade period in one data base (MacCall and Prager, 1987; Prager and MacCall, 1986). Equally important has been an effort for the first time to place confidence limits about historical estimates of stock sizes (Prager and MacCall, in press). This has never before been done for a marine fishery stock and will place important limits on subsequent conclusions about forces that might and might not have driven stocks of sardine, mackerel and anchovy to near demise over the past half century.

An equally important current result of the project, performed under subcontract, is the compilation of pollutant input data. Four to five decades of pollutant and contaminant trends have been assembled into a data base (Summers *et al.*, 1987) and explored for coincident and disparate patterns. The next step--comparing the pollutant, environmental, and stock trends--is now underway. This, plus the incidental products mentioned above, should provide new insight into the extent to which pollution may have affected regional stocks, identify how monitoring could be improved and provide a more compact regional oceanographic data base than has previously existed for the region.

Parallel to this activity, OAD has also sponsored a very specific project to determine the extent to which current levels of contamination may be affecting the ability of coastal fish to reproduce. Using a suite of biochemical, physiological and genetic indicators, Drs. Jeffrey Cross of the Southern California Coastal Water Research Project (SCCWRP) and Jo Ellen Hose of Occidental College have followed white croaker and sand bass stocks at polluted and reference sites and compared reproduction indices with pollutant levels. It is clear that at the upper end of PCB and DDT levels existing today in these fish, their ability to reproduce has been impaired. Markers and indices of reproductive damage may be useful to assess the reproductive health of fish in other coastal areas. For example, there is a strong correlation between occurrences of micronuclei (a result of chromosomal breakage in blood cells of white croaker) and mixed function oxidase activity (a measure of the metabolic processing of toxic substances) (Hose *et al.*, 1987).

Conclusion and Implications for the Future

Man's future accommodation to life in the Southern California Bight may depend on how well he heeds the signals of both his own actions and those of nature. There is no question that marine life in the Bight is subject to these dual forces with the major source of variability being longterm and interannual. The lesson, summarized in Figure 10, is that both sides of the ocean variability - waste management equation need to be watched, monitored and researched.

There is a tremendous wealth of existing information that can and should be used to assess the history of health of the Southern California Bight and the Santa Barbara coastal area and to help identify needs for new information and monitoring. Much of the data is being assembled for other purposes but much remains unpublished and in old files and boxes. It is critical that these data be identified, captured and re-archived into at least a regional system before the corporate memory of the scientists and agencies who collected the data is lost. This should be a high priority item among the Channel Islands Marine Sanctuary planning activities.

References

Dana, R. 1840. *Two Years Before the Mast*. London: J.M. Dent and Sons, Ltd., 1969. 346 pp.

Duke T.W., and A.J. Wilson, Jr. 1971. Chlorinated hydrocarbons in livers of fishes from the northeast Pacific Ocean. *Pest. Mon. J.* 5(2): 228-232.

Hose, J.E., J.N. Cross, S.G. Smith, and D. Diehl. 1987. Elevated circulating erythrocyte micronuclei in fishes from contaminated sites off southern California. *Mar. Env. Res.* 22: 167-176.

MacCall, A.D., and M.H. Prager. 1987. Historical abundance indexes for six fish species off southern California, based on CalCOFI larva samples. Admin. Rpt.LJ-

87-18, Southwest Fisheries Center, NMFS, La Jolla, CA. 45 pp.

Matta, M.B., A.J. Mearns, and M.F. Buchman. 1986. Trends in DDT and PCBs in U.S. West Coast fish and invertebrates. Seattle, WA: OAD/OMA/NOAA, 95 pp.

Mearns, A.J. 1988. The "odd fish": Unusual occurrences of marine life as indicators of changing ocean conditions. In *Marine Organisms as Indicators*, D.F. Soule and G.S. Kleppel (eds). New York: Springer-Verlag, pp. 137-176.

Mearns, A.J., and T.P. O'Connor. 1984. Biological effects versus pollutant inputs: The scale of things. In *Concepts in Marine Pollution Measurements*, H.H. White (ed). College Park, MD: University of Maryland UM-SG-TS-03, pp. 693-721.

NOAA. 1987. National Status and Trends Program for Marine Environmental Quality: Progress Report -- A summary of selected data on chemical contaminants in tissues collected during 1984, 1985 and 1986. NOAA Tech. Mem. NOS OMA 38. Rockville, MD: OAD/OMA/NOS/NOAA, U.S. Department of Commerce. 22 pp. and append.

Prager, M.H., and A.D. MacCall. 1986. An environmental data base describing coastal southern California in the years 1920 - 1984. Part 1: Procedures and summaries. Admin. Rpt. LJ-86-31, Southwest Fisheries Center, NMFS, La Jolla, CA. 40 pp.

Prager, M.H., and A.D. MacCall. In press. Sensitivities and variances of virtual population analysis as applied to the mackerel, *Scomber japonicus*. *Can. J. Fish. Aquat. Sci.* 44.

Rathbun, R. 1894. Summary of the fishery investigations conducted in the North Pacific Ocean and Bering Sea from July 1, 1888 to July 1, 1892 by the U.S. Fish Commission Steamer *Albatross*. *Bull. U.S. Fish Comm.*, 12.

Soutar A., and J.D. Isaacs. 1969. History of fish populations inferred from fish scales in anaerobic sediments off California. CalCOFI Report 13. pp. 63-70.

Stout, V.F., and F.L. Beezhold. 1981. Chlorinated hydrocarbon levels in fishes and shellfishes of the northeastern Pacific Ocean, including the Hawaiian Islands. *Mar. Fish. Rev.* 43(1): 1-13.

Summers, J.K., C.F. Stroup, and V.A. Dickens. 1987. A retrospective pollution history of southern California. In *Proceedings, Oceans '87*. IEEE 87-CH 2498-4. New York, pp. 1641-1645.

Young, D.R., A.J. Mearns, and T.K. Jan. 1987. The cesium:potassium index of food web structure and biomagnification of trace elements in a polluted harbor of southern California. In *Proceedings of the International Conference on Heavy*

Metals in the Environment, Vol. 2, S.E. Lindberg and T.C. Hutchinson (eds). Edinburgh, UK: CEP Consultants, Ltd., pp. 74-76.

Young, D.R. and T.R. Folsom. 1973. Mussels and barnacles as indicators of the variation of ^{54}Mn, ^{60}Co and ^{65}Zn in the marine environment. In *Radioactive Contamination of the Marine Environment, Proceedings.* Vienna: International Atomic Energy Agency (IAEA), pp. 633-650.

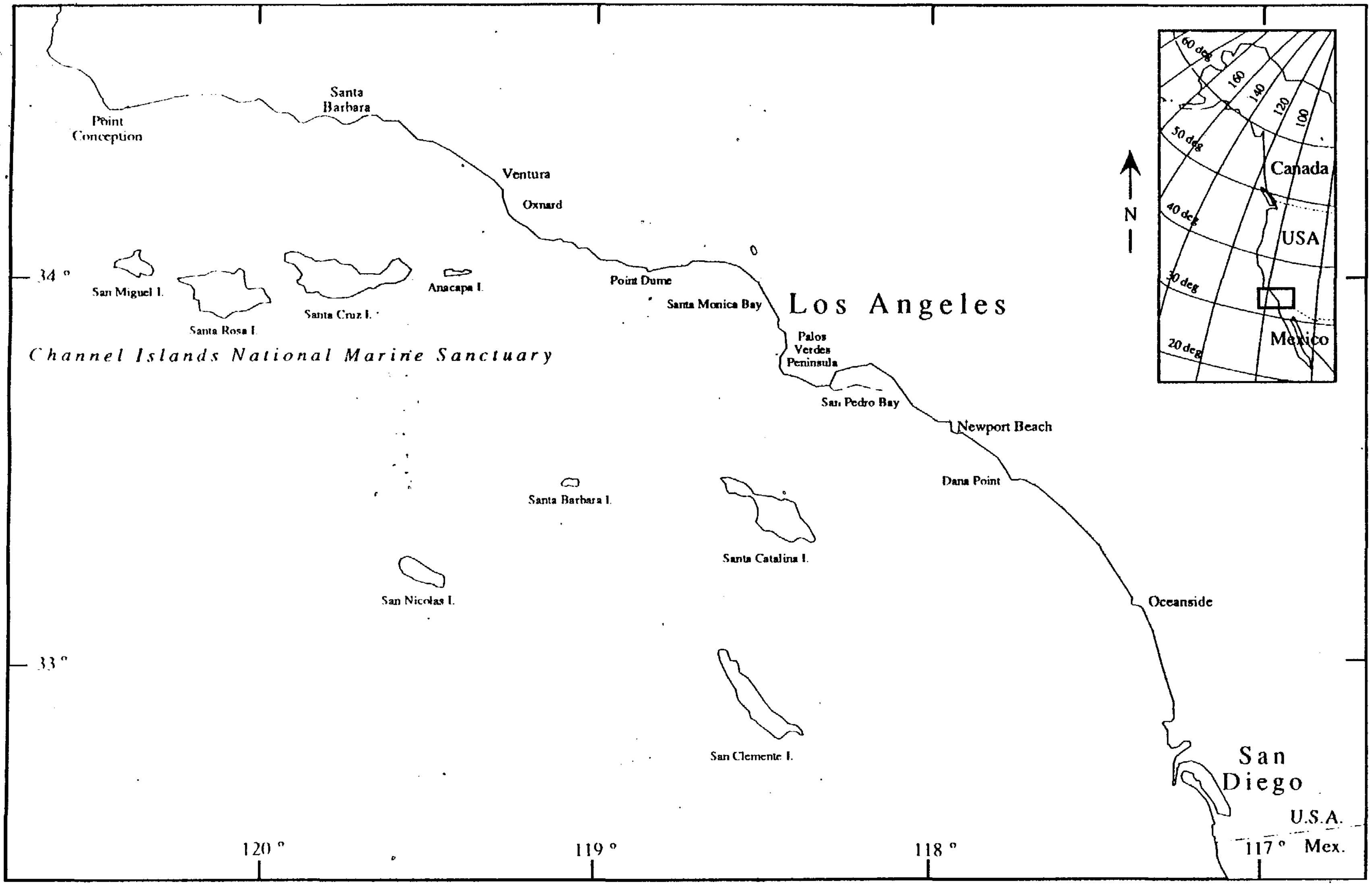


Figure 1. General map of the Southern California Bight, showing major features and cities.

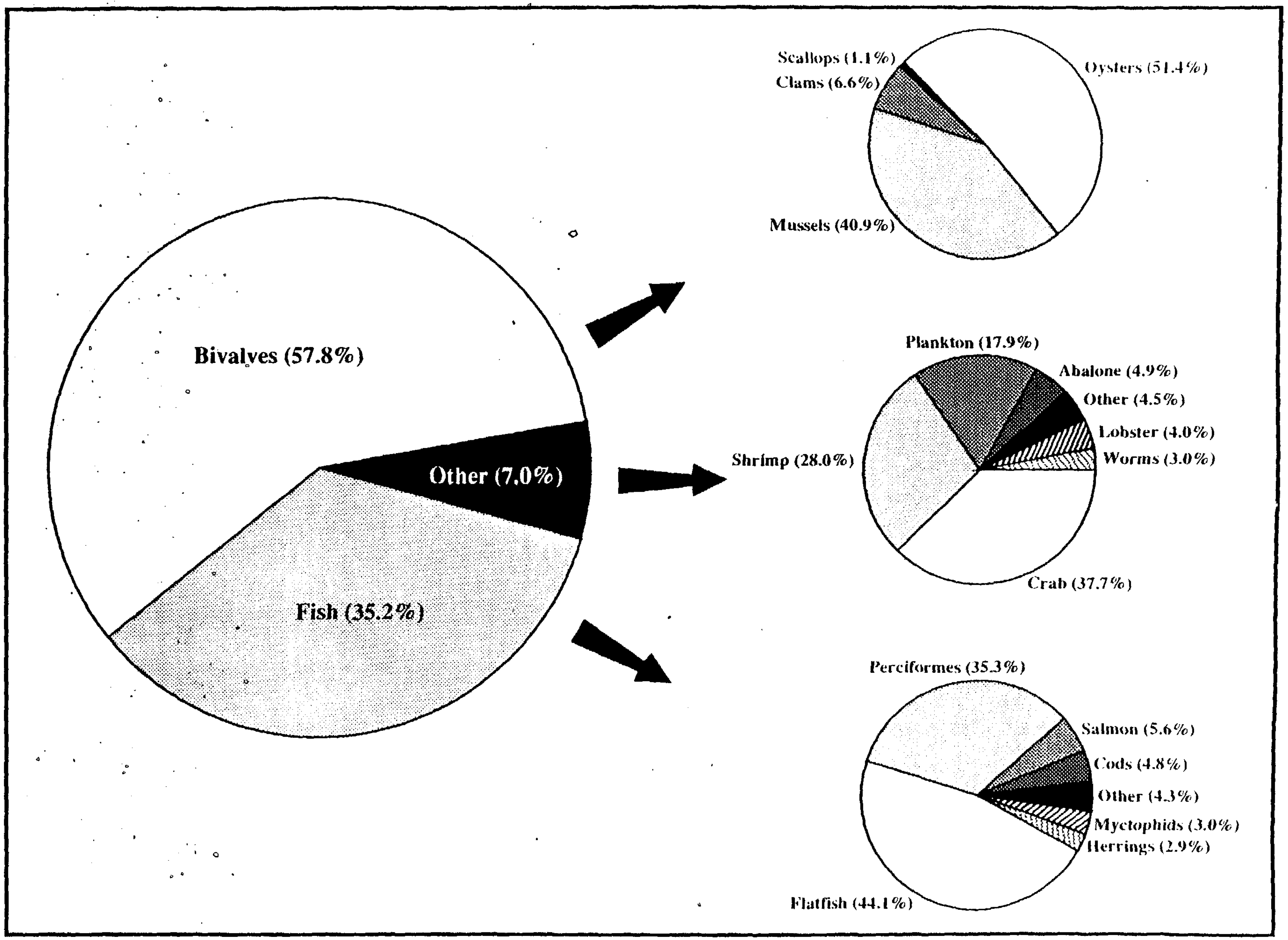


Figure 2. Distribution by taxa of data on DDT and PCBs in 4800 samples of fish and shellfish from the U.S. west coast. One third of these originated in the Southern California Bight. From Matta et al. (1986).

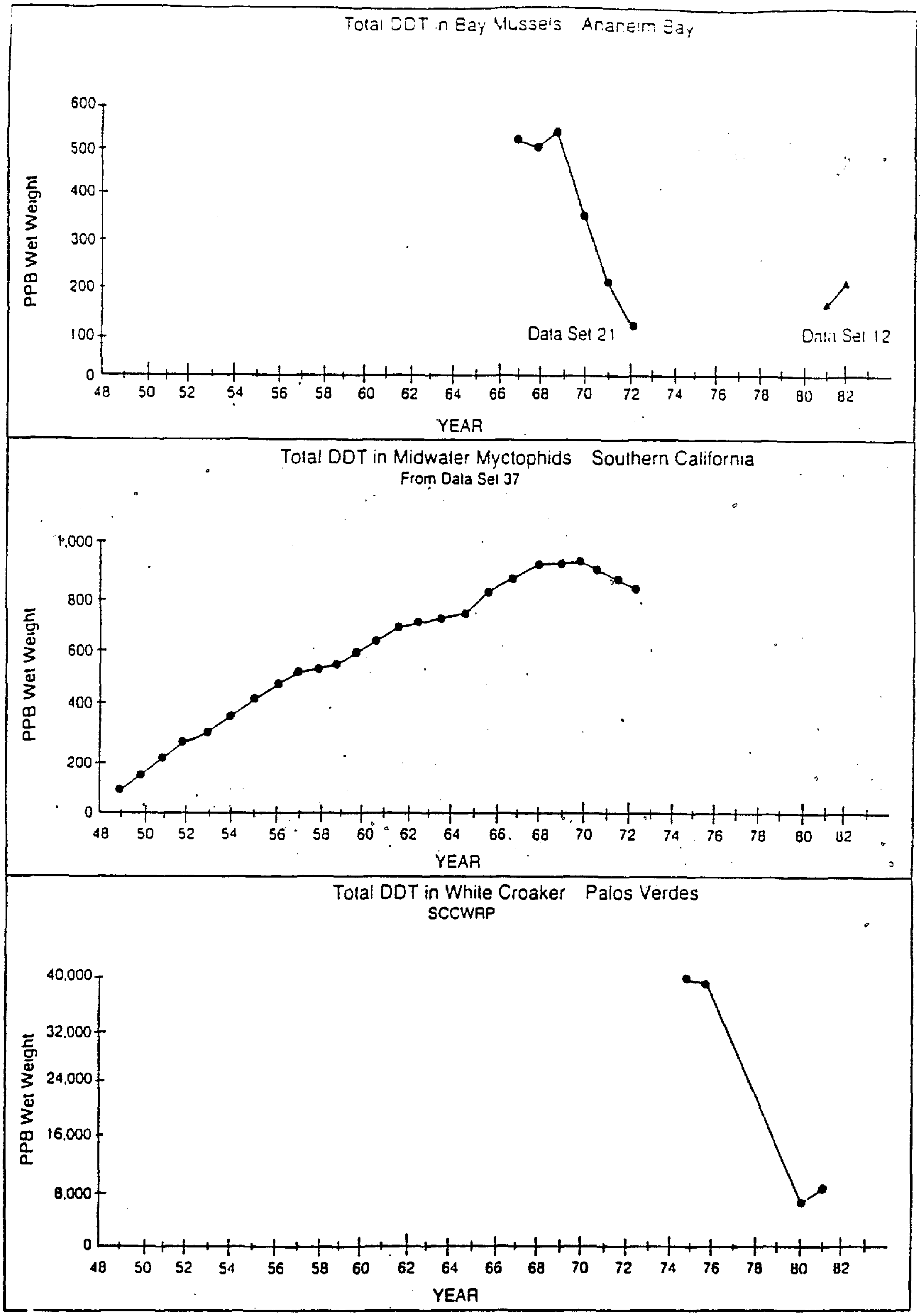


Figure 3. Trends of DDT contamination in three southern California species. From data sets described in Matta et al. (1986).

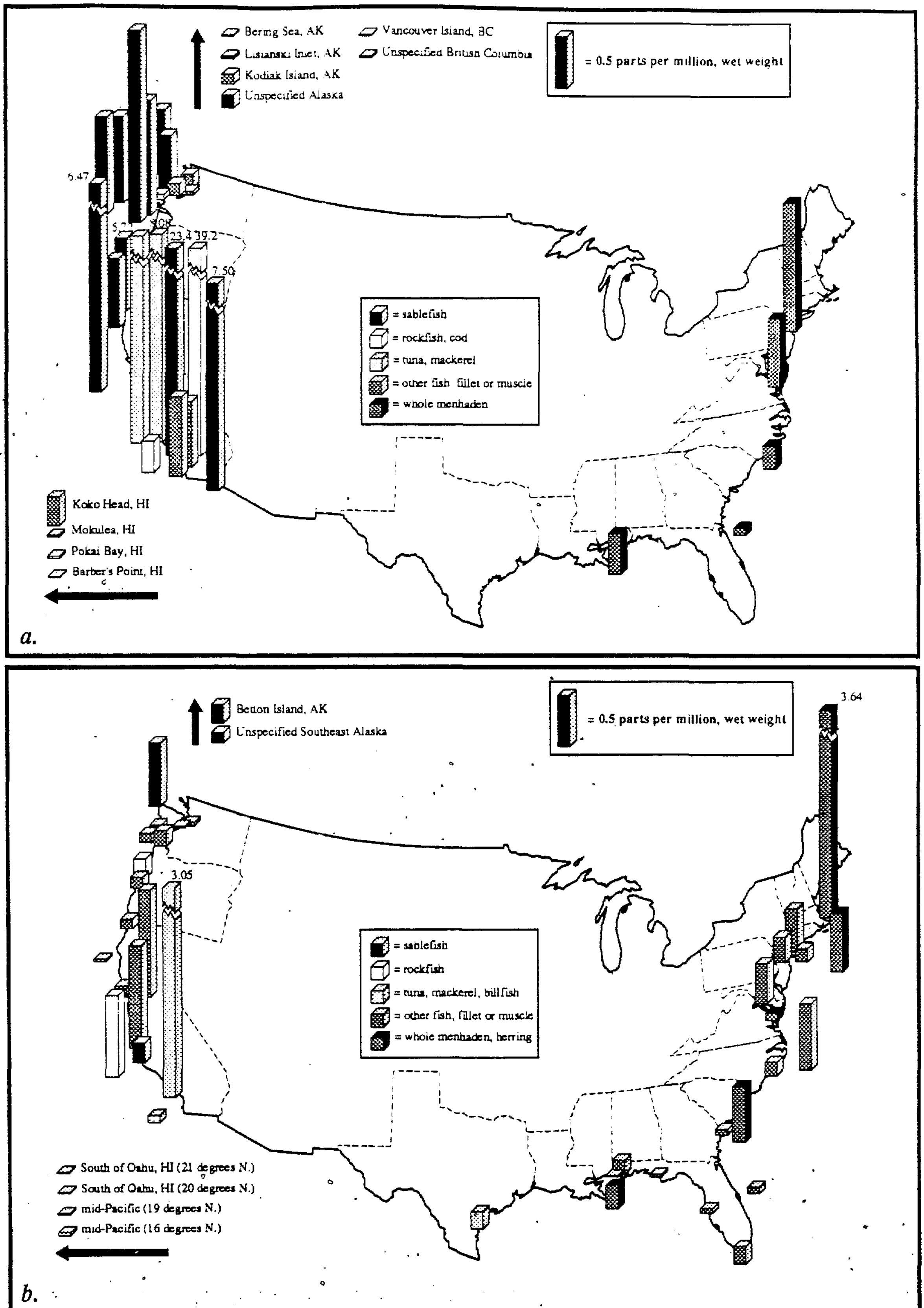


Figure 4. Total DDT in fillets (muscle of many species) or whole fish (menhaden) for (a) 1969-71, and (b) 1972-75. Bar represents given mean or mean computed from original data. Compiled from original data supporting Stout (1980); Stout and Beezhold (1981); and Stout et al. (1981).

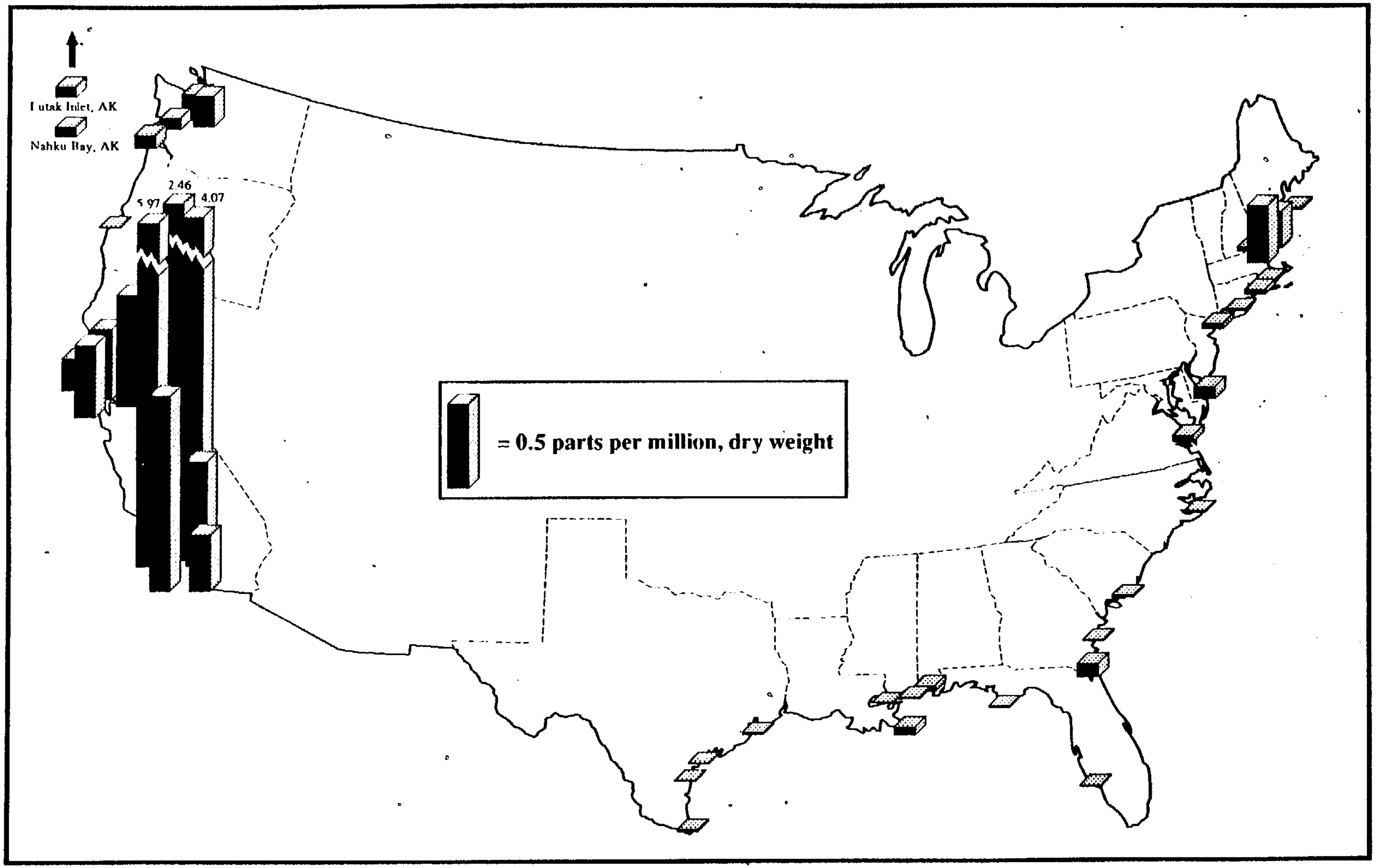


Figure 5. Total DDT in liver of estuarine fish composites collected at 42 sites in 1984. Computed from original data for the 1984 NOAA National Status and Trends Program, Benthic Surveillance Project supporting NOAA (1987). Bar represents mean of 1 to 5 composite values (approximately 30 fish per composite). Species differ among sites.

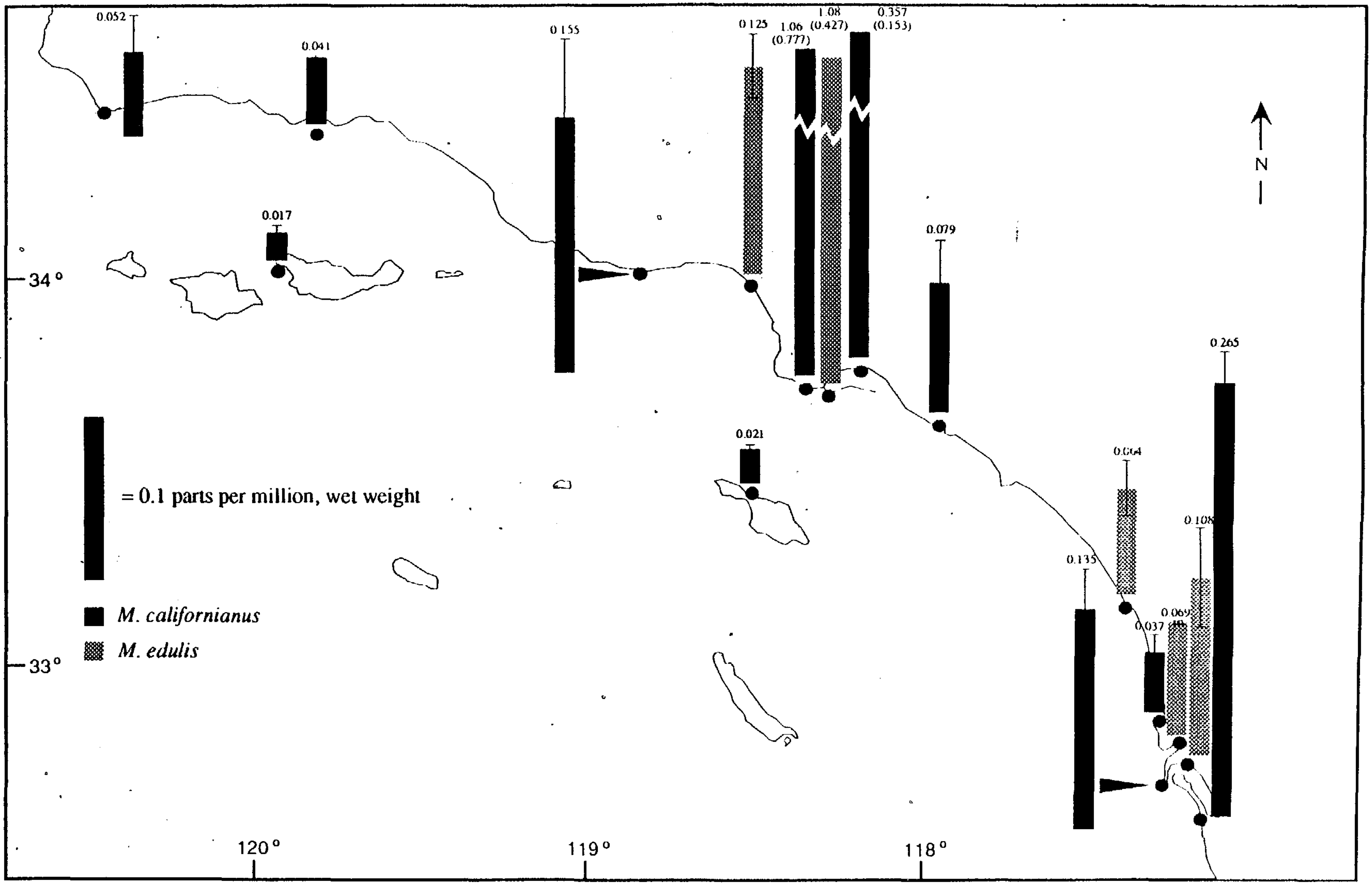


Figure 6. tDDT in whole soft body tissue of M. californianus and M. edulis mussels, sampled in southern California in 1986. Values shown are means of three composites of 30 individuals each. Source: NOAA, National Status and Trends Program.

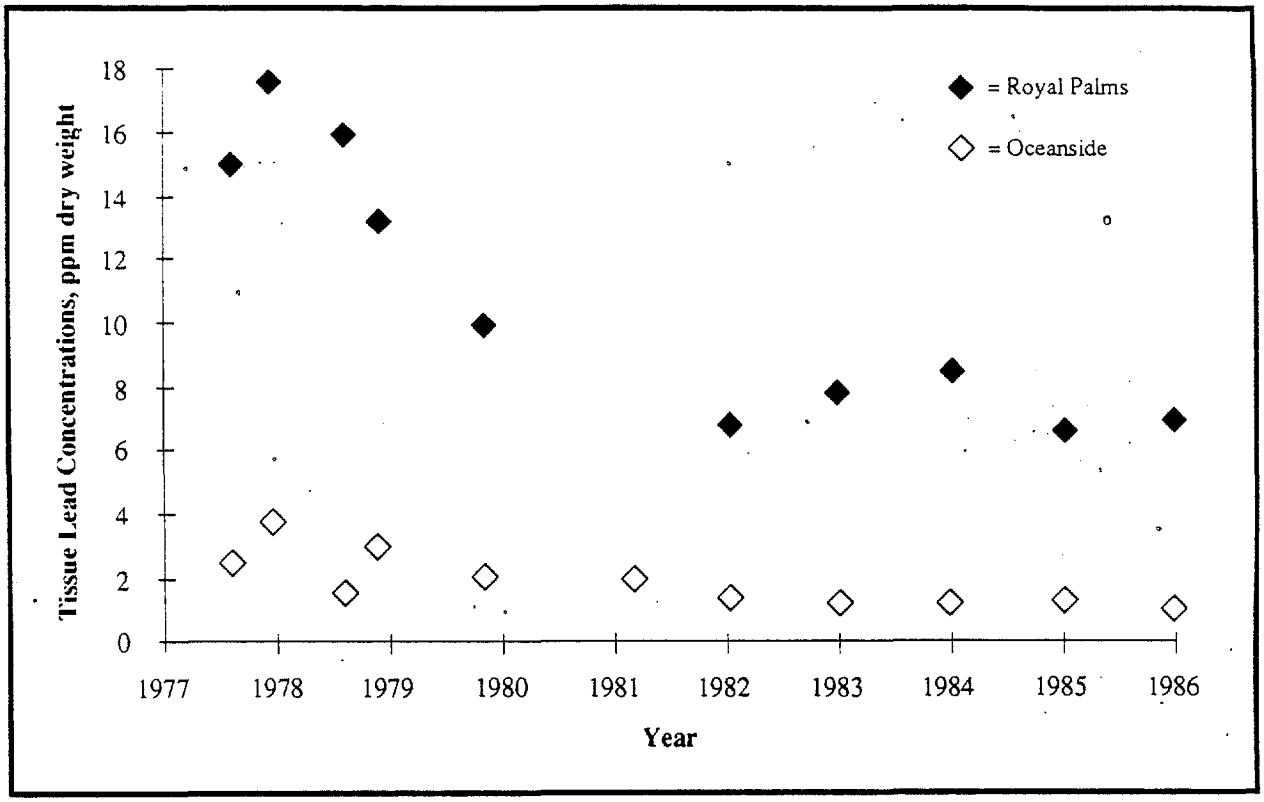


Figure 7. Times series of lead concentrations measured in M. californianus mussels from Royal Palms and Oceanside, 1977-1985. Values in parts per million, dry weight. Source: California Mussel Watch Program.

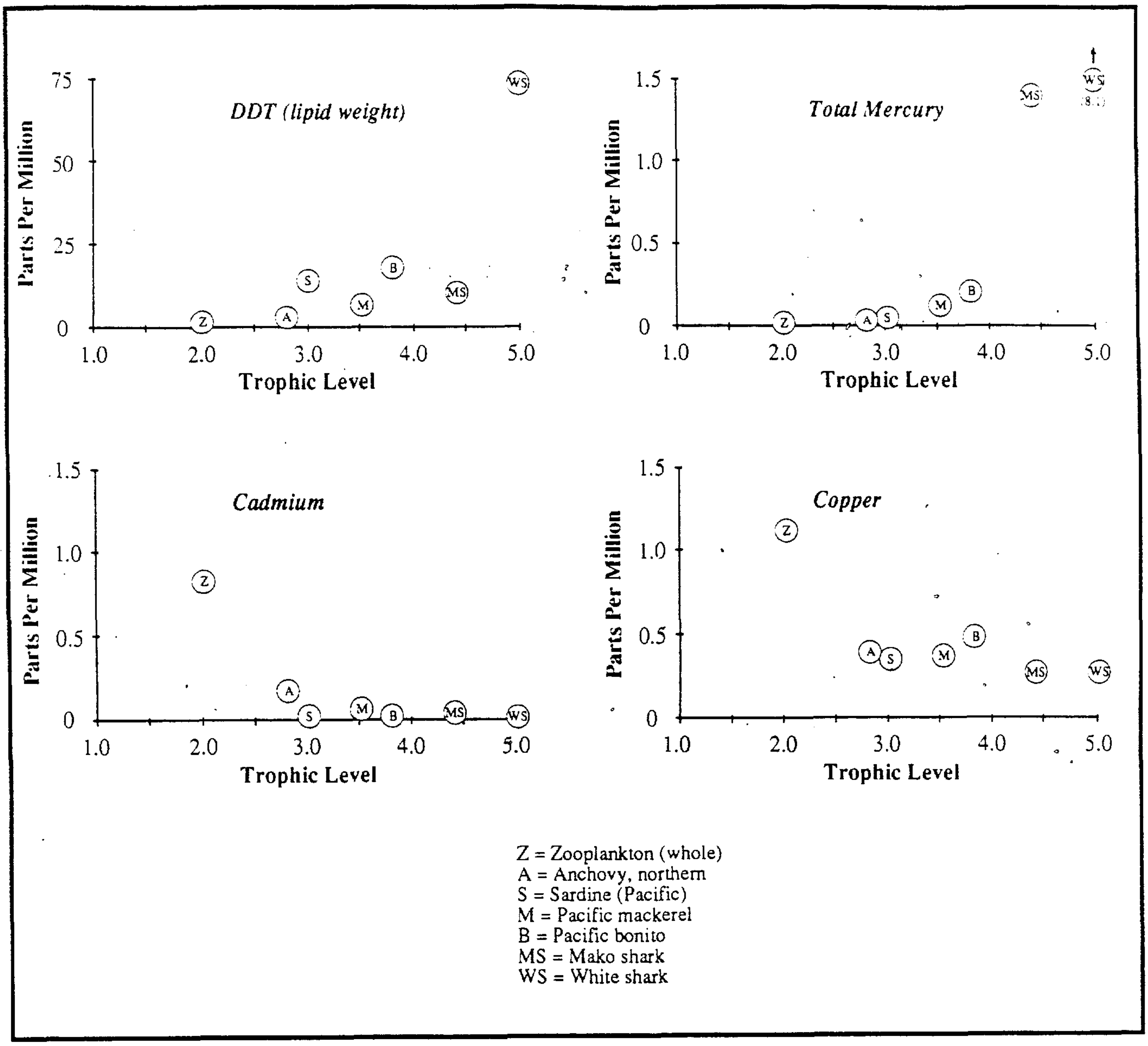


Figure 8. Concentrations of four contaminants in replicate composites of whole zooplankton and flesh of six species of fish from the pelagic food web of the Southern California Bight. Based on trophic level assignments in Mearns and Young (1982) and contaminant data in Schafer et al. (1982).

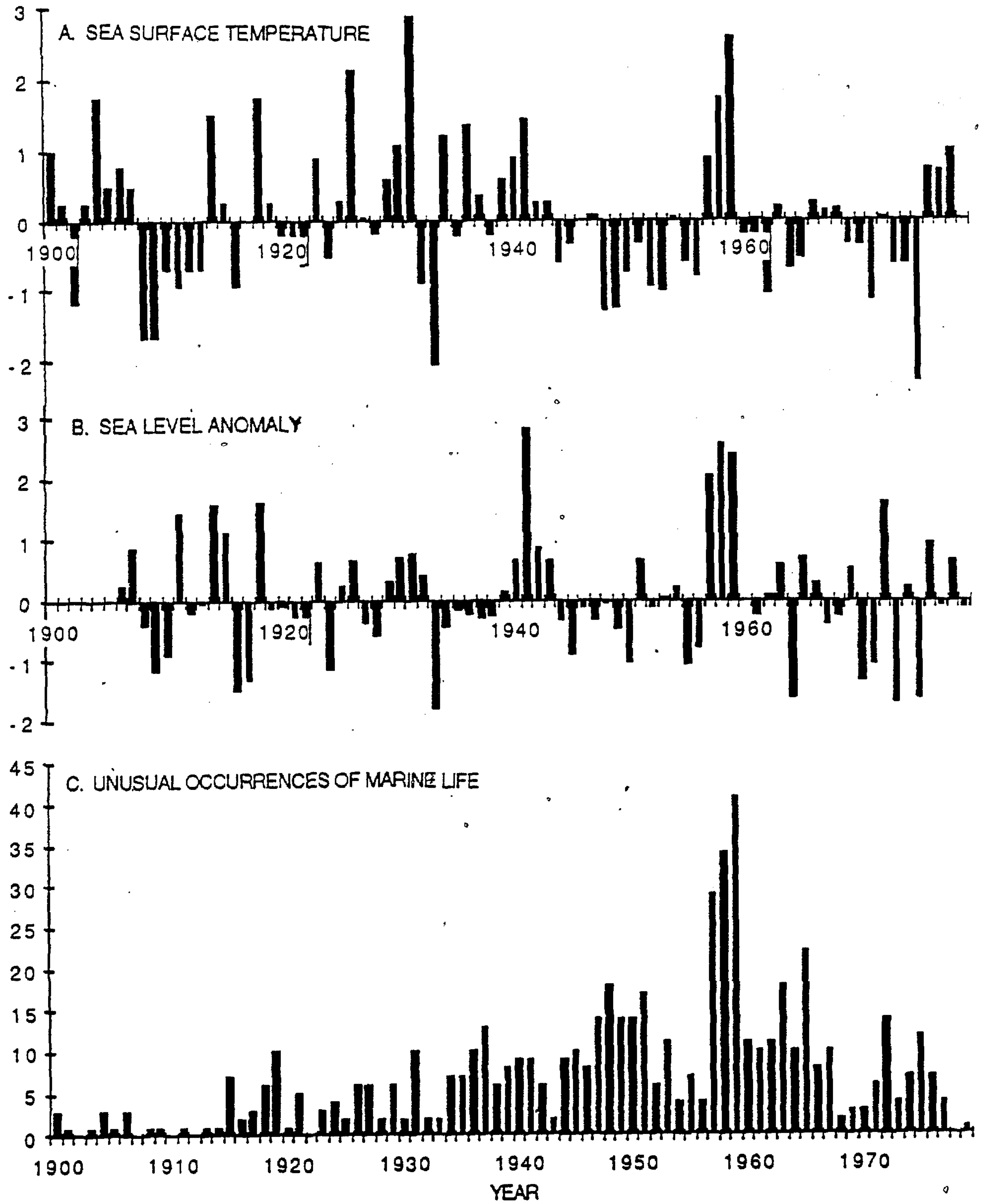


Figure 9. Year-to-year variations in (a) sea surface temperature at Scripps Pier, (b) detrended sea level at San Diego and (c) occurrences of unusual organisms along the west coast, 1900 through 1979. Values in (a) and (b) are standard deviations from longterm annual means; values in (c) are number of species with unusual occurrences. Modified from information in Mearns (1988).

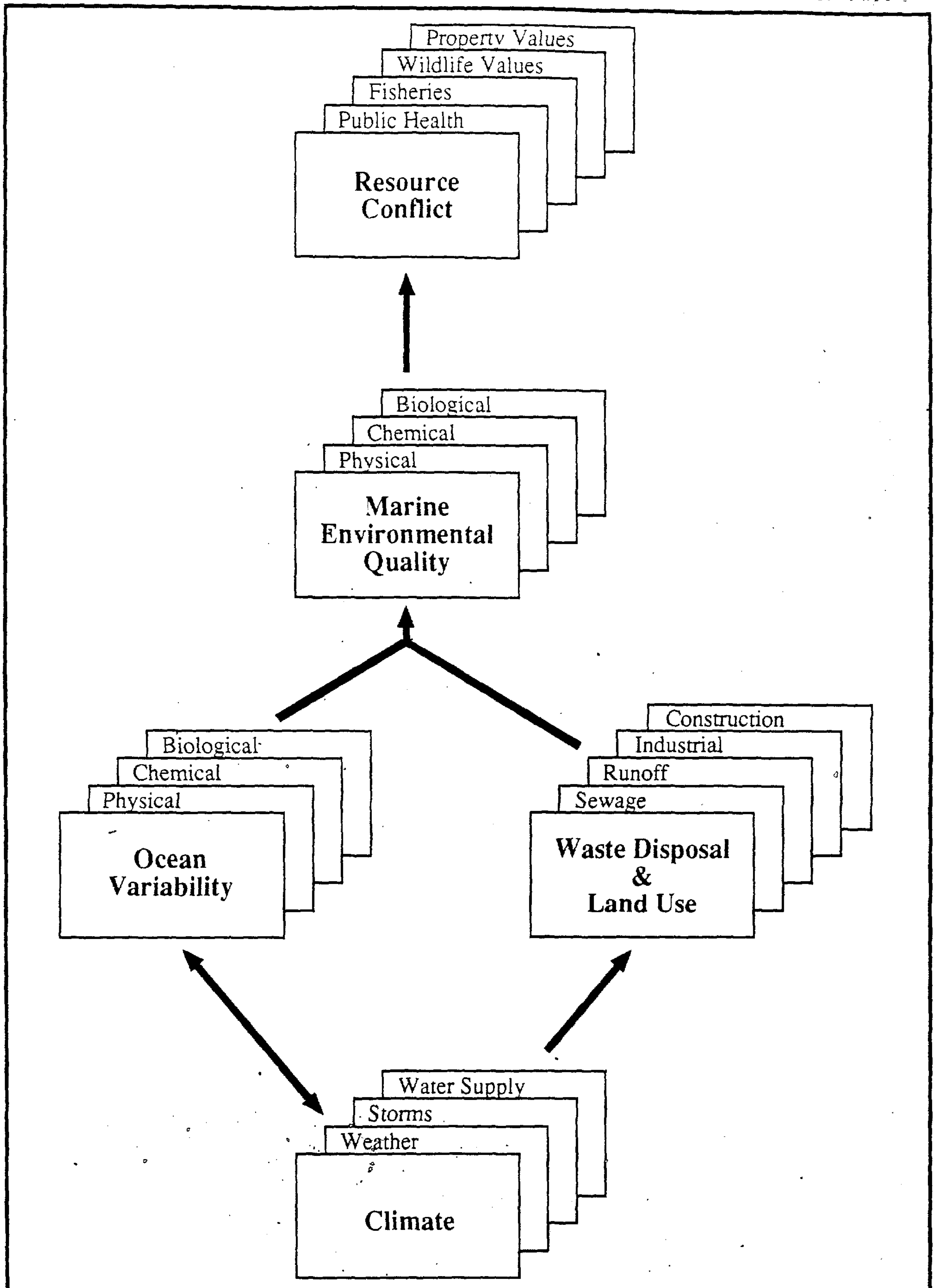


Figure 10. The dependency of resource use conflicts and marine environmental quality on ocean variability, waste disposal and land-use practices and, ultimately, on climatic variability.

Oil Spill Response in The Santa Barbara Channel Focusing on the Recent Sinking of the M/V *PACBARONESS*

L. A. "Skip" Onstad
Clean Seas, 1180 Eugenia Place, Suite 204, Carpinteria, CA 93013

Good afternoon, I am Skip Onstad and manager of Clean Seas. Today I am presenting an industry perspective to oil spill preparedness in the Santa Barbara Channel and a brief description of Clean Seas responses to the *PACBARONESS* sinking. This prospective not only includes offshore exploration and production activities, but also preparedness measures taken by companies involved with the transportation and refining of petroleum products.

What I am about to describe is a three tier response system. The concept is based upon on-site equipment suitable for first response and sufficient to handle the majority of spills supported by larger more capable equipment stockpiled by industry-owned oil spill cooperatives as the second in the response system. Finally, this all backed by industry owned equipment from outside the local area and by equipment from outside the local area and by equipment owned and operated by the federal government.

The available equipment and mandated response times are based upon the perceived threat to the environment posed by potential spills. The policies of the California Coastal Commission, U.S. Coast Guard and MMS dictate the preparedness levels associated with particular oil and gas projects. Enforcement of these policies is carried out by the State Lands Commission, MMS and USCG. To meet these policies, the oil industry has purchased equipment, trained personnel and developed plans to respond to oil spill emergencies.

The first level is the on-site immediate response equipment. This is usually owned or leased by the individual company operating the facility--whether it be an offshore platform, exploratory drilling vessel, or a marine terminal.

Each offshore operator has an approved oil spill contingency plan. These plans dictate response procedures and equipment for initial response. The immediate response equipment always includes at least 1500 feet of open ocean boom on site. This boom will contain any small spill and provide initial containment of large spills. The offshore boom is stored on standby vessels, crew boats or on the platform itself. The boom at marine terminals is located in such a way that company personnel with their boats or local responders such as the Fire Department or Harbor Department can rapidly deploy it around a vessel or berth involved in a spill.

To recover spilled oil, operators are required to have a skimmer capable of open-ocean use on or near the site. Most operators have a skimmer that has proven successful both in Europe and, the U.S. The skimmer system is stored on the platform, on a standby boat or in some cases ashore with the capability of being brought to the scene very rapidly.

In addition to the skimmer, offshore operators must have the support equipment to assist in response. This means an oil-water-separator system, limited storage for recovered oil, sorbents and a support boat for boom tending and logistics. For exploratory drilling operations, this first response equipment must be located on a dedicated standby boat at the scene of drilling.

The first response equipment is sometimes shared between operators of platforms within a close proximity to one another. There are also cases where Clean Coastal Waters or Clean Seas provides this first response capability such as for the Beta Field off Huntington Beach and the Arguello Field near Point Conception.

This brings us to the second tier of the response system--the local oil spill cooperative. Within their respective operating areas, each cooperative has detailed contingency plans, a large inventory of equipment and trained personnel readily available for response. In this regard you can think of the cooperative much like a fire department but for oil spills. We each spend a great deal of time making sure we have the best available equipment, it is properly maintained and ready for instant use. Our people are trained professionals who also train others and regularly participate in drills and exercises. In the case of CCW and Clean Seas, the large oil spill responses vessels are manned and ready 24 hr/day/7 day/week to get underway on a moments notice. Likewise, Clean Bay's contractors are on call and ready to respond within an hour of notification.

The response goal of the cooperatives is to keep oil from impacting the shoreline in an uncontrolled manner. Conditions of the spill, such as magnitude, oil type, proximity to shore, location of sensitive areas, weather, equipment type and availability, all determine the techniques which will be undertaken to minimize the impacts of the spill. this can mean diverting oil to shoreline areas in a controlled manner where it can be effectively recovered and environmental harm minimized. It can also mean containing and recovering oil at sea or using chemical agents to disperse the oil at sea and protect certain sensitive areas. What must be understood about oil spills is that no two spills of significance are alike and response actions will be dictated by the unique circumstances of each spill.

Cleans Seas is the cooperative responsible for the Santa Barbara Channel and Santa Maria Basin. The backbone of Clean Seas are the spill response vessels *MR. CLEAN*, *MR. CLEAN II*, and *MR. CLEAN III*. *MR. CLEAN* and *MR. CLEAN II* are moored in Santa Barbara and Avila Bay, and are always manned and ready to get underway on a moments notice. *MR. CLEAN III* is constantly on station in the Arguello Field near platforms Hidalgo, Hermosa, and Harvest, and is manned by a crew of 12. *MR. CLEAN III* provides first and second level response to these three platforms plus platform Irene in the Pedernales Field, 10 miles to the north. Each of the Cleans Seas vessels is supported by a fast response support boat.

Each of the Clean Seas vessels is a complete oil spill response system in itself carrying about 5000' of high seas boom, a stationary skimmer, two or three advancing skimmer systems, a crane, on-board storage for recovered oil, dispersant equipment, sorbents, and other supplies needed for extended offshore operations.

The wheelhouse of each vessel is fully equipped to act as an on scene command and control center should the need arise. *MR. CLEAN III* has the additional responsibility of supporting the Arguello Field ship traffic warning system.

Clean Seas has additional support equipment in vans, trucks, and trailers at its support yard in Carpinteria as well as at various locations along the coast. The equipment in these vans has been selected for particular sensitive areas along the coast such as Magu Lagoon and Morro Bay.

The full-time staff of Clean Seas numbers about 50 with literally hundreds of trained personnel from member companies and contractors available for additional support.

The use of chemical dispersants to assist in the control of oil slicks is another tool in the cooperatives inventory. In order to have the capability to apply dispersants over a large area, the three cooperatives have contracted for a dedicated DC4 aircraft. The aircraft is on full-time standby and can be on scene in 4-6 hours loaded with 2000 gallons of dispersant--enough to theoretically disperse 20-40,000 gallons of oil. It saw limited use for the first time on an actual spill in the U.S. on the T/V *PUERTO RICAN*. In addition each cooperative has systems for spraying from helicopters. They are suitable for small spill areas and for test applications prior to spraying large quantities.

Clean Seas has a detailed contingency plan covering its geographic area of responsibility. The plan includes organizational matters, job descriptions of response team personnel, equipment lists and communications information plus other important data. In order to ensure the equipment works properly and there are sufficient personnel available in event of a significant spill, Clean Seas conducts twice monthly training throughout the year.

These sessions include not only equipment operation and response procedures, but also bird cleaning and wildlife rehabilitation. These latter sessions are done in conjunction with experts in the filed such as California Department of Fish and Game, and International Bird Rescue Center. The end result, however, is hundred of persons receiving various types of spill response training annually.

The third and final level of response it the Federal Government and outside industry resources available in a 24-48 hour time frame. The U.S. Coast Guard National Strike Force is available with open ocean response and salvage equipment.

One of their teams is located in Marin County at Hamilton Air Force Base. They are available to assist and supplement industry equipment. Additionally, U.S. Navy owned equipment is available from Stockton, CA. Both agencies equipment were successfully used on the T/V *PUERTO RICAN* spill. The other segment of this third level is industry equipment available from outside the local area. The cooperatives have agreed to provide mutual aid to one another if needed. As an example, at the request of Clean Bay, *MR. CLEAN II* was sent to the scene of the T/V *PUERTO RICAN* and both Clean Coastal Waters and Clean Seas sent supplies of dispersants for potential use. We also assisted on the Ixtoc and Burma Agate spills in the Gulf of Mexico.

It is our assessment the equipment available here in California is sufficient for our requirements. Between industry owned equipment spread throughout the area, the three large cooperatives, and the equipment and personnel available through the Federal Government, there is sufficient capability for most any catastrophic event. In fact, I don't believe there is an area in this country or the world as well protected as the California Coast--particularly southern and central California and the Bay Area.

With this statement in mind, I'd like to move onto some specifics on the *PACBARONESS* incident.

At 5:30 a.m., Monday, September 21, 1987, the *PACBARONESS*, a 562-foot, dry bulk carrier collided with the *ATLANTIC WING*, a 494-foot freighter. The *PACBARONESS* was damaged below the water line and began to take on water in two holds on the starboard side, forward of the bridge. The crew of the *PACBARONESS* abandoned ship to the *ATLANTIC WING* which, though damaged, was able to maneuver on its own. By 7:30, the *PACBARONESS* was reported to have a 10-degree list to starboard, and its stern was under water.

The *PACBARONESS* foundered throughout the day and, at one point, was drifting toward platform Hermosa. The *PACBARONESS* agreed to take on a tow line at 1:00 p.m. and was under tow, out to sea, when it sank at 4:18 p.m.

Prior to sinking, the *PACBARONESS* released a small quantity of oil (i.e., < 25 barrels). At 5:00 p.m., a large discharge of oil began rising to the surface from the sunken vessel, and by 6:00 p.m. a slick had formed in the vicinity of the wreck site which was 1.5 miles long and 0.5 miles wide. At this time the wind was about 30 knots, fog was present and darkness setting in--conditions not conducive for containing and recovering oil at sea.

A large quantity of oil continued to bubble to the surface from the sunken ship for several days. Initially, wind and current conditions combined to confine the slick to an offshore area well away from the Channel Islands and mainland. By Thursday, however, a shift in wind direction and intensity caused the slick to move to the south toward San Miguel Island.

By Friday, a reduced quantity of oil bubbling to the surface, weather conditions which enhanced the natural dispersion and degradation processes, and response efforts which included both mechanical recovery and dispersant application operations succeeded in eliminating the threat to San Miguel Island. Although the *PACBARONESS* was still leaking a small quantity of oil by October 12, 10 days of observation overflights indicated that the slick was confined to the wreck site and did not pose a threat to the Channel Islands or the mainland.

The Clean Seas response organization was activated minutes after the collision. *MR. CLEAN III,* stationed in the Point Arguello Oil Field, was notified of the collision and dispatched to the scene. *MR. CLEAN III* arrived on-scene at 7:45 a.m., accompanied by the fast response vessel, *DASH*. At 7:30 a.m., Clean Seas dispatched *MR. CLEAN II* from Avila Beach to the western portion of the Santa Barbara Channel to stand by, and *MR. CLEAN* departed its mooring in Santa Barbara Harbor at 10:45 a.m. for the sheltered Cojo Anchorage which is situated just to the east of Point Conception.

All three of Cleans Seas' oil spill response vessels were on-scene from Tuesday, September 22, to Friday, September 25, when the U.S. Coast Guard released *MR. CLEAN* and *MR. CLEAN II* from service. *MR. CLEAN III* remained on-scene until September 29. During the incident, Clean Seas engaged in the following activities:

Search and rescue operations, including the transfer of the crew of The *PACBARONESS* from the *ATLANTIC WING* to another vessel for transport to shore.

Monitoring and reporting of weather conditions.

Surveillance of the slick by vessel, helicopter, and tracking buoys.

At sea containment and recovery of 350 barrels of oil.

The test application of 100 gallons of dispersant, and the monitoring of results.

The operational application of 250 gallons of dispersant, and the monitoring of results.

Participation in the test application of dispersants for a government-sponsored research program.

Oiled seabird cleaning, rehabilitation and release operations.

Clean Seas response operations were hampered by the fact that the oil spill incident involved a non-member company which refused, throughout the incident, to sign a contract with Clean Seas. The continuous and unproductive negotiations with the vessel owner created severe administrative burdens on Clean Seas which distracted from the management of response operations, however did not distract from the physical response efforts.

In addition, conditions at the wreck site were not, for the most part, conductive to the conduct of operations. Because of the water depth at the wreck site (i.e., approximately 1,500 feet), Clean Seas was unable to station containment boom and surround the oil as it bubbled to the surface. As a result, the oil spread out on the ocean surface, primarily in the form of sheens and discontinuous oil mats. In addition, dense fog restricted vessel and aerial observations of the slick, thus reducing Clean Seas' ability to direct its oil spill response vessels and the DC-4 dispersant application aircraft to areas where slick concentrations were conducive to mechanical recovery and/or chemical treatment operations. Finally, strong winds and high seas either prevented the deployment or reduced the effectiveness of equipment. Despite these problems, Clean Seas oil spill response vessels were able to recover 350 barrels of oil, and the DC-4 dispersant application aircraft was able to disperse approximately 100 barrels of oil.

In summary, the operation was a success. We did not overreact or under-react. We did what was necessary and possible given the on-scene conditions. We collected oil when conditions permitted, we dispersed oil when necessary and we watched mother nature naturally disperse the oil under heavy sea conditions. Had weather conditions been more conducive to mechanical recovery, we would have collected much more oil; had there been more of a threat to sensitive coastal areas, we would have dispersed more oil--as it was we did what was necessary. There were no shoreline impacts, no measurable impacts to the environment and all oil had dispatched within 4-5 days with the exception of the very small quantity that continues to surface from the wreck.

PART IV. RESEARCH WORKSHOP FINAL REPORT

THE MARINE ENVIRONMENT OF SANTA BARBARA AND ITS COASTAL WATERS - A SYMPOSIUM/WORKSHOP - January 28, 1988

A major purpose of **The Marine Environment of Santa Barbara and its Coastal Waters--A Symposium/Workshop** was to define future research requirements to support management decisions in the Santa Barbara region. The goals of the National Marine Sanctuary Program (NMSP) and the Channel Islands National Marine Sanctuary (CINMS) were used as a basis to frame these discussions.

The CINMS program has four goals:

- **Resource protection**
- **Research**
- **Interpretation (education)**
- **Enhance Visitor Use**

The workshop was a forum to identify research activities directed at potential management decisions relating to resource protection, interpretation and enhanced visitor use. This process consisted of pre-planning efforts by the designated discussion leaders who prepared the following information for discussion at the workshop:

1. Lists of resources, both biological and physical, of concern in the Sanctuary (biological resources such as marine mammals, marine birds, invertebrates, fish, etc; unique habitats such as coral reefs, kelp beds, geological and physical oceanographic resources, etc. and the necessary environmental quality to sustain these habitats; and, cultural resources such as shipwrecks).

2. A draft of priority research needs and actions.

3. A list of potential risks to the Sanctuary resources.

4. A list of possible education or visitor use activities and needed information related to these activities.

Based on this preparation, the discussion leaders and work groups were asked to focus on the following:

1. Review lists 1-4 above, in order, and ask for additions in a plenary session.

Divide into sub-groups: Biological resources, environmental quality, shipwrecks/marine safety and education/visitor use. (Editor's Note: These subdivisions were chosen as they represent the majority of on-going Sanctuary activities and because they address the Sanctuary's programmatic goals. It is recognized that this division was somewhat arbitrary and that overlap between sub-groups occurred. This was rectified in part by including plenary sessions before and after the sub-group sessions to allow multi-disciplinary discussion).

2. In the biological resources, environmental quality and shipwrecks/marine safety sub-groups - Evaluate each possible risk and degree of potential impact on resources, e.g., probable impact, possible impact, unlikely impact or unknown. Obtain opinions and descriptions of most urgent research or other action needed for resource-risk rates "probable" - then the "possibles" if time permits.

3. In interpretation and visitor use sub-group, evaluate each activity as to value to the community, e.g. "very valuable", "valuable", "little value". Ask for opinions and actions necessary for implementing each "very valuable" activity.

4. Prepare brief (two-page) written summaries of results and recommendations.

5. Reconvene sub-groups into plenary session to discuss results.

As a result of this process, the workshop reports and the following summaries were prepared:

SYNOPSIS OF THE SYMPOSIUM/WORKSHOP

The symposium/workshop attracted significant media interest and was well attended by representatives of government agencies, academia, industry, environmental groups, and the general public. Most of the speakers at the symposium came from University of California at Santa Barbara or other southern California universities.

While a variety of scientific topics were discussed, four overall themes emerged. First, conditions in the Channel are influenced by far-removed events (e.g. El Niño, north Pacific storms). Second, long time-series observations are necessary to understand this environment. Third, data are valuable beyond their immediate purpose and must be preserved and made available to others. Fourth, many complex problems can be solved if modern technology can be brought to bear on them. There was a pervasive feeling that new approaches and institutional arrangements are needed if the greatest progress is to be realized.

The workshop demonstrated that there is great local interest and tremendous local expertise relevant to management of the Channel, but it was clear that application of this expertise to Sanctuary management is yet to be fully realized. There was broad support for establishment of a process to bring scientists into the management arena. Also, there was broad support for a continuing forum to describe current research and management activities and determine future needs.

Four working groups were established to discuss environmental quality, shipwrecks and marine safety, marine education, and biological resources. It was determined that ship-related incidents pose the greatest risk to the Channel and that this issue should be a top priority. All working groups recognized the value of education in achieving environmental quality goals in the Channel, with specific recommendations dealing with kindergarten to post-graduate level activities. Another common theme was community outreach, with lectures, symposia, video clips, newsletters and other "tools" being suggested as useful means. The workshop participants were asked for recommendations on what the CINMS should do to most effectively preserve and protect the environment in the Sanctuary and surrounding area.

All working groups agreed on several functions for the CINMS office. Serving as the first point of contact for anyone wanting information relevant to environmental issues concerning the Sanctuary and Channel area, the CINMS Sanctuary Manager and staff should provide either the needed information or directions to the appropriate source. The CINMS office should also serve an active coordination role by maintaining awareness of programs and plans of all relevant Federal, state and local agencies. This knowledge should be used to encourage consistency and sharing of information. In addition, the CINMS office should serve a liaison function between management agencies and academic scientists.

ENVIRONMENTAL QUALITY WORKING GROUP

NAME	AFFILIATION/ADDRESS	TELEPHONE
Dr. John A. Calder (Chairman)	National Science Foundation Chemical Oceanography Program 1800 G St. NW, Room 609 Washington, D.C. 20550	202-357-7910
Robert Almy	Resource Management Dept. Energy Division 1266 Anacapa, Second Floor Santa Barbara, CA 93101	805-568-2040
Jenifer Dugan	Dept. of Biological Sciences University of California Santa Barbara, CA 93106	805-961-2675
Dr. Craig Fusaro	Joint Oil/Fisheries Liaison 121 Gray Avenue, Suite 3 Santa Barbara, CA 93101-1809	805-963-8819
John T. Gunn	SAIC. 13400 B Northup Way, #36 Bellevue, WA 98005	206-747-7152
Dr. F. G. Hochberg	Santa Barbara Museum of Natural History 2559 Puesta del Sol Santa Barbara, CA 93105	805-682-4711
Janet LeCroy	CRL Environmental 29 N. Olive Ventura, CA 93001	805-985-1797
Dr. Wilbert Lick	Dept. of Mechanical & Environmental Engineering University of California Santa Barbara, CA 93106	805-961-4295
Ed R. Long	NOAA Ocean Assessments Div. 7600 Sand Point Way NE Seattle, WA 98115	206-526-6338

NAME	AFFILIATION/ADDRESS	TELEPHONE
Dr. Stanley V. Margolis	Marine Science Institute University of California Santa Barbara, CA 93106	805-961-4496
Dr. Dwayne C. Maxwell	California Dept. of Fish and Game 245 W. Broadway, Suite 350 Long Beach, CA 90802	213-590-5140
Dr. Alan J. Mearns	NOAA Ocean Assessments Div. 7600 Sand Point Way NE Seattle, WA 98115	206-526-6336
Dr. Brian D. Melzian	Environmental Protection Agency 215 Fremont Street San Francisco, CA 94105	415-974-8106
Peter Schuyler	Nature Conservancy Santa Cruz Island Project 213 Stearns Wharf Santa Barbara, CA 93101	805-962-9111
LT Reed V. Smith	California Dept. of Fish and Game P.O. Box 5965 Oxnard, CA 93031	805-989-1797
Dr. Adrian M. Wenner	Marine Science Institute University of California Santa Barbara, CA 93106	805-961-2838

BIOLOGICAL RESOURCES WORKING GROUP

NAME	AFFILIATION/ADDRESS	TELEPHONE
Dr. Russell J. Schmitt (Chairman)	Coastal Research Center Marine Science Institute University of California Santa Barbara, CA 93106	805-961-2051
Dr. Richard F. Ambrose	Coastal Research Center Marine Science Institute University of California Santa Barbara, CA. 93106	805-967-5579
Mark H. Carr	Dept. of Biological Sciences University of California Santa Barbara, CA 93106	805-961-2975
LCDR Miles M. Croom	Gulf of the Farallones Nat'l. Marine Sanctuary, NOAA/NOS/OCRM Fort Mason, Bldg. #201 San Francisco, CA 94123	415-556-3509
Dr. Gary E. Davis	Channel Islands National Park 1901 Spinnaker Drive Ventura, CA 93001	805-644-8157
William Douros	Energy Division, RMD 1226 Anacapa Street Santa Barbara, CA 93010	805-568-2040
Dr. Jack Engel	Channel Islands Research Program Tatman Foundation, Catalina Marine Science Center Box 398 Avalon, CA 90704	213-743-6792
Dr. Tina B. Hartney	Minerals Management Service 1340 W. 6th St. Los Angeles, CA 90017	213-514-6663
Robert S. Hoffman	National Marine Fisheries Service 300 S. Ferry Street Terminal Island, CA 90731	213-514-6663

NAME	AFFILIATION/ADDRESS	TELEPHONE
Dr. Sally J. Holbrook	Dept. of Biological Sciences University of California Santa Barbara, CA 93106	805-961-3956
Dr. Lyndal Laughrin	Santa Cruz Island Reserve University of California Santa Barbara, CA 93106	805-961-4127
David Lewis	Channel Islands National Park 1901 Spinnaker Drive Ventura, CA 93001	805-644-8157
Dr. Andrew Lissner	SAIC 10260 Campus Point Drive, MS #10 San Diego, CA 92121	619-535-7471
Dr. Milton Love	Marine Science Institute University of California Santa Barbara, CA 93016	805-961-2935
Frank Manago	Minerals Management Service 1340 W. 6th Street Los Angeles, CA 90017	213-894-4480
Dr. Bobette V. Nelson	1801 Clearview Santa Barbara, CA 93101	805-682-3463
Richard J. Nitsos	CA Dept. of Fish & Game 245 West Broadway, Suite 350 Long Beach, CA 90802	213-590-5174
Mary M. Perez	Coastal Research Center Marine Science Institute University of California Santa Barbara, CA 93106	805-961-2051
LCDR Wayne L. Perryman	National Marine Fisheries Service SWFC 8604 La Jolla Shores Dr. La Jolla, CA 92038	619-961-2975

NAME	AFFILIATION/ADDRESS	TELEPHONE
Peter Raimondi	Dept. of Biological Sciences University of California Santa Barbara, CA 93106	805-961-2975
John Richards	UC Cooperative Extension/Sea Grant Extension Program 377 Storke Goleta, CA 93117	805-968-2149
Amy Roda	Dept. of Biological Sciences University of California Santa Barbara, CA 93106	805-961-3511
Peter Schuyler	The Nature Conservancy 213 Stearns Wharf Santa Barbara, CA 93106	805-962-9111
Paul H. Scott	Santa Barbara Museum of Natural History 2559 Puesta del Sol Road Santa Barbara, CA 93105	805-682-4711
Dana J. Seagars	National Marine Fisheries Service 300 S. Ferry Street Terminal Island, CA 90731	213-514-6665
Dr. Adrian M. Wenner	Marine Science Institute University of California Santa Barbara, CA 93106	805-961-2838
Dr. Charles D. Woodhouse	Santa Barbara Museum of Natural History 2559 Puesta del Sol Road Santa Barbara, CA 93105	805-682-4711
Dr. Richard K. Zimmer-Faust	Coastal Research Center Marine Science Institute University of California Santa Barbara, CA 93106	805-961-4680

SHIPWRECKS/MARINE SAFETY WORKING GROUP

NAME:	AFFILIATION/ADDRESS	TELEPHONE
Peter Howorth, (co-Chairman)	Howorth and Associates P.O. Box 20204 Santa Barbara, CA 93120	805-687-2368
Barry Schuyler, (co-Chairman)	Dept. of Environmental Studies University of California Santa Barbara, CA 93106	805-961-3930
Dexter Chan	NOAA/HAZMAT U.S. Coast Guard, MSO Coast Guard Island, Bldg. 14 Alameda, CA 94501	415-437-3125
Greg Feet	Waterfront Department City of Santa Barbara P.O. Drawer P-P Santa Barbara, CA 93102	805-963-2633
Debby Fleischer	Resource Management Dept. County of Santa Barbara 1226 Anacapa Street Santa Barbara, CA 93101	805-568-2040
Amy Margerum	Resource Management Dept. County of Santa Barbara 1226 Anacapa Street Santa Barbara, CA 93101	805-568-2040
Dan Seitz	6 Harbor Way, #136 Santa Barbara, CA 93109	
LT Joe C. Talbott	NOAA/HAZMAT Scientific Support Coordinator 400 Oceangate Blvd., Suite 709 Long Beach, CA 90822-5330	213-499-5330

EDUCATION WORKING GROUP

NAME	AFFILIATION/ADDRESS	TELEPHONE
Gary Robinson (Chairman)	Sea Center, Manager 211 Stearns Wharf Santa Barbara, CA 93101	805-963-1067
Ron Abate	Dept. of Education, UCSB Santa Barbara, CA 93106	805-961-3102
Bruce Anderson	Dept. of Education, UCSB 6504 Madrid, Apt. 4 Goleta, CA 93117	805-968-2828
Genny Anderson	Marine Science Program Dir. Santa Barbara City College 721 Cliff Drive Santa Barbara, CA 93109	805-965-0581
Barbara Berggreen	Dept. of Education Santa Barbara Museum of Natural History 2559 Puesta del Sol Road Santa Barbara, CA 93105	805-682-4711
Dr. Willis Copeland	Dept. of Education, UCSB Santa Barbara, CA 93106	805-961-3102
Victor Cox	Freelance Journalist 82 Warwick Place Goleta, CA 93117	805-968-1109
Robert Durand	Student, Environmental Studies, UCSB 6750 El Colegio Road #39 Goleta, CA 93117	805-968-6401
Michael Marzolla	4-H Youth Advisor University of California Cooperative Extension 377 Storke Road Goleta, CA 93117	805-968-2149

NAME	AFFILIATION/ADDRESS	TELEPHONE
Catherine McCammon	City Harbor Commission 307 E. Carrillo Street Santa Barbara, CA 93101	805-963-0363
Isabel Melendez	Student, Stanford University 118 Puesta del Sol Oakview, CA 93002	805-649-1129
Cindy Neilsen	Chief of Interpretation Channel Islands National Park 1901 Spinnaker Drive Ventura, CA 93001	805-644-8157
Robin Rene Roe	Dept. of Education Santa Barbara Museum of Natural History 2559 Puesta del Sol Road Santa Barbara, CA 93105	805-682-4711
Glen St. Amant	Channel Islands National Marine Sanctuary 735 State Street Santa Barbara, CA 93101	805-966-7107
Kay Woolsey	Curator of Education Santa Barbara Museum of Natural History 2559 Puesta del Sol Santa Barbara, CA 93105	805-682-4711
Larry Yee	County Director University of California Cooperative Extension 800 South Victoria Ventura, CA 93009	805-654-2925

APPENDIX A.
CHANNEL ISLANDS NATIONAL MARINE SANCTUARY POTENTIAL OR PLANNED MARINE EDUCATION PROJECTS

The following briefly lists potential or planned marine education projects:

1. Cosponsorship of the Sea Center of the Santa Barbara Museum of Natural History. The purpose of the Sea Center is to advance appreciation and understanding of the Santa Barbara Channel and the Channel Islands National Marine Sanctuary. This will be accomplished through interpretive exhibits, interpretive talks and tours of the facility, and coordination of research and education activities throughout the region. The Sea Center will act as a primary mechanism to communicate the existence of the Sanctuary and the value of its resources to the public. Information will be provided that is informative to the casual visitor, boaters, naturalists, and the general public.

2. Adoption of McKinley's 5th/6th Grade Science Class. This activity hopes to demonstrate how participatory educational experiences within the Marine Sanctuary can improve students' overall interest and learning in science, aid in prevention of high school drop outs, and prevent juvenile delinquency. This will serve the community in the longer term by reducing the number of children at risk of becoming future wards of society.

3. Assistance in Creation of a Marine Education Consortium. The purpose of this Consortium is to reach the many teachers, community leaders, and other professionals that conduct, direct or set policy for education in the Santa Barbara, San Luis Obispo, and Ventura at the K-12 levels. The Consortium will strive to consolidate and supplement existing community-wide programs. This should not only reduce overall costs, but allow for a much more effective and expanded education program within the tri-county area.

4. Cosponsor Exhibits with the Channel Islands National Park. NOAA and the Channel Islands National Park Service (NPS) have already developed exhibits at the Ventura Visitor Center and on Anacapa and Santa Barbara islands. Update of exhibits and introduction of new exhibits will continue. Coordination between agencies will also continue to be a major activity.

5. Development of an Interactive Computer-Based Exhibit Describing the Sanctuary and Its Resources. A computer display has already been developed and is on display at the Sea Center. This display will be expanded to include other living and cultural resources of the Sanctuary. A second display is planned for exhibit at the National

Park Service Visitor's Center in Ventura.

6. Development of a Sanctuary/Santa Barbara Channel Research Information Database. No comprehensive inventory of current or historical research and available data exists for this region. An interactive computer-based system to identify who is conducting this research and what data are available will be developed in the same manner as the resource database described above. This system will be keyed geographically and textually to describe this information. The Sanctuary will also provide focus for coordination of this information for the entire region.

7. Sea Center/Sanctuary Educational Notebook. Assistance with the production of an educational workbook, now in progress, which will follow the theme of the Sea Center, "A Window to the Channel," and will contain information on the Santa Barbara Channel and the Sanctuary. This workbook will be bilingual with English and Spanish text describing the physical and biological resources as well as human uses of the Channel and Sanctuary.

8. New Sea Center/Sanctuary Brochure. A twelve-panel color brochure has been designed for distribution to the general public to describe and publicize the Sea Center and Sanctuary. Massive distribution is in progress at well traveled tourists areas such as train stations, the Chamber of Commerce, hotels, etc.

9. New Channel Islands National Marine Sanctuary Educational Package entitled "Things to Do & Things to See." This will replace the current Sanctuary brochure. One part will identify eight major activities (e.g., fishing, diving, sailing, etc.), key these activities to a map, and identify some locations for these activities within the Sanctuary. The second part will identify living and cultural resources to see within the Sanctuary. Panels will illustrate several frequently seen species of marine mammals and sharks. Well-known shipwrecks, migratory routes, haul-out areas, rookeries, etc., will be identified on a map of the Sanctuary.

10. Interpretive Material on the Channel Islands National Marine Sanctuary. A presentation of the Sanctuary, its boundaries and access points to the Sanctuary has been developed for boaters and tourists visiting the Sanctuary on "Island Packers-type tours." This will also provide a medium to present references to Ecological Reserve locations, airplane restrictions and other regulations.

11. Cosponsor a Lecture Series. A 10-part, Fall-Winter lecture/slide series, entitled "Rediscovering the Treasures of the Santa Barbara Channel," is in progress and is aimed at providing a free public education service to the Santa Barbara community. The purpose of the series is to educate residents on the unique resources of the Santa Barbara Channel and the Channel Islands National Marine Sanctuary. The National Park conducts a similar lecture series that was used as a model for this program. Public response has been good with average attendance exceeding 70 per lecture. Future lecture series are under consideration.

12. Upgrade the Marine Floating Lab Educational Process. Floating classrooms are already offered through Island Packers in Ventura. In Santa Barbara, the Sea Center and Sanctuary office are developing a prototype floating marine laboratory program for children and young adults.

13. Develop a Training Series for Docents/Teachers. Formalized training of docents, teachers and others could greatly improve the educational success of marine-related activities. The Sanctuary, Santa Barbara Museum of Natural History, Santa Barbara City College, UCSB, and/or others could collaborate and develop such a training workshop. The scope of effort and interest needs to be examined.

14. Public Service Announcements. Local radio and television should be solicited concerning the possibility of airing public service announcements on the Sanctuary. If this is possible, short public announcements, videos or other material should be developed around an educational theme.

15. Update Slide-Dissolve Program on Sanctuary. A Sanctuary slide-dissolve presentation is currently featured daily at the National Park Service Visitor's Center in Ventura. Many of these slides are either obsolete or physically deteriorating and should be replaced with newer information. A possibility may be to replace this whole approach with a short 15 minute video. Negotiations are underway with a professional photographer to complete an educational video concerning the issue of submerged cultural resources and the Sanctuary's conservation role of these resources.

APPENDIX B.
CONTRIBUTING AUTHORS*

Allen, G. B.	Brooks Institute	12-B East Cota St. Santa Barbara, CA 93101
Ambrose, R. F.	Marine Science Institute	University of California Santa Barbara, CA 93106
Antonelis, G.	National Marine Mammal Laboratory National Marine Fisheries Service	7600 Sand Point Way, NE Seattle, WA 98115
Baker, K. S.	UCMBO Scripps Inst. of Oceanography	University of California San Diego, CA 92093
Barthelmess, D.	International Underwater Contractors, Inc,	4835-B Colt St. Ventura, CA 93003
Bidigare, R. R.	Geochemical & Environmental Research Group	Texas A&M University College Station, TX 77843
Carr, M. H.	Dept. of Biological Sciences	University of California Santa Barbara, CA 93106
Chan, D. S.	Hazardous Materials Response Branch Ocean Assessments Division National Oceanic and Atmospheric Administration	Coast Guard Island, Bldg.14 Alameda, CA 94501
Childress, J. J.	Dept. of Biological Sciences & Marine Science Institute	University of California Santa Barbara, CA 93106
Cicin-Sain, B.	Dept. of Political Science	University of California Santa Barbara, CA 93106

* Names and addresses of the workshop participants are listed in the workshop report in Part IV of this document.

Claeys, P.	Dept. of Geology	University of California Santa Barbara, CA 93106
Clayton, J. R., Jr.,	Science Applications International Corp	10260 Campus Dr. San Diego, CA 92121
Connell, J. H.	Dept. of Biological Sciences	University of California Santa Barbara, CA 93106
Davis, G. E.	Channel Islands National Park	1901 Spinnaker Dr. Ventura, CA 93001
DeLong, R. L.	National Marine Mammal Laboratory	National Marine Fisheries Service 7600 Sand Point Way, NE Seattle, WA 98115
DeLuca, M.	National Undersea Research Program National Oceanic and Atmospheric Administration	6010 Executive Blvd. Rockville, MD 20852
DeNiro, M. J.	Dept. of Earth & Space Sciences	University of California Los Angeles, CA 90024
Doehne, E.	Dept. of Geology	University of California Davis, CA 95616
Ebeling, A. W.	Dept. of Biological Sciences	University of California Santa Barbara, CA 93106
Glassow, M. A.	Dept. of Anthropology	University of California Santa Barbara, CA 93106
Gunn, J. T.	Science Applications International Corp.	13400 B Northup Way #36 Bellevue, WA 98005
Haaker, P.	California Department of Fish and Game	1301 West 12th Street Long Beach, CA 90813
Haymon, R.	Marine Science Institute	University of California Santa Barbara, CA 93106
Henderson, K.	California Department of Fish and Game	1301 West 12th Street Long Beach, CA 90813

Holbrook, S. J.	Dept. of Biological Sciences	University of California Santa Barbara, CA 93106
Howorth, P. C.	Marine Mammal Center	3930 Harrold Ave. Santa Barbara, CA 93101
Hyland, J. L.	Battelle Ocean Sciences -Ventura	1431 Spinnaker Dr. Ventura, CA 93001
Jones, B. H.	Alan Hancock Foundation	University of Southern California Los Angeles, CA 90089
Kennett, J. P.	Marine Science Institute	University of California Santa Barbara, CA 93106
Lagerloef, G. S. E.	Science Applications International Corp.	13400 B Northup Way #36 Bellevue, WA 98005
Lick, W.	Dept. of Mechanical and Environmental Engineering	University of California Santa Barbara, CA 93106
Long, E. R.	Ocean Assessments Division National Oceanic and Atmospheric Administration	7600 Sand Point Way, NE Seattle, WA 98115
Luyendyk, B.	Marine Science Institute	University of California Santa Barbara, CA 93106
Margolis, S. V.	Marine Science Institute	University of California Santa Barbara, CA 93106
Martinez, L.	Neurosciences Research Program IES	University of California Santa Barbara, CA 93106
Mearns, A. J.	Ocean Assessments Division National Oceanic and Atmospheric Administration	7600 Sand Point Way, NE Seattle, WA 98115
Onstad, L.A."Skip"	Clean Seas	1180 Eugenia Place #204 Carpenteria, CA 93013
Page, M.	Marine Science Institute	University of California Santa Barbara, CA 93106

Parker, D.	California Department of Fish and Game	1301 West 12th Street Long Beach, CA 90813
Payne, J. R.	Science Applications International Corp.	10260 Campus Dr. San Diego, CA 92121
Petty, R. L.	Marine Science Institute	University of California Santa Barbara, CA 93106
Piltz, F. M.	Minerals Management Service Pacific OCS Region	1340 W. Sixth St. MS 300 Los Angeles, CA 90017
Prezelin, B. B.	Dept. of Biological Sciences	University of California Santa Barbara, CA 93106
Ricard, Y.	Marine Science Institute	University of California Santa Barbara, CA 93106
Robison, B. H.	Monterey Bay Aquarium and Marine Science Institute	Research Institute Monterey, CA University of California Santa Barbara, CA 93106
Schmitt, R. J.	Dept. of Biological Sciences	University of California Santa Barbara, CA 93106
Schroeter, S	Dept. of Biological Sciences	University of Southern California 531 Encinitas Blvd., Suite 113 Los Angeles, CA 92024
Shields, J. D.	Dept. of Biological Sciences	University of California Santa Barbara, CA 93106
Smith, R. C.	Center for Remote Sensing and Environmental Optics, UCMBO	University of California Santa Barbara, CA 93106
Smyth, G.	Dept. of Applied Probability and Statistics	University of California Santa Barbara, CA 93106
Stewart, B. S.	Sea World Research Institute	Hubbs Marine Research Center 1700 South Shores Rd. San Diego, CA 92109

Stout, P.	Marine Science Institute	University of California Santa Barbara, CA 93106
Swarbrick, S.	Marine Science Institute	University of California Santa Barbara, CA 93106
Wenner, A. M.	Marine Science Institute	University of California Santa Barbara, CA 93106
Wilcoxon, L. R.	Dept. of Anthropology	University of California Santa Barbara, CA 93106
Woodhouse, C. D.	Santa Barbara Museum of Natural History	2559 Puesta Del Sol Rd. Santa Barbara, CA 93105
Yochem, P. K.	Sea World Research Institute	Hubbs Marine Research Center 1700 South Shores Rd. San Diego, CA 92109
Zimmer-Faust, R.K.	Marine Science Institute	University of California Santa Barbara, CA 93106

AUTHOR INDEX