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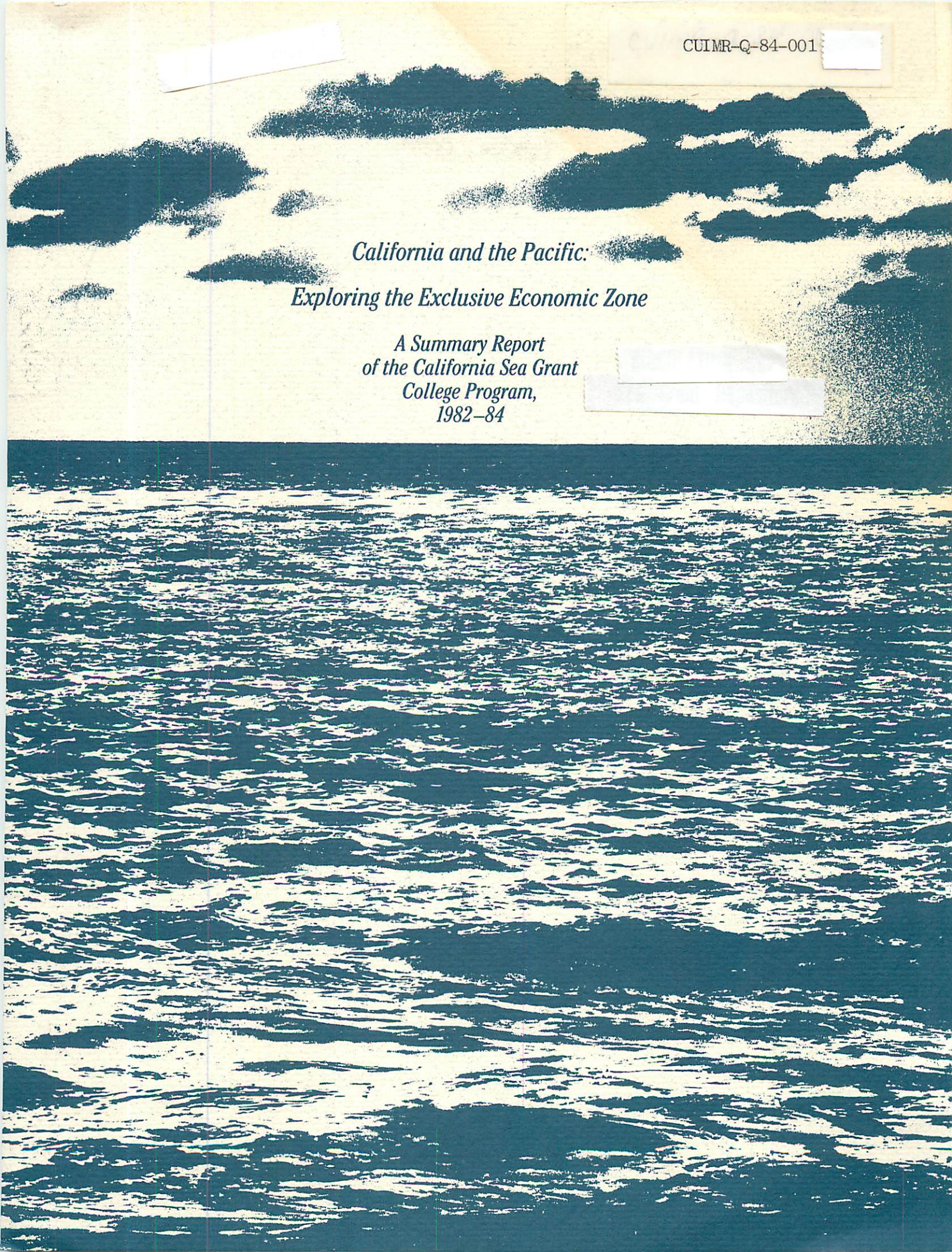

California and the Pacific:

Exploring the Exclusive Economic Zone

A Summary Report
of the California Sea Grant
College Program,
1982–84

CALIFORNIA
SEA GRANT

The California Sea Grant College Program is a statewide multiuniversity program of marine research, education, and advisory services, administered by the University of California Institute of Marine Resources. Sea Grant-sponsored research contributes to the growing body of knowledge about our coastal and ocean resources and, consequently, to the solution of many marine-related problems facing our society. Through its Marine Advisory Program, Sea Grant transfers information and technology developed in research efforts to a wide community of interested parties and actual users of marine information and technology, not only in California but throughout the nation. Sea Grant also supports a broad range of educational programs for university students, public school teachers and students, and the general public so that our coastal and ocean resources can be understood and used judiciously by this and future generations.

Rosemary Amidei,
Communications Coordinator

Published by the California Sea Grant College Program, University of California, La Jolla, California, 1985. Additional single copies are available free of charge from Sea Grant at: University of California, A-032, La Jolla, California 92093.

This work was sponsored in part by NOAA, National Sea Grant College Program, Department of Commerce, under grant no. NA80AA-D-00120, Project # A/P-1 and by the California State Resources Agency. The U.S. Government is authorized to produce and distribute reprints for governmental purposes.

California and the Pacific: Exploring the Exclusive Economic Zone

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California Sea Grant College Program
University of California
La Jolla, California 92093

Report No. R-CSGCP-016

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Introduction

This has been the Year of the Ocean, a national celebration of the heritage and future of our seas. It is a celebration in which the California Sea Grant College Program has been pleased to play a role.

The period from July 1, 1984 through June 30, 1985 was designated as the Year of the Ocean by the President and endorsed by a joint resolution of Congress. The designation was made just one year after the President had proclaimed our offshore waters as the "Exclusive Economic Zone of the United States of America." This proclamation gave America sovereign rights over an enormous area of the sea adjacent to U.S. coasts, including areas around U.S.-controlled islands in the Pacific and the Caribbean.

In this summary of the activities of California Sea Grant from 1982 to 1984, we examine how research funded by the program is contributing to basic knowledge necessary to fully realize the potential of the Exclusive Economic Zone (EEZ). The California program—largest of 30 Sea Grant programs in the United States and Puerto Rico—is a statewide partnership of government, industry, colleges and universities, and the public. Its mission is to promote the sound development of our nation's marine resources through research, educational programs, and advisory services. As you will see from this report, one of the primary aims of California Sea Grant is to support practical research that has the potential to be economically beneficial to the state and the nation.

We at California Sea Grant are excited by the potential of the undersea frontier that lies just off our coast. As one of the Sea Grant programs for the Pacific area, we cooperate with Alaska, Hawaii, Oregon, and Washington through a regional program, the Pacific Sea Grant College Program (PSGCP), aimed at conservation and development of the vast resources of the Pacific. Some of the recent regional activities of PSGCP are reported elsewhere in this report.

As a California program, we are especially aware that "regional" considerations must now often extend to the nations of the Pacific Rim, an area characterized by University of California President David P. Gardner as one of the most dynamic regions of the globe, destined, he believes, to become "one of the greatest centers of trade, commerce, and cultural exchange the world has ever known." Since 1978, more U.S. trade has crossed the Pacific than the Atlantic: the "Far East" has become America's "Near West."

In the period covered by this report, California Sea Grant has been involved in several international activities with Pacific Rim neighbors. To cite some examples (others appear throughout the report), we participated in the Second North Pacific Aquaculture Symposium, held in Japan; cooperated in an International Symposium on Salmonid Reproduction in Seattle; hosted an international symposium on Recent Innovations in Pacific Molluscs; and sponsored a workshop in Guam on economically important algae of the Pacific (attendees at the Guam meeting included a small group of leading taxonomists from the United States, Guam, the People's Republic of China, Australia, Taiwan, Chile, and Japan). We have also worked cooperatively with the University of Hawaii for the past several years to sponsor training workshops for science teachers from the U.S. trust territories in the Pacific; our aim here is to raise the consciousness of teachers to the spectacular educational resource represented by the oceans.

The Year of the Ocean was proclaimed to reawaken America to the tremendous resource potential of our oceans. We trust that this brief report will help to illustrate their enormous wealth.

James J. Sullivan
Program Manager
California Sea Grant College Program

Proclaiming an Exclusive Economic Zone

"The significance of the EEZ to the future of our country may well be greater than the 1803 Louisiana Purchase acquisition—considering the rate of depletion of the Earth's natural resources on land and the potential that the oceans are believed to have for addition to our resource base."

National Advisory Committee on Oceans and Atmosphere (*The Exclusive Economic Zone of the United States: Some Immediate Policy Issues*)

The Bettmann Archive

The Louisiana Purchase of 1803 nearly doubled America's size, extending U.S. boundaries to include an enormous frontier later explored by Lewis and Clark on their famous expedition from the Mississippi to the Pacific. Similarly, the newly proclaimed Exclusive Economic Zone off U.S. coasts gives the nation sovereignty over another new frontier—one that is again nearly twice the land area of the United States.

On March 10, 1983, President Reagan made a historic statement whose effect on our nation has been likened to that of a modern-day Louisiana Purchase. He proclaimed the establishment of an *Exclusive Economic Zone (EEZ)* off our coasts, thereby claiming sovereign rights over all resources, both living and nonliving, within 200 nautical miles of our shoreline. In all, the President's action extended our boundaries to embrace an enormous and largely unknown frontier of nearly 4 billion acres, or nearly two times the land area of the United States.

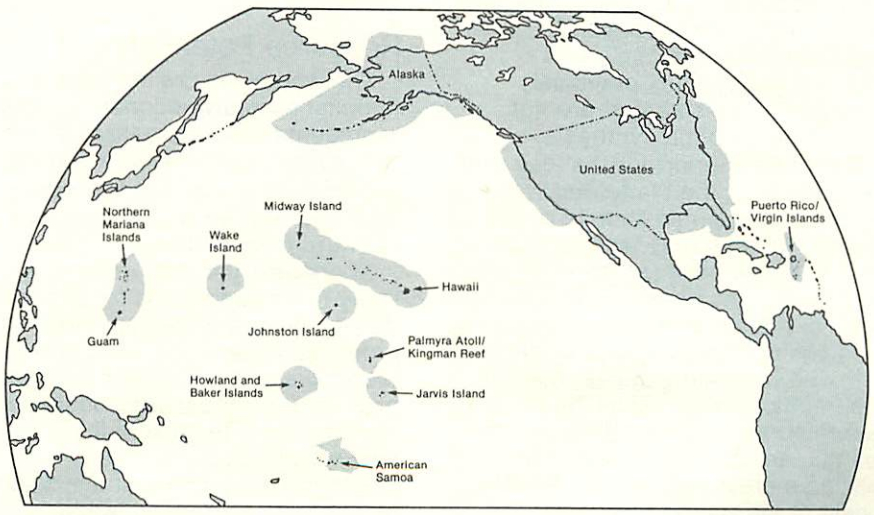
This action came one year after the United States had voted against the Convention on the Law of the Sea, largely because of its provisions on deep seabed mining. In declaring an EEZ, the United States exercised a right claimed by more than 50 nations and recognized in the Law of the Sea Convention.

Our country's steps toward such a declaration began in 1945, when President Truman asserted America's right to explore and exploit the mineral and petroleum reserves on our continental shelf—including those portions that extend far beyond the conventional 3-mile territorial sea. This was an unprecedented action in the history of modern states—the first time since the 16th century that a major power had asserted an exclusive claim to an area previously assumed to be part of the high sea.

Some thirty years later, in 1976, the United States passed the Magnuson Fishery Conservation and Management Act, which asserted exclusive management rights over fish in a 200-nautical mile zone coinciding with the present EEZ. Prior to this, many foreign countries, but particularly Japan, Korea, and the Soviet Union, had harvested large quantities of fish within 200 miles of the U.S. coastline. Today, through proclamation of the EEZ, the United States has sovereign rights over this area and now controls an estimated 15 to 20% of the world's edible fish.

President Reagan's proclamation recognizes the international community's rights within the EEZ to such traditional high sea activities as navigation, overflight, the laying of submarine cables and pipelines, and other lawful uses. And, significantly, it does not regulate foreign scientific research within the EEZ, although it recognizes the rights of other countries to control scientific research within their zones of influence.

What we have gained by proclaiming an EEZ is authority for environmental regulation and for enforcement over foreign activities in our zone; in addition we have staked a claim on all future economic uses of the zone. What are these economic uses likely to be? And just how much is known about the potential of our EEZ?



The Exclusive Economic Zone of the United States.

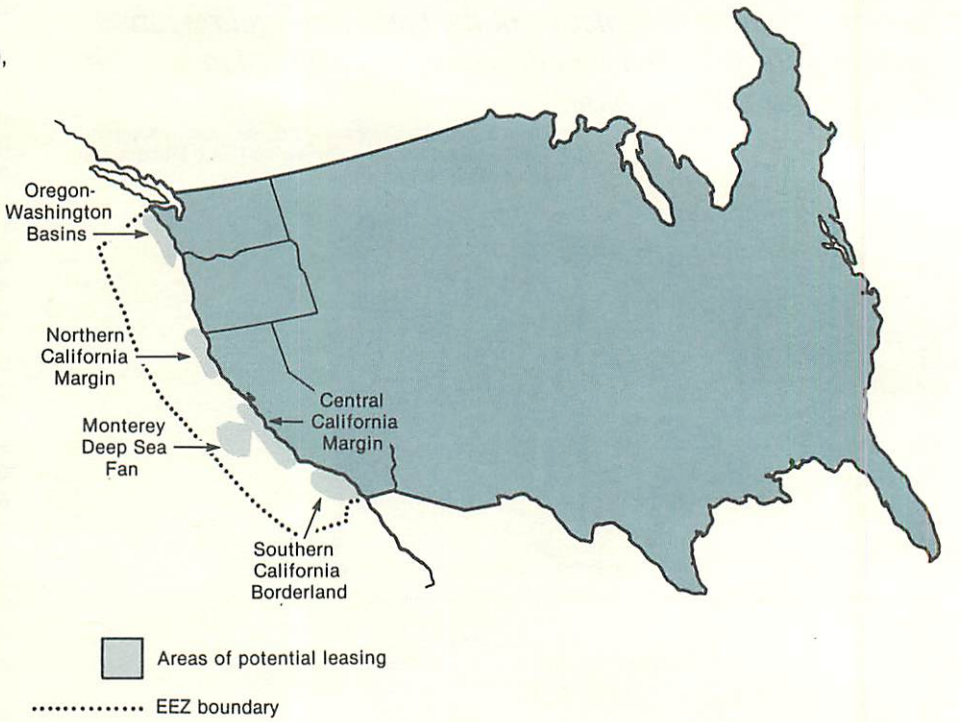
We know, of course, that major deposits of oil and gas and potentially important deposits of minerals occur off U.S. coasts, though resource estimates are based on spotty data. We know, too, that there exists a wealth of life in the waters off our shores. But our expanding vision of the potential wealth of the EEZ is also coming from rapid advances in marine geology, marine biology, and other sciences.

The Ocean Frontier

One scientist has observed that geology is geology whether you cover it with trees or water. But terrain covered with water is obviously much more difficult to explore. Only within the last 20 or 30 years has improved technology allowed the mapping of the topography of the seafloor through the use of sonar images and deep-diving submersible research vessels.

In their recent investigations of the ocean's bottom, scientists have learned that the floor of the world's oceans is dominated by a tremendous mountain range, known as the mid-ocean ridge, which stretches for approximately 75,000 km around the globe. When they started mapping this range in 1973, they were startled to find that, contrary to mountain ranges on land, the axis of the ridge is characterized by the spreading (or "rifting") of great crustal plates, accompanied by the upwelling of hot magma from deep within the Earth. Scientific exploration of mid-ocean ridges and rifting zones between plates has led to very recent discoveries of unsuspected kinds of mineral deposits and unique, previously unknown organisms that are not dependent on photosynthesis.

Scientific support for the idea that the surface of the planet Earth is made up of gigantic, mobile plates of crust is itself only two decades old. It is now believed, for example, that the Pacific coast is the leading edge of the North American plate as it moves north and west, colliding with and overriding the seafloor of the Pacific Ocean. Thus, this coast is termed an "active" continental margin. In contrast to a passive, trailing margin such as the Atlantic coast of the United States, the Pacific coast is marked by earthquakes and by volcanism. The volcanic activity of Mt. St. Helens, for example, results from interactions between the North American and Pacific plates.



Location of basins with oil and gas potential within the EEZ off the western coast of the United States.

Because the Atlantic, Pacific, and Gulf coasts have had different geological histories, they have different resource potentials. In this brief report, the focus will be limited to the Pacific region, particularly California.

Resource Potential

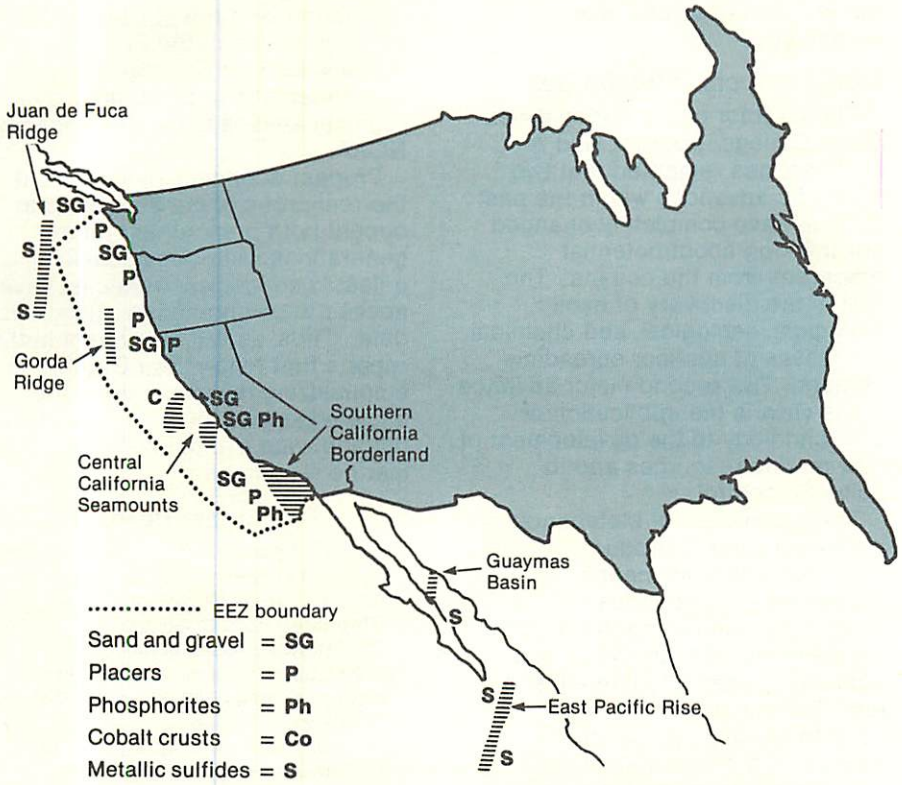
The worldwide proliferation of national exclusive economic zones represents growing realization that our planet's land-based resources are limited. As we head into the 21st century, we will have to look seaward for resources.

At present, the resources most likely to be candidates for economic development are fish and fish products, oil and gas, hard minerals (sand, gravel, and "placer minerals"), phosphate, manganese nodules and crusts, heavy metal sulfides, and new marine products. Many also stress the importance of the ocean's potential for recreation, waste disposal, and generation of energy.

Fisheries

In California, commercial fishing is a major industry. Each year, according to the State Coastal Conservancy, commercial fishing contributes $300 million to $400 million to the state economy and generates nearly 40,000 jobs.

Since the 1976 passage of the Magnuson Act, mentioned previously, U.S. management of fishery resources between 3 and 200 nautical miles of the shoreline has helped the industry (inside the 3-mile territorial sea, fisheries are subject to state law). Foreign harvesting has declined and domestic catches have grown. "Joint ventures" (which occur when fishing fleets deliver their catch directly to foreign processing ships) have also grown. Ironically, however, a significant share of the fish processed by foreign interests is ultimately shipped back to the United States as part of the $5 billion of seafood we import annually. Developing our own fish-processing capacity would help the seafood industry and reduce our trade imbalance, but industry progress has been slow because of



Known occurrences of hard minerals off the western United States.

the massive capital investments needed.

There are numerous fisheries issues that may take on increasing importance as activity within our EEZ expands: rights of foreign fishermen; conflicts between commercial fishermen and saltwater recreational fishermen; management of highly migratory species such as tuna; and reconciliation of state and federal differences in fisheries management, where these exist.

Oil and Gas

In terms of value and strategic importance, petroleum is likely to continue to dominate economic activities in the U.S. EEZ. The value of subsea oil and gas presently recovered from U.S. waters approaches $33 billion annually. (In comparison, fish landings account for approximately $2.5 billion.)

The oil and gas industry is about to expand significantly its offshore exploration based in part on estimates by the U.S. Geological Survey that as much as one-third of our undiscovered and recoverable oil and gas may lie offshore. Increased emphasis will be placed on sites in deep water and off Alaska, where technological advances are needed to deal with severe weather conditions.

Although 90% of the oil and virtually all the gas produced in federal waters has thus far come from the Gulf of Mexico, with the remainder from California, major discoveries off central California suggest that the state may contain significantly more petroleum than once estimated, perhaps as much as 30 billion barrels. State citizens and officials are openly concerned about protecting California's unique environment and have pressed for special conditions on all drilling sites being offered for sale. Among the conditions are provisions for protecting sensitive biological areas, including fishing areas; protecting water supplies; controlling air pollution; and assuring vessel traffic safety.

Hard Mineral Resources

Sand and gravel are expected to be the first hard mineral resources extracted from the EEZ in any sizeable amounts. The construction industry uses these for aggregates, as well as for landfill, beach management, and manufacturing.

Land deposits presently provide nearly all the sand and gravel produced in the U.S., but several West Coast cities, such as Los Angeles, San Diego, and San Francisco, are experiencing shortages. Because water transport is so much less expensive than transport by truck, the use of marine sand and gravel is sure to become increasingly attractive to metropolitan areas located on the coasts or having commercial port facilities.

Heavy metal deposits (called "placer deposits") are often associated with sand and gravel and are likely to prove valuable in certain sections of the EEZ—especially in Alaska coastal areas. Placer deposits have been found off Alaska, California, Oregon, and Washington, and others are probably buried within the continental margin. Although development of placers is not thought economically feasible at present, technological advances in methods of recovery or increases in mineral prices might make their development profitable. Gold has been found in ocean sediments near Crescent City and off the mouths of rivers in southern California. Zircon and chromite have also been reported near Crescent City, and platinum has been reported near Crescent City, north of Orick, and at Monterey Bay.

Phosphorites

World demand for phosphorite, used to produce fertilizers, has been on the increase, and the United States is a major exporter of this mineral. Offshore reserves appear to be enormous, and as land resources diminish over the next 20 years we will likely turn to the EEZ for this critical mineral.

Phosphorite deposits are known to occur off both the east and west coasts of the U.S. and on several seamounts in the EEZ of the Pacific Ocean. Deposits have been widely recovered in the California Continental Borderland and near Monterey Bay.

Nodules and Crusts

Manganese nodules cover much of the deep seafloor, and appear to be a rich potential resource for

manganese, copper, nickel, and cobalt—all elements of strategic and economic importance. The richest fields of nodules occur in international waters of the eastern equatorial Pacific between the latitudes of 5° and 15°N. Manganese nodules have been reported within the EEZ off the west coast of the United States, Hawaii, and the Pacific Island territories. But known occurrences off the Pacific coast are at present not considered suitable for mining.

Recently interest has shifted from manganese nodules to cobalt-rich manganese crusts. Cobalt is essential for manufacturing jet engines and cutting tools, and for other industrial applications, but the U.S. must import more than 90%, largely from southern Africa. Cobalt-rich crusts are exciting interest because they are closer, at least as mineral rich as nodules, and clearly within U.S. jurisdiction.

Metallic Sulfides

In the last six years, mineral deposits of potentially great economic value have been discovered in several parts of the eastern Pacific Ocean. These deposits are metallic sulfides found along seafloor spreading centers, several of which occur within the EEZ.

The idea that metallic sulfide deposits originally formed as a result of volcanism on the ocean floor was confirmed by the 1979 discovery on the East Pacific Rise of "hydrothermal vents" around which zinc, copper, iron, and silver sulfides had been precipitated in mounds and chimneys several meters high. Similar deposits were subsequently found at the Galapagos Rift, the Guaymas Basin within the Gulf of California and the Juan de Fuca Ridge. In 1983 metallic sulfide deposits were recovered by dredge on the Gorda Ridge, a vast seafloor canyon about the size of the Grand Canyon, which lies within the EEZ off Oregon and northern California and encompasses a geothermal rift system.

Other attractive sites for massive sulfide deposits within the EEZ are the active volcanic island arcs (Aleutians and Marianas) and isolated seafloor volcanoes throughout the Pacific EEZ. But development of this newly discovered—and essentially renewable resource—depends on the creation of wholly new technology.

New Products from the Sea

The director of the National Sea Grant College Program, Ned A. Ostenso, has remarked that two scientific advances within the past decade have completely changed our thinking about potential resources from the oceans. The first is the discovery of exotic biological, geological, and chemical processes at seafloor spreading centers. The second major advance in his view is the application of biotechnology to the development of new marine resources and to pollution control.

The techniques of biotechnology are being used to produce entirely new products from marine organisms—drugs, industrial chemicals, cultures for treating industrial wastes, algicides, and antifouling agents to name just a few. Biotechnology can also be used to produce successful aquaculture of many species of invertebrate animals, since large populations of shellfish can be manipulated and their genes cloned at the larval and intermediate stages. Scientists are optimistic that we will one day reap entirely new harvests from the sea, based on the unusual chemistry of marine plants and animals.

Road Maps to the EEZ

At present we lack even the most basic road maps needed for developing and protecting the EEZ. But several major departments and agencies of the government have launched ambitious programs that will generate a wealth of information about the new frontier. For example, the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey have launched a major cooperative program to carry out extensive bathymetric and geophysical surveys of the EEZ. Two NOAA ships, the *Davidson* and *Surveyor*, have already begun surveying west coast EEZ waters off southern California between Cape Mendecino and Point Conception. Also, satellite data are being used to develop national data bases on discharges of water pollutants, life cycles, and distribution of valuable marine organisms, marine recreation, and the physical characteristics of the EEZ. Much of the new EEZ data will be compiled in a series of five comprehensive regional atlases being developed by NOAA.

Prudent economic development of the resources of the EEZ so as to benefit both present and future generations will not be possible unless management agencies have access to comprehensive scientific data. Thus, as will be evident in the reports that follow, Sea Grant is emphasizing development of the knowledge that will be needed for full and wise exploitation of our marine resources.

For Further Reading

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Enhancing the Survival of Hatchery-Reared Salmon

"We can and should be a fishing nation. We should develop an attitude that it is in the best interest of the United States, not only for this generation but for succeeding generations, that this renewable resource should be responsibly developed and managed so that its benefits will be available forever."

Robert F. Morgan
Pacific Seafood Processors Association
(*Exclusive Economic Zone Papers*, OCEANS '84, p. 28)

Salmon display a marvelous physiological trick mastered by few other organisms. As hatchlings, they live in the fresh water of rivers, but as they migrate downstream to the ocean they transform themselves from freshwater fish to saltwater fish, modifying their internal organs and tissues to accommodate the new seawater environment. Just prior to this transformation, called smoltification, salmon produce a burst of the hormone thyroxine from their thyroid glands. The thyroxine burst appears to help the young fish undergo changes necessary for survival and growth in seawater.

Hatchery-raised salmon must also make the transition from fresh water to saltwater when they are placed in seawater holding pens prior to release, but the timing of that transition is controlled by hatchery personnel rather than by nature. If salmon are placed in seawater before they are ready to make the transition, many of them die and many of the survivors are stunted for life. Hatcheries can reduce this decimation of young fish by monitoring them for the thyroxine surge that indicates the fish are ready for seawater entry. However, repeated sampling of salmon blood for hormone levels is laborious and costly.

Howard Bern, Charles Nicoll, Richard Nishioka, their Sea Grant trainees, and other associates at the University of California, Berkeley, have been grappling with the problem of smoltification in coho salmon (*Oncorhynchus kisutch*) for several years. The Sea Grant researchers' first success came when they discovered that nearly all the fish in a population became primed for smoltification simultaneously, and in concert with the phase of the moon. Their then postdoctoral fellow, Gordon Grau, discovered that on the new moon closest to the spring equinox, concentrations of thyroxine surged in the bloodstreams of the salmon. When the transfer to saltwater was timed to coincide with the thyroxine surge, many more fish survived, and stunting was drastically reduced. Since the thyroxine surge occurs with the new moon, a fisheries biologist need only look at the lunar calendar to determine when to release the fish for maximum survival. In the past three years, several hatcheries have used the phase of the moon to time the release of nearly 300,000 tagged fish, and this simple procedure has nearly doubled the number of salmon returning from the sea.

The research effort did not stop there. Further investigation by Nishioka revealed that the quality of the water used to raise the salmon influenced the timing and extent of thyroxine production. They discovered that salmon raised in water taken from the depths of reservoirs produced smaller, more erratic thyroxine pulses, less synchronized to the new moon than occurred in salmon raised in undammed river water. Deep reservoir water remains constant through the year, unlike "wild" river water, which shows seasonal changes in temperature, suspended matter, and dissolved minerals. Apparently, salmon require changes in water quality to prime the thyroid fully for the smoltification process. Bern's group believes that salmon benefit from variability in their environment: slightly varying temperature, food, and salinity just prior to smoltification may promote full development of the thyroid response and may increase still further the percentage of fish that survive to return to the hatchery.

Because Pacific and Atlantic salmon support one of the most valuable fisheries in the northern hemisphere, this project numbers scientific collaborators from Canada, Ireland, France, Hong Kong, and Japan, as well as from California, Washington, and Hawaii. International exchange has occurred through a series of meetings as well as through a program of joint research conducted by scientists in Japan and California. For example, Munehiko Iwata, a postgraduate research zoologist from the University of Tokyo's Ocean Research Institute at Otsuchi, spent a year with Bern at Berkeley studying indices of seawater adaptability in salmon before returning to Japan, where he continues to participate in cooperative research. Similarly, Patrick Prunet in Rennes, France, and Tetsuya Hirano in Tokyo have both developed assay methods for other salmon hormones, which are being used to analyze further the changes accompanying salmon development.

Smoltification, while strongly influenced by thyroxine, is proving to be an exceedingly complex transformation involving at least six separate hormones that affect salt balance regulation, gill function, intestinal nutrient uptake, kidney function, and fat metabolism. Understanding the complex interactions among the hormones and their target organs promises both practical benefits and a deeper understanding of growth and development in salmon.

(H. A. Bern and C. S. Nicoll, "Endocrine Control of Salmonid Development and Seawater Adaptation," R/F-78.)

Related Sea Grant Projects (Fisheries Research & Development)

California Sea Grant research focuses on enhancing traditional fisheries to increase our supply of protein from the sea; on developing fisheries of underutilized species; and on developing new seafood products.

Development and Enhancement of Fisheries

Thomas J. Hassler, "Artificial Imprinting of Salmon in an Anadromous Fish Hatchery," R/F-77.

During the 1982 spawning season, this project monitored adult salmon returning to the Mad River hatchery. The synthetic odor morpholine—the chemical used to imprint juvenile salmon—was added to the hatchery raceway from mid-September through mid-December as an attractant. Thirty-two adult 1979 BY chinook salmon returned to the hatchery in 1982—18 imprinted and 14 control. Imprinting could make it possible for managers to direct the final stages of salmon migration.

Graham A.E. Gall, "Contribution of Coho and Chinook Spawning Populations to Mixed Fisheries: A Management Study," R/F-87.

Using biochemical and genetic methods, this project seeks to identify the distribution of coho and chinook salmon breeding populations along the California–Oregon coast as an initial step in developing regulatory policies for the fishery and salmon enhancement programs. The geographic limits of samples for the study have been identified, and fish from a number of chinook and coho populations have been sampled.

G.A.E. Gall and F.W. Utter, "Genetic Structure of Coho Salmon Populations on the Pacific Coast," R/F-76.

Maintaining genetic diversity within coastwide populations while maximizing harvestable yield is a primary goal of salmon fisheries management. This project compiled electrophoretic profiles documenting existing variability in coho salmon. The researchers analyzed 23 populations from both hatchery sources and the wild and found four relatively discrete groups based on electrophoretic profiles.

Dennis Hedgecock, "Genetic Analysis of Spatial and Temporal Structure in Populations of the Northern Anchovy," R/F-82.

This project sought to resolve two important issues pertaining to the management of the northern anchovy fishery: (1) whether and to what extent Mexican and U.S. fisheries are harvesting different stocks, and (2) whether the main California stock of anchovy is a single, randomly mating population. The researchers demonstrated that the central stock is not a single, randomly mating population as previously supposed.

Reuben Lasker, "The Effects of Climate and Weather on Albacore Migration and Distribution in the Northeastern Pacific," R/F-86.

The objective of this project is to determine the influence of climatic and weather fluctuations on the migration and distribution of albacore tuna along the North American coast. The researchers are using satellite remotely sensed data to monitor surface thermal and chlorophyll patterns; surface wind stress estimates to monitor the variability in wind forcing; and catch data from the North American fishery to study seasonal albacore migration. In addition, they are testing the possibilities of using satellite images and atmospheric data for predicting the location of favorable and unfavorable fishing areas.

Serge Doroshov and Joseph Cech, "Establishment of Parameters Critical to Sturgeon Management in the Pacific Northwest," R/F-90.

Wild stocks of white sturgeon, *Acipenser transmontanus*, were sampled in California and Oregon in order to characterize the stock's reproductive status. Biopsy samples were taken for electrophoretic analysis, and fin-ray sections were used to determine population age structure. Some fish were spawned at a hatchery by hormonal induction techniques to evaluate reproductive performance and to produce young for research on feeding behavior, diet, and disease susceptibility and treatment.

Gary L. Hendrickson and Ronald A. Fritzsche, "Ecology and Possible Causes of the 'Jellied' Condition in Dover Sole, *Microstomus pacificus*," R/F-89.

This project is providing data that will help reduce the amount of "jellied" Dover sole harvested by commercial fishermen and subsequently rejected by fish processors and is seeking to determine, if possible, the cause(s) of the jellied condition. The researchers have correlated the jellied condition with water depth at which fish are caught; in addition, the data seem to indicate that the utilization of body muscle protein for gonadal maturation is the prime factor associated with the jellied condition.

Gregor M. Cailliet, "Age Verification and the Application of Aging Techniques to Emerging Elasmobranch Fisheries," R/F-81.

This project has sought to determine whether growth zones in the vertebrae of elasmobranchs (e.g., sharks) are formed annually and to apply as many age-verification approaches as possible. The researchers have developed two techniques for validating age estimates. A collection of shark vertebrae has been compiled with corresponding information on size, age, reproductive maturity, and other morphological and life history features.

Gregor M. Cailliet, "Age Determination and Confirmation in Large Pelagic Fishes (Sharks and Billfish) from Californian and Hawaiian Waters," R/F-84.

The researchers sought to determine the ages of large, pelagic fishes (sharks and billfish) and to construct growth models that correlate size, age, and other life history features. They used various age determination and validation techniques and applied the resulting age and growth information to develop population dynamics models for these large pelagic fishes.

David Hankin, "Vital Statistics of the Female Stock of Dungeness Crab in Northern California," R/F-72.

The California dungeness crab fishery is managed on a single-sex harvest basis: only mature males may be harvested, whereas the female stock is protected. This project undertook study of the vital statistics of the female crab. Over 12,000 crabs were tagged, of which nearly 500 were recovered. Recoveries provided data concerning adult female crab molt increments, molting probabilities, and fecundity.

Armand M. Kuris, "Effect of Nemertean Egg Predators on the Dungeness Crab Fishery," R/F-75.

The vulnerability of dungeness crab populations to nemertean worm egg predators continues to be a major concern in the commercial crab fisheries. The project has developed a model system for the experimental analysis of egg mortality and crab fishery, as well as techniques to remove worms from crabs for laboratory experiments and field tests.

Mia J. Tegner, "Evaluation of the Experimental Abalone Enhancement Program," R/F-73.

Four experimental approaches to enhancing depleted abalone stocks in southern California are being evaluated: (1) seeding hatchery-reared juveniles, (2) habitat modification to enhance the survival of seed and the settlement and survival of native juveniles, (3) fishery closure, and (4) transplantation of adults as brood stock.

Daniel P. Costa, "Assessment of the Impact of the California Sea Lion and

Northern Elephant Seal on Commercial Fisheries," R/F-92.

This project's objectives are to quantify the foraging energetics of the California sea lion and to characterize the foraging habitat of the northern elephant seal. The data will provide an assessment of these animals' impact on commercially important prey species as well as define their foraging requirements.

Fisheries Product Development

James F. Case, "Improving Efficiency of Commercial Shellfishing by Analysis of Bait and Trap Functions," R/F-67.

This project investigated the physiological mechanisms and behavioral tactics of foraging in the California spiny lobster and certain commercially valuable crabs to develop information useful in shellfish trapping operations.

W. D. Brown (deceased) and D. M. Ogrydziak, "Seafood Science and Technology: Modified Atmosphere Storage," R/F-68.

The researchers studied the use of modified atmospheres (particularly those containing high levels of carbon dioxide) in order to improve shelf life, handling, and distribution of seafood products.

Constantin Genigeorgis, "Effect of Modified Atmospheres on the Potential of *Clostridium Botulinum* Growth at Low Temperatures," R/F-83.

The seafood industry has been making increased use of modified atmospheres (MA) to delay seafood spoilage, but the food safety implications are not well known. These researchers were able to develop a predictive model of the probability of *C. botulinum* growth and toxin production in seafood stored at both acceptable and abused temperatures under MA. Appropriate technical changes can now be made to minimize the risk of food spoilage.

David Sinclair Reid, "Freezing-Induced Changes in Fish Tissue," R/F-95.

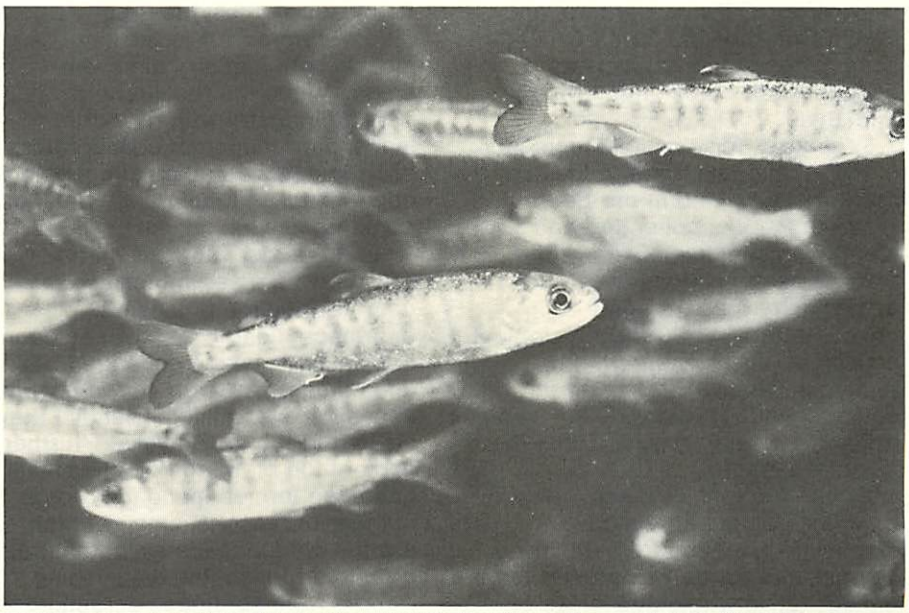
Both freezing and frozen storage change the tissue of fish, resulting in dry, woody texture, toughness, drip loss on thawing, and "off flavors." These researchers are using new microscope methods to get a clear picture of the actual structure of the frozen system. They are attempting to correlate, where possible, biochemical/chemical (structural) change with quality change to better understand the processes by which frozen, stored fish loses its quality with time.

Judith W. Zyskind, "Enzymatic Degradation of Material from Shellfish Processing," R/F-93.

This project's overall goal is to develop a market for chitin, thereby making it more profitable to convert shellfish waste material than to dispose of it. The researchers have cloned the two genes necessary to make the enzymes chitinase and chitobiase. Thus, with genetic engineering techniques, it will be possible to produce much larger amounts of these enzymes than was previously possible. An interesting corollary to this research is the finding that chitinase is a powerful insecticide and fungicide.

David M. Ogrydziak, "Genetic Improvement of a Chitinase-Producing Microorganism," R/F-96.

Chitin disposal is an expensive problem for shellfish processors, and bioconversion could be an attractive long-term solution. This project is using genetic engineering techniques to produce a strain of microorganisms that will convert chitin wastes into a product usable as animal feed, as feed for aquaculture applications, and by biochemical suppliers and researchers. (See also "Rapid Response Projects.")



Because salmon support one of the most valuable fisheries in the northern hemisphere, this project on enhancing the survival of hatchery-reared fish has attracted collaborators from around the world.

Pharmaceuticals from the Sea

"We can now envision entirely new 'harvests' from the sea. The unusual chemistry of exotic plants and animals is within reach of industry, reproducible on a mass scale for the betterment of human health and well-being."

Rita R. Colwell
University of Maryland
(*Sea Technology*, July 1984, p. 23)

When we learn that ancient remedies for illness and injury included such ingredients as hog's lice, toads, and foxes' lungs, it comes as no surprise to learn that the Greek word for pharmacy originally meant either the practice of medicine or witchcraft. The modern pharmaceutical industry still looks to exotic organisms for possible new drugs, but today's scientists are armed with a sophisticated and growing knowledge of the relationship between the chemical structure of a compound and its action in the body.

Since 1977 California Sea Grant has been supporting the work of an interdisciplinary team of University of California researchers and their graduate-student trainees who are exploring the potential of marine invertebrates and algae to supply new drugs. Team members—who include John Faulkner and William Fenical of UCSD's Scripps Institution of Oceanography, Robert Jacobs of UC Santa Barbara, and Phillip Crews of UC Santa Cruz—are examining such organisms as sponges, soft corals, nudibranchs, and algae.

Each year, for example, members of the team spend time in Mexico, the Caribbean, and in the South and Western Pacific, collecting and identifying specimens. Extracts from these specimens are immediately prepared and concentrated so that their biological activity can be measured. In particular, researchers test for compounds that retard cell division, are anti-inflammatory, or affect the skeletal system.

One of their major discoveries to date is a compound called manoalide. Derived from a marine sponge, manoalide has proved to be a model for a whole new class of nonsteroidal, anti-inflammatory drugs. Several pharmaceutical companies are now involved in testing this new substance.

In addition to identifying new marine products, the researchers hope to learn how they act. For example, by explaining the chemical action of a new compound called stypoldione—derived from a brown seaweed—they now understand its biological properties. Stypoldione can not only destroy tumors, it can also kill both sperm cells and the parasitic blood fluke that causes schistosomiasis, a chronic infectious disease affecting millions of people in tropical and subtropical regions.

Since the beginning of this project, over 800 compounds have been tested, 90 of which have been retained for further study. Of those retained, 14, representing six classes of chemical structure, are currently the focus of intensive investigation.

In order to facilitate the patenting of the bioactive drug candidates isolated in the past few years, researchers have established a "Marine Materia Medica" program within the UC Santa Barbara Foundation. Also, the drug discovery program is working closely with industry at several steps. While the researchers provide industry with new drug leads, their industrial collaborators provide advanced biotesting, patent counseling, and matching funds for continued investigation.

No drugs derived from marine organisms are yet in commercial use. (Bringing a promising pharmaceutical to market has been estimated to take a decade of basic and clinical research and to cost in excess of $10 million.) Despite the costs and the time involved, further exploration of marine biochemicals has been termed mandatory for a number of reasons, among which are the unique leads which natural products furnish, the diminishing returns from continued screening of land-based plants and animals, the length of time it takes to synthetically develop drugs with specific pharmacological properties, the lack of effective treatment for many diseases, and the continuing development of resistance by pathogenic organisms to existing drugs.

Of the wealth of resources that can be extracted from the sea, drugs may prove to be one of the least expected, but most exciting harvests.

(Marine Chemistry and Pharmacology Program, Phase II: R. Jacobs, "Pharmacological Screening and Evaluation," R/MP-31; W. Fenical, "Chemical Studies of Tropical Marine Algae and Coelenterates, R/MP-32; D. Faulkner, "Metabolites from Marine Invertebrates," R/MP-30; P. Crews, "Natural Products from Toxic Marine Organisms," R/MP-33)

Related Sea Grant Projects (New Marine Products Research & Development)

An array of interesting new products is being developed from marine organisms found within the EEZ. These include carrageen, a protein from red seaweeds that is widely used as an extender in foods and related products; algin, a gelatinous substance derived from kelp, which is used by many industries as a thickening, stabilizing, and gelling agent; and glycerol, used in cosmetics, plastics, and explosives.

Leonard J. Deftos, M.D., "Natural Marine Products that Regulate Mineral and Bone Metabolism," R/MP-28.

Research from this project has demonstrated that there are differences in the ability of cartilaginous sharks (chondrichthyes) and bony bass (osteichthyes) to dissolve (resorb) implanted bone particles and that the two groups differ in their metabolic responses to the hormone calcitonin. This work has potential importance in the diagnosis and treatment of human skeletal disease.

(See also "Rapid Response Projects.")

A graduate student diver from Scripps Institution of Oceanography collects soft coral in the Caribbean for studies of marine natural products. This particular coral contains newly discovered anti-inflammatory agents that could one day aid arthritis victims.

Exploring the Seafloor with RUM III

"The initial discovery of most hard-mineral resources in the EEZ was made during routine scientific marine-geologic surveys aimed at understanding the framework geology and geologic processes of an offshore region."

Robert D. Ballard
Woods Hole Oceanographic Institution
James L. Bischoff
U.S. Geological Survey
(*National Program for the Assessment and Development of the Mineral Resources of the U.S. Exclusive Economic Zone*, p. 185.)

If it is true, as some scientists believe, that deposits of polymetallic sulfides may build up at vents in the ocean floor on a scale of tens rather than thousands of years, then these mineral-rich deposits would be in effect renewable resources. Before this idea can be confirmed, however, the internal structure of these deposits must be examined in detail. One problem is that coring methods commonly used to examine mineral beds on land are not readily adaptable to work on the seafloor.

The vent deposits appear at various sites along approximately 75,000 km of submerged ridge crests. But of this vast distance, it has been estimated that only 10 km have been explored in any detail.

A new unmanned deep-sea exploration vehicle may change this picture. RUM III (Remote Underwater Manipulator), designed and built by Victor C. Anderson and his colleagues at the Marine Physical Laboratory of Scripps Institution of Oceanography, has the unique features necessary for probing our undersea frontier. RUM III has been built to work on the abyssal plains and spreading centers of the world's ocean basins. The vehicle, which is about the size of a compact car, can operate at a depth of as much as 6,000 meters and is powered and controlled from a surface ship to which it is tethered by 10,000 meters of coaxial strain cable. The fact that any standard oceanographic ship can serve as its base is one of RUM III's major advantages; another is its ability to sit on the seafloor for hours, limited neither by energy storage nor life-support requirements.

The vehicle consists of a main chassis mounted by a turret capable of rotating 400°. Among the complex equipment to be installed on the turret are

- TV booms and cameras, which allow scientists on the surface ship to see both the seafloor and the activities of the vehicle's "hand." The cameras provide high-resolution photographs of the bottom, which can be used to construct photomosaic maps of particular seafloor sites.
- Two side-looking sonar transducers, which allow mapping of the ocean terrain.
- The seawater hydraulic system, which provides a nonpolluting source of hydraulic power for the manipulator boom and other hydraulic activators.
- A manipulator boom that can lift 100 kilograms at a time. Devices attached to the end of the boom—RUM III's "wrist" and "hand"—allow it to pick up mineral or biological samples in addition to installing, operating, and recovering instruments.
- Independently controllable thrusters, which position the vehicle and keep it properly oriented as it is being lowered onto the seafloor.

RUM III may be towed from one position to another by its cable, or it can crawl along the bottom on the two smooth conveyor-belt tracks that cover the entire underbody and allow for fine adjustments in positioning. To move it over significant distances, the vehicle is lifted off the bottom by the cable and propelled with the aid of thrusters.

With its cable power source and manipulative capability, RUM III will provide an excellent platform from which to survey polymetallic sulfide deposits. Its stability will allow the use of a rotary corer, and the precision with which it can be positioned will allow geologists to employ acoustic tomography or holography—survey methods exploiting, respectively, the transmission of sound and its reflection.

RUM III was taken on its first sea trials in January 1985. Final outfitting of instruments and mechanical parts is still being conducted, but it is anticipated that the vehicle will be ready for use in research investigations in early 1986.

Both the exploration of the EEZ and development of its resources will depend on the development of new technological innovations, of which RUM III is a prime example. (V.C. Anderson, "Design of a Sea Floor Work System," R/OT-6)

Related Sea Grant Projects (Ocean Technology)

An enormous amount of technological innovation and development will be needed to fully exploit the nonliving resources of the EEZ—from collectors for mining nodules on the seafloor and turbines for harnessing the renewable energy of ocean currents to wholly man-made islands to be used as sites for industry, farming, and power plants.

Ben C. Gerwick, Jr., "Development of a Methodology for the Design of an Offshore Oil Production Platform on the Alaskan Arctic Ocean Continental Shelf," R/OT-11.

The objective is to assess the design, construction, and durability factors involved in building and maintaining an offshore oil-production platform in the ice-infested waters of the southern Beaufort Sea (off Alaska's north slope). The researchers have prepared a methodology for designing production structures, including an analysis of ice force.

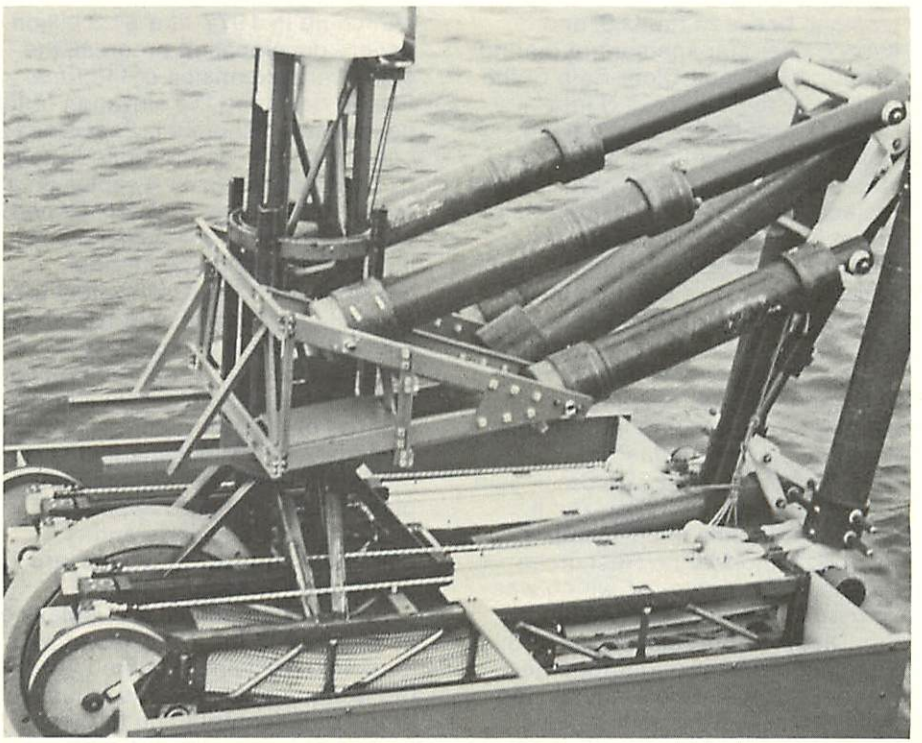
Bruce P. Luyendyk, "The Geology and Structure of the Southern Hosgri Fault Zone Offshore California: A 3-D View Using Computer Color Graphics," R/OT-10.

This project seeks to describe the structure of the southern end of the Hosgri Fault Zone offshore south central California, a seismically active region being developed for offshore oil and gas. These researchers have developed computer software to display the sub-bottom structure in three dimensions. Further work is being done on increasing graphic flexibility so that views from various distances, azimuths, and elevations can be incorporated in the models.

C. S. Cox and A. Chave, "Design of a Towed Electromagnetic Prospecting System," R/OT-8.

This project explored the use of a towed electromagnetic prospecting system as a tool for geophysical surveys for petroleum or mineral exploration under the ocean.

(See also "Rapid Response Projects.")



RUM III will provide a deep ocean research capability now available only with manned submersibles, but without the many limitations of manned devices.

Toward Better International Relations

"Many oceanic phenomena are global or regional in nature and cannot be fully understood by research in just one part of the ocean. For any American scientist to propose and conduct efficient and effective studies in a foreign EEZ will require cooperation with scientists and scientific institutions from the foreign nation."

David A. Ross
Massachusetts Institute of Technology
(*Oceanus*, Vol. 27, no. 4, p. 57)

Deteriorating relations between the United States and Mexico over fishing rights reached a climax in 1980 when the U.S. embargoed all Mexican tuna products, thus closing to Mexico one of the largest tuna markets in the world. The result was higher prices for U.S. consumers, while cans of tuna piled up in Mexican warehouses. The U.S. action was taken in response to Mexico's seizure of U.S. tuna boats within its Exclusive Economic Zone. Prior to 1976, four U.S. fisheries—the West Coast tuna fishery, the Gulf shrimp fishery, the Southern California wetfish industry, and the Southern California recreational party-boat complex—had caught a significant portion of their catch in Mexican waters.

In an effort to gain fuller understanding of the escalating tensions between the U.S. and Mexico over management of marine resources, Biliana Cicin-Sain of the University of California, Santa Barbara, and Michael K. Orbach, University of California, Santa Cruz, initiated a special Sea Grant-funded project in the area of marine affairs. The project sought to examine bilateral relations between the two nations in terms of a variety of factors, including the effect of each nation's unique culture, history, and world position; domestic forces; differing styles of negotiating behavior; and ongoing interactions in various marine industries.

As part of the work, Dr. Cicin-Sain and her colleagues organized a major conference, "U.S.–Mexican Relations and Marine Resources: A Binational Conference," which was held at the University of California, San Diego, in September of 1983. The conference brought together distinguished marine analysts and policy makers from both nations, including former Mexican President Luis Echeverria, to discuss shared problems.

Issues highlighted were tuna management; the San Jose Tuna Pact (a "regional arrangement" that does not include Mexico); U.S. scientific research in Mexican waters; and difficulties arising from the Law of the Sea Convention, which Mexico signed, but the United States did not.

The conference and subsequent work by Dr. Cicin-Sain and her colleagues has demonstrated how differently each nation views and manages its marine resources. The Mexican system for managing resources (particularly fisheries), is highly centralized, with major direction emanating from the President and his cabinet. The Mexican government is thus responsible for the significant efforts made in recent years to raise the status of Mexico as a fishing power to "world class." Key features of this expansion include the launching in 1977 of a $1.3 billion fishery development program, the significant expansion of the tuna fishing fleet, and the elevation of the government fisheries bureaucracy to cabinet status. In the United States, by contrast, the fishing sector is almost completely privately owned, and government policy makers do little to actually guide marine development. The U.S. system for governing marine resources can be characterized as complex and decentralized. It is open to pressure at a number of points from a large number of interest groups—something the Mexicans find very hard to understand. Groups that play a major role in U.S. policy making, such as sports and conservation interest groups, are still largely absent in Mexico.

On the international level, Mexico, as a leader of the Third World, was an active participant in the Law of the Sea negotiations, and is justly proud of its contribution to the forging of a new international ocean regime. It is therefore somewhat impatient with the United States, since the United States did not sign the LOS Convention and expects unsettled issues relating to marine boundaries, resource utilization, pollution, and scientific research to be resolved through bilateral negotiations.

Problems can arise too from unrecognized differences in the perspective of a developing nation versus that of a fully industrialized nation. Mexico, for example, attaches a great deal of importance to the potential of the oceans for national growth—for the production of food and the creation of employment opportunities. In the United States, on the other hand, popular interest in the oceans has centered around natural history, conservation, science, and recreation. The government has played only a minor role in the economic activities of ocean industries.

Drs. Cicin-Sain and Orbach point out that despite all of the difficulties facing the two nations, there is strong motivation on both sides to move forward cooperatively. Labor, supplies, capital, vessels, and fishery products have continued to flow between the marine industries of the two countries, and informal negotiations are underway to create joint shrimp ventures in the Gulf of Mexico and to resume nearshore tuna harvesting by U.S. vessels in the Mexican EEZ. Thus, they suggest, the commercial and industrial interests of the two nations may move independently toward cooperation and help to heal the differences between their two governments.

Additional efforts toward increasing understanding and professional collaboration between U.S. and Mexican marine scientists are being facilitated by George Hemingway of UCSD's Scripps Institution of Oceanography (SIO). With funding from California Sea Grant, Hemingway introduces scientists from the two countries who share research interests and helps to promote joint research planning and information exchange. During 1983-84, 36 Mexican scientists participated in research on SIO vessels, and cooperative work was conducted on both U.S. and Mexican vessels in the California Current and the Gulf of California.

(B. Cicin-Sain and M. K. Orbach, "U.S.–Mexican Relations on Fishery Policy: Focus on West Coast

Fisheries," R/MA-18; G. Hemingway, "Scientific Liaison, Joint Research Planning, and Information Exchange Amongst Alta California, Baja California, and Gulf of California Marine Scientists," A/S-1.)

Related Sea Grant Projects (Marine Affairs)

Public policy is the product of compromise based on knowledge of technical considerations and political realities. California Sea Grant's subject area in marine affairs brings together public policy projects associated with coastal resources, aquaculture, fisheries development, and ocean technology.

Harry N. Scheiber, "Law, Ecology, and Economic Change: The California Fisheries, 1850-1980," R/MA-13.

This project has sought to provide a historical model for the analysis of law and public policy affecting the management and exploitation of fishery resources. For example, the California sardine failure is examined as a case study of the interaction of organized science, resource management, and public law. A book has been completed that provides a systematic overview of law and policy concerning the fisheries in California over more than a century.

Edwin M. Smith, "Legal Analysis of Multispecies Fishery Management: The Pacific Groundfish Plan," R/MA-14.

This project analyzed the legal constraints imposed on the development of a multispecies fishery plan: the Pacific Groundfish Management Plan.

Daniel Goodman, "Management of Multispecies Systems: The Pacific Hake Example," R/MA-2.

The major goal for the final year of this project was to generate a multispecies model of the Pacific hake system, representing population dynamics and interactions of all the major species affecting hake abundance.

Louis W. Botsford, "Chinook Salmon Abundance in California," R/MA-16.

This study has identified several influences of the oceanographic environment on California chinook salmon populations. The effects of upwelling, sea-surface temperature, and sea-level height on grilse, spawning adults, and catch have been examined for both central and northern California. A mathematical model of the salmon fishery, including estimates of population parameters, is being developed that will explain more than 60% of the variability in abundance.

Louis W. Botsford, "Comparative Study of Dungeness Crab Fisheries," R/MA-20.

This project has sought to identify a larval-transport mechanism that may be primarily responsible for the cyclic fluctuations in crab abundance. A strong correlation was found between southward onshore winds during the late larval period and crab catch 4 and 5 years later along the Pacific Coast.

Factors affecting larval exchange between stocks along the California, Oregon, and Washington coasts are being analyzed.

Dennis M. King, "Revision and Development of Update Procedure for the 1980 California Interindustry Fisheries Model," R/MA-17.

The California Interindustry Fishery (CIF) model developed during 1980 was updated and expanded to include several more fish-harvesting sectors. The project resulted in an enormous amount of new information about vessel operations, costs, sales, and market linkages associated with California fisheries. One of the products from the research is believed to be the most complete and reliable economic profile and database available for West Coast fisheries.

Leon Garoyan, "Analysis of Industrial Organization of Commercial Pacific Marine Fisheries," R/MA-4.

This project sought to apply an econometric model to all ports and species in an effort to analyze the commercial Pacific marine fisheries. Although it proved impossible to apply the model universally, results for Eureka, Fort Bragg, Crescent City, San Francisco, and Bodega Bay did demonstrate the usefulness of the regression models in identifying consistent port and species differences.

(See also "Rapid Response Projects.")

A student from the Escuela Superior de Ciencias Marinas of the Universidad Autónoma de Baja California (left) washes down a plankton net with a scientist from the Southwest Fisheries Center aboard Scripp's R/V *New Horizon*. Through the coordination of the Sea Grant-funded liaison office at Scripps, a total of 36 Mexican nationals participated in research on Scripp's vessels during 1983-84.

Oceanography from Space

"Recent events have demonstrated that the need has never been greater for man to understand the workings of the ocean and its resources. Satellite data are the key to global measurements."

Joint Oceanographic Institutions, Inc.
(*Oceanography from Space: A Research Strategy for the Decade 1985–1995*, p. 3)

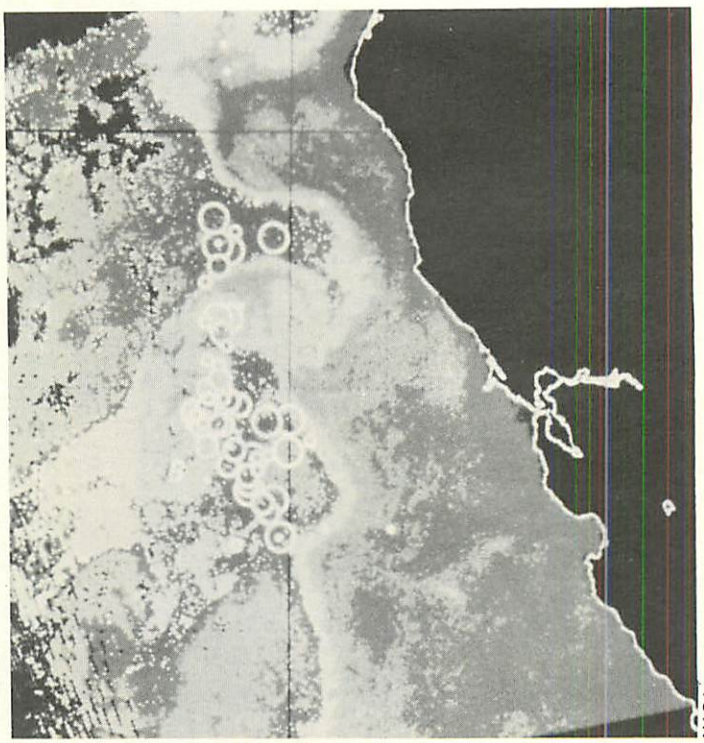
The use of satellites to study oceanography is a technique barely out of its infancy. Nonetheless, satellites have already demonstrated an incredible ability to measure the numerous ocean characteristics that are critical to understanding global weather and climate. Their power was shown during NASA's 1978 Seasat flight, which, during its 100-day mission, made as many individual measurements of wind speed and direction as had been collected during the previous 100 years of ship-borne observations.

Sea Grant researchers R. W. Austin, Director of the Visibility Laboratory at UCSD's Scripps Institution of Oceanography, and W. W. Broenkow, Professor of Oceanography at Moss Landing Marine Laboratories, San Jose State University, have been using satellite data to create atlases of the area around Monterey Bay, a highly productive fishing area.

Over the past several years, imagery from the Coastal Zone Color Scanner on board the Nimbus 7 satellite has been collected by the Visibility Laboratory. These data have been used to construct large-scale maps showing the distribution of phytoplankton—the microscopic plants that form the basis of the marine food web. The atlas, developed since 1982, provides an exciting catalog of oceanographic features in the Monterey Bay area, including zones of upwelling at prominent capes, transient eddies and jets, and seasonal surface circulation within Monterey Bay. The atlas also shows many persistent features, such as the San Francisco Eddy, a semi-permanent cyclonic eddy directly offshore Monterey Bay.

Satellite data are of great potential use to the fishing community. It has long been known that fish, and therefore fishermen, collect at the boundaries between nutrient-rich, newly upwelled waters—marked by phytoplankton blooms—and waters from which the nutrients have been depleted. But fishermen currently expend a great deal of time and costly fuel searching for these areas. Since 1981 the Scripps Visibility Laboratory has been using satellite data to generate charts that depict in color the boundaries between the nutrient-rich coastal waters and clear, deep ocean waters. The charts are produced at the Scripps Satellite Oceanography Facility and then sent out to fishing vessels by radio facsimile from Scripps Radio Station WWD and the NOAA Redwood City station. By using these charts as guides to the likely whereabouts of their prey, fishermen have estimated savings of 25 to 30% in both fuel costs and search times.

(R. W. Austin and W. W. Broenkow, "Use of the Nimbus 7 CZCS to Evaluate Circulation and Productivity Processes Along the Central California Coast," R/CZ-63.)



NASA

Variations in ocean color (which are largely a function of phytoplankton abundance) can be measured quite accurately from space. In this photo, locations of albacore tuna catches (shown by circles) have been superimposed on a satellite image showing gradations in ocean color off central California. The photo indicates that most of the albacore were caught along the seaward side of the boundary between offshore and coastal waters.

Related Sea Grant Projects (Coastal Resources Research)

It has been observed that EEZs encompass that part of the ocean that "has the most variability, receives most of the erosion and waste products from land, and is the most used and abused." California Sea Grant research on coastal resources seeks to understand more about the natural functioning of this fragile eastern-most border of California's EEZ, as well as the impact of human activities.

Thomas G. Dickert, "Planning Methods for California's Coastal Wetland Watersheds: A Composite Report," R/CZ-57.

The project investigated those aspects of urbanization, agricultural development, and forestry practices that may affect estuarine environments. A notable accomplishment was that the planning system that was developed, which set permissible levels of development within Elkhorn Slough watershed, was later adopted by the Monterey Board of Supervisors and certified in the land use plan by the California Coastal Commission.

Robert N. Colwell and Allen W. Knight, "Development of a Remote Sensing-Aided Procedure for Water Quality Monitoring," R/CZ-68.

The San Francisco Bay and the associated delta that is formed by the confluence of the Sacramento and San Joaquin Rivers constitute one of California's most important resources. Because conventional techniques for studying water quality are costly, inadequate, and slow, these researchers are developing a series of operational models based on Landsat data. Understanding the spatial distribution of salinity, chlorophyll, suspended solids, and turbidity is proving useful for studying estuarine dynamics in this region.

I. Noorany, "Study of Feasibility of Using Geofabrics in Coastal and Offshore Fills," R/CZ-65.

Many coastal fills have been constructed by dredging sand from the seafloor and dumping it under water without compaction. Such fills are typically weak and are, in seismically active regions, in danger of liquefaction by earthquakes. The results of this study indicate that the inclusion of geotextiles in the form of fabric in the sand can, under certain circumstances, improve the sand's resistance to liquefaction.

George A. Jackson and Clinton A. Winant, "Kelp Bed Physical Oceanography," R/CZ-59.

Giant kelp, *Macrocystis pyrifera*, is the dominant seaweed of the southern California coast. This project has shown that the high drag of the massed kelp beds drastically alters the character of water flow within; currents in a kelp bed were found to be about one-tenth as energetic as those outside. The information provided about the interactions between kelp and currents is essential for studying larval dispersal and nutrient uptake.

Raymond C. Smith, "Phytoplankton Dynamics in Eutrophic Coastal Waters," R/CZ-64.

The overall objective of this project is to understand the processes governing the abundance, distribution, and variability of phytoplankton and to model phytoplankton dynamics in the Southern California Bight region. The project is utilizing complementary information provided by imagery from satellites and data from ships and shore stations.

(See also "Rapid Response Projects.")

Raising Marine Animals for Seafood

"The renewable but vulnerable nature of living marine resources requires effective conservation and management to assure the continued productivity and future availability of the resources. . . ."

William G. Gordon
National Marine Fisheries Service
(*Exclusive Economic Zone Papers*, OCEANS '84, p. 16)

Aquaculture promises an abundance of high-protein food that rivals, acre for acre, the production from land-based agriculture. That the promise has not yet been fully realized is partly the result of wide gaps in our knowledge of the biology of some of the most popular marine animals raised for seafood. Unlike hogs and chickens, whose requirements for growth and reproduction have been not only understood but optimized through decades of intense research, lobsters, shrimp, and other commercial marine species still harbor many secrets. Wallis H. Clark, Douglas Conklin, Ernest Chang, Dennis Hedgecock, and their Sea Grant trainees at the University of California's Bodega Marine Laboratory, are working to reduce that information shortage on several fronts. They are concentrating on basic problems of biological significance in four aquaculture organisms of commercial interest: lobsters, shrimp, oysters, and sturgeon.

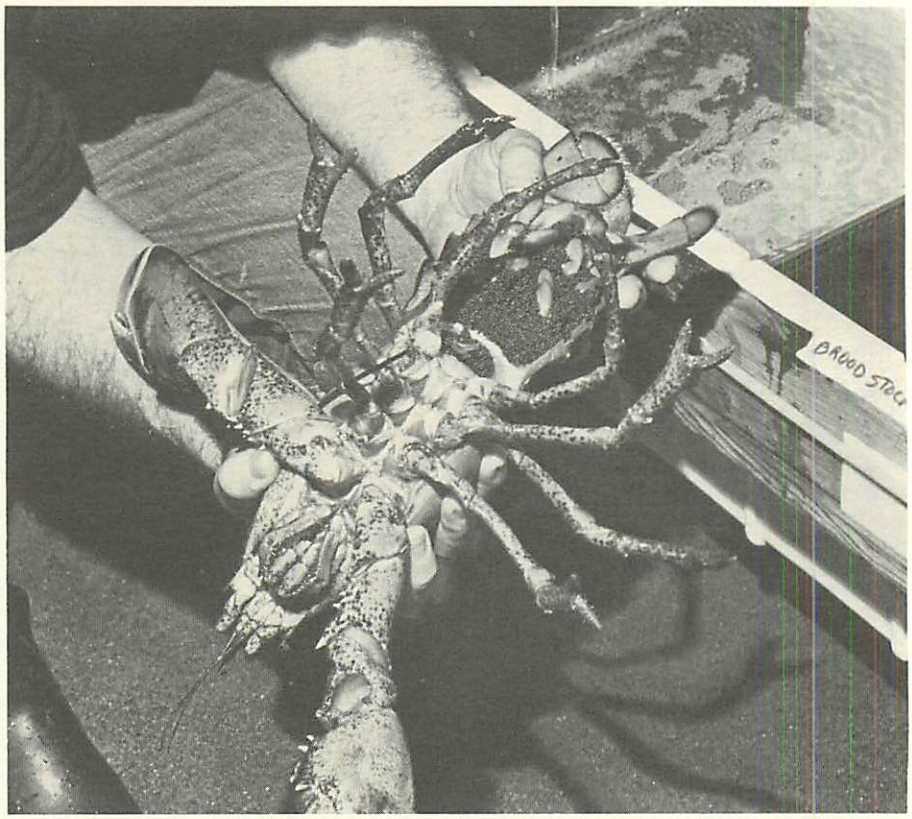
Ready access to breeding adults throughout the year is essential for the success of any aquaculture venture. Unfortunately, the natural breeding season of many marine invertebrates is quite limited. In crustaceans, the situation is complicated by the cyclic molting of the shell as the animal grows, since molting interferes with egg production. The researchers have found that in the American lobster, *Homarus americanus*, egg production can be shifted by using artificial lights to alter the day length. A cycle of 80 short days followed by 120 long days stimulates the females to produce a clutch of eggs, regardless of the actual season. By this means, not only can the entire reproductive cycle be scheduled to fit between molts, but by staggering the light cycle among different groups of lobsters, a proportion of the adults can be made to spawn throughout the year.

Progress has also been made in understanding the relationship between egg production and molting in natural populations of the shrimp *Sicyonia ingentis*. The researchers have now documented that the shrimp confine their reproduction to the interval from May to October and grow most rapidly in the winter and early spring. The patterns of shrimp reproduction and growth are important in the development of sound management practices for natural stocks.

Aquaculture has lagged behind agriculture in the ability to produce specially tailored domestic species through selective breeding. Clark, Conklin, and their coworkers Chang and Hedgecock have been advancing fundamental research in several animal husbandry breeding programs in several species. They have produced a hybrid lobster that shows superior growth characteristics and may, through backcrosses with the two parent species, allow desirable attributes of one species to be incorporated into other species. Efforts are also underway to raise oysters from larvae to adults to allow crosses to be performed between oysters of known breeding history.

Sperm banks are key features of any long-term breeding program, so the researchers have been studying sperm preservation. They have developed techniques for the extended storage of sturgeon sperm and are working with another Sea Grant project leader, John Crowe (UC Davis), to develop cryopreservation methods for shrimp sperm (see "Related Sea Grant Projects").

(Wallis H. Clark, Jr., and D. E. Conklin, "Aquatic Animal Production," R/A-45)



Researchers at Bodega Marine Laboratory have found that egg production can be shifted in the American lobster by using artificial light to alter day length. By staggering the light cycle among different groups of lobsters, a proportion of the adults can be made to spawn throughout the year—a condition necessary for the success of commercial aquaculture ventures. As shown above, female lobsters can carry many thousands of eggs.

Culturing a Japanese Delicacy

"We especially need to support academic research. Most innovative ideas have originated in academia, and I believe that this will continue to be the case for the foreseeable future."

Joel S. Watkins
Gulf Oil Company
(*A National Program for the Assessment and Development of the Mineral Resources of the U.S. EEZ*, U.S. Dept. of Interior, p. 47)

When herring lay their eggs on the blades of the kelp *Laminaria sinclairii*, they unwittingly produce the exotic and highly prized Japanese seafood delicacy called Kazunoku Kombu, or eggs-on-seaweed. Because of its scarcity, the algae-and-roe combination commands prices up to $20,000 per ton in Japan. With such economic incentive, and an abundance of herring to make the roe, the California fishery for herring eggs-on-seaweed could be expanding were it not for the rarity of *Laminaria* plants in herring spawning areas.

Sea Grant researchers Mike Moser and Judith Hansen of the University of California, Santa Cruz, intend to boost the fishery by bringing together the spawning herring and the kelp plants. Aquaculture of this natural combination dish is a delicate procedure, because a successful fishery depends on being able both to culture *Laminaria* and to induce herring to spawn in the cultivated kelp beds when the seaweed is ready to harvest.

The path from the wild parent kelp to a forest of cultivated algae took Hansen into the laboratory to study the optimum growth requirements of *Laminaria sinclairii*. Mature kelp produce spores that grow into the microscopic life-history stage called the gametophyte. The male and female gametophytes then reproduce, creating the sporophyte generation that grows into the large seaweed. Because the gametophyte is microscopic, it must be cultivated entirely in the laboratory. The researchers nurse the tiny plants through maturity using the proper combination of light, temperature, water motion, and nutrients. The critical mix of conditions was determined experimentally with the help of X. G. Fei from Academia Sinica in China. The small sporophytes remain in the laboratory until they are about 2 cm long.

The small laboratory-reared plants, "seeded" on meters of nylon line, are returned to San Francisco Bay for cultivation. Oddly enough, the algae cannot be allowed to float on the surface of the water because full sunlight kills them. Hansen experimentally determined the optimum light levels for growth of juvenile plants to be about 10 percent of mid-day surface illumination, corresponding to the light levels at a depth of three or four meters. Thus, the plants must be suspended in mid-water. Professor Fei lent his expertise in the Chinese long-line method of mariculture to the positioning of the young kelp plants. The kelp is strung on short weighted lines that are suspended from a long line buoyed along its length and anchored at the ends. The plants are held by the long line in mid-water at the proper depth. By placing many long-lines in parallel, row upon row of plants can be grown in San Francisco Bay and harvested almost as easily as a field of corn.

The lush forest of *Laminaria* so carefully cultivated will be wasted unless herring can be encouraged to lay their spawn on the algae, so colleague Michael Moser is studying the spawning habits of herring. No one knows yet whether herring return to breed in the place they themselves were spawned, a phenomenon known as homing. If herring were able to home, then eggs placed in a cultured kelp bed would prime the system for future generations of returning herring, ensuring the eggs-on-seaweed fishery a predictable crop year after year. To study homing in herring, Moser released a metric ton of herring eggs in an area where herring did not naturally spawn. An estimated eighty percent of the transferred eggs hatched. If herring do home, then monitoring should show that the adults that hatched from these eggs return to the same area to spawn. If the homing instinct is demonstrated in herring, it can be used to establish breeding populations in cultivated kelp beds.

While herring eggs-on-seaweed may not become common supermarket items anytime soon, a flourishing mariculture industry for this delicacy would not only invigorate a severely limited fishery, but might also help acquaint North Americans with this highly sought-after oriental dish.

(Michael Moser and Judith E. Hansen, "Seaweed Mariculture for the Herring Eggs-On-Seaweed Fishery," R/A-53.)

Using Biochemical and Genetic Engineering to Improve Abalone Production

"Greater use of the sea as a source of food can certainly help mitigate, if not totally avert, the ever worsening food crisis instigated by the rapid growth of the world population and its dwindling food supply."

R. P. Anand
East-West Center, Hawaii
(*Ocean Development and International Law Journal*, Vol. II, No. 3/4.)

Modern biochemical and genetic techniques are being used to improve control over biological processes that limit the production of commercially valuable shellfish, such as abalone. These processes include several stages of reproduction, larval development and metamorphosis, and survival of the cultivated animals.

Experiments conducted by Daniel E. Morse, Marine Science Institute, University of California, Santa Barbara, with funding provided by California Sea Grant, have concentrated on the Red Abalone, a major commercial resource in California.

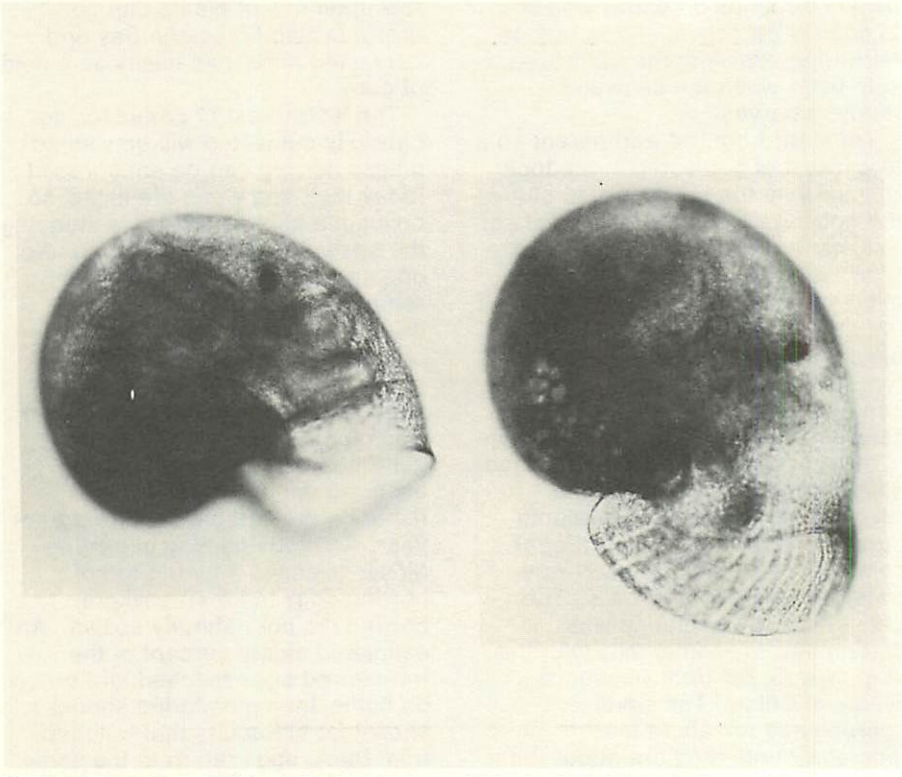
Dr. Morse and his research associates initially sought to improve control over reproduction. They found that they could induce abalones to spawn by adding a small amount of the hormone prostaglandin to the surrounding seawater. A search for a less expensive procedure led to the discovery that hydrogen peroxide stimulates production of prostaglandins, and thus also induces spawning.

A second research problem arose from the fact that the larvae that hatch from fertilized abalone eggs frequently exhibit high mortality—a problem that had been plaguing efforts at industrial cultivation for years. Dr. Morse found that the swimming larvae are normally induced to settle and undergo metamorphosis to their juvenile form at the surfaces of specific red algae. In subsequent work, Dr. Morse was able to isolate the substances in these algae that are responsible for the induction of settlement and metamorphosis. Of these, the most potent and least expensive proved to be a simple amino acid known as GABA (for gamma-amino-butyric acid). Use of this chemical provides a safe and inexpensive method for inducing rapid metamorphosis with high efficiency and survival. Most exciting perhaps is the potential application of GABA to human medicine, since the amino acid is known to be a potent neurotransmitter that controls nearly one-half of the cells in the human brain. New compounds have been discovered by this research group in marine algae and bacteria that mimic the action of GABA; these are now being explored for their usefulness as diagnostic and therapeutic agents.

One of the major problems remaining in the commercial production of abalone is the animal's relatively slow growth. To attack this problem, Dr. Morse has begun to clone and amplify the genes that code for growth-accelerating hormones, thereby applying the techniques of genetic engineering to mariculture.

By far the greatest application of Dr. Morse's work has been in the area of marine aquaculture. The methods developed are simple, inexpensive, reliable, and applicable to a large number of species. Procedures developed by Dr. Morse have been applied to a large number of mollusc species under cultivation or harvest in Mexico, Europe, Africa, New Zealand, Australia, Japan, and China.

(D. Morse, "Biochemical Engineering for Improved Production of Commercially Valuable Marine Shellfish," R/A-43.)



Sea Grant researchers at UC Santa Barbara have been able to chemically induce developmental metamorphosis of abalone larvae.

Related Sea Grant Projects (Aquaculture Research & Development)

To fully exploit the living resources of the EEZ will require the kind of knowledge being generated by California Sea Grant's aquaculture projects. Research on the culture of marine animals and plants focuses on finding solutions to fundamental problems confronting commercial development of many marine species.

Animals

Prudence Talbot, "Development of Procedures for Insemination and Sperm Storage in Lobsters," R/A-46.

This project has sought to develop a procedure for improving *in vitro* fertilization of shellfish. Over 50% of the project's artificially inseminated female lobsters have spawned fertilized eggs. The researchers have shown that most egg loss results from faulty formation of the egg attachment stalk and that sperm and spermatophore production are normal in captive lobsters; however, hybrids do not produce sperm. In addition, research has been conducted on the structure of the pleopod glands in females.

John H. Crowe, "Variation in Intracellular pH and Its Effect on Hatchability of the Brine Shrimp, *Artemia salina*," R/A-47.

The researchers have determined that dormant brine shrimp cysts—important in aquaculture as a primary food source—possess a depressed intracellular pH, the result of high concentrations of organic acids. When the cysts are placed in water, these acids are rehydrated and intracellular pH rises, permitting resumption of active metabolism. If pH is elevated artificially by exposing the cysts to ammonia, hatchability rises considerably. The researchers are also investigating the possibility of using trehalose, a compound found at high concentrations in dormant cysts, for preservation of other living systems.

James F. Steenbergen, "Particle Size Limitations in Osmotic Infiltration Techniques for Immunization of Shrimp," R/A-52.

One of the major problems encountered in shrimp mariculture is disease. The goal of this project was to determine the size and type of materials that can be used to immunize shrimp against disease using osmotic infiltration. The researchers are testing different types of antigens that may be useful in preventing specific mariculture diseases. They have established that larger particle sizes, such as sonicated cell wall fractions, do not appear to enter the shrimp during osmotic infiltration, and they are currently investigating the possibility of using soluble extracts of the cell wall as an infiltrable vaccine.

Laura Kingsford and Douglas W. Hill, "*In Vitro* Cultivation of Marine Crustacean and Molluscan Cells," R/A-56.

Major objectives were to establish the conditions necessary for maintenance and growth of marine molluscan invertebrate cells *in vitro*. Using cells from clam cardiac tissues, researchers have achieved maintenance for up to two months. Of the hormones and growth factors studied, only fibroblast growth factor and ecdysterone displayed any discernable activity.

Grover C. Stephens, "Culture of Marine Bivalves: Nutritional Role of Dissolved Organic Solutes," R/A-48.

The major goal of this project was to establish the role of uptake of amino acids in economically important larval and juvenile molluscs. The researchers have established that there is substantial net influx of amino acids from natural seawater into bivalve larvae. They have developed and refined the use of high-performance liquid chromatography for analyzing minute quantities of amino acids in seawater. In addition, they have analyzed the amino acid content of seawater at various points in commercial mariculture systems and shown that major quantities of amino acids are inadvertently introduced when culture media is supplemented with algal food organisms.

Daniel E. Morse, "Genetic Engineering: Modern Technology Applied to Improvements in Molluscan Aquaculture," R/A-51.

This project has sought to directly measure and then purify insulin from abalone. The researchers have characterized the distribution of insulin, finding highest concentrations in cells throughout the abalone digestive tract. They have also constructed abalone recombinant DNA gene banks and have screened abalone recombinant DNA and genomic DNA for genes homologous to the mammalian insulin gene. These genes are being further investigated prior to their experimental use.

Ronald P. Hedrick, "Evaluation of the Protective Antigens of *Aeromonas salmonicida*" R/A-58.

The major goal of this project is to examine the immunogenicity of the main antigens of the bacterial pathogen *Aeromonas salmonicida*, which causes furunculosis in salmon and trout, with the objective of creating an effective vaccine. The researchers have collected four strains of the bacteria, two of which are virulent and two of which are avirulent. These strains have been grown in batch cultures, and two major components of the bacterial cell wall and one intercellular product have been purified and are being tested for their ability to confer protection in trout and salmon.

Jared M. Diamond, "Nutrient Uptake by Fish Intestine," R/A-57.

This project seeks information about nutrient absorption mechanisms in fish intestine that will be important in designing diets for fish production. The researchers have established holding facilities for the fish to be studied, have modified techniques being used to study nutrient absorption in other vertebrate classes (e.g., electrophysiological techniques and radioactive tracer methods), and have begun to determine differences among fish species in absorption of amino acids and carbohydrates.

Plants

Aharon Gibor, "Vegetative Propagation of Commercially Important Benthic Algae," R/A-54.

The goal of this project is to develop the technology that will enable researchers to efficiently propagate and genetically improve valuable seaweeds (turning them into sea crop-plants). The researchers have developed procedures for obtaining bacteria-free cell suspensions from the tissues of several important seaweeds. They have learned to cultivate and regenerate new plantlets from such isolated cells. They also have found suitable conditions for preserving cells from some algae so that they could be held as seed stock for future cultivation.

Robert A. Rasmussen, "Spore Release in Two Species of *Porphyra*," R/A-55.

Interest in algal mariculture has progressed as seaweeds have been shown to have commercial potential. The goal of this project was to study the spore release mechanism in the genus *Porphyra*.

(See also "Rapid Response Projects.")

Rapid Response Projects

The rapid response project allows California Sea Grant to respond to unanticipated or immediate marine and coastal problems by supporting short-term projects, thus avoiding the long lead time required of projects submitted in the annual proposal. Another important use of rapid response funding is program development. A few small projects are funded each year to explore new areas of potential research.

Mia J. Tegner and Paul K. Dayton, "El Niño Effects on Kelp Forest Communities," R/NP-1-12F.

Researchers monitored changes in the population dynamics of giant kelp and competitive understory algae during the El Niño of 1982-83 in order to develop an understanding of how an economically important ecosystem responds to a major environmental perturbation.

John A. McGowan, Pearn P. Niiler, and James J. Simpson, "A Study of the Effect of the 1983 El Niño on the California Current," R/NP-1-12G.

Researchers conducted monthly cruises of 3-days duration from March to December 1983 in order to monitor El Niño-induced changes in the California Current. The data collected provided the basis for understanding what physical mechanisms produced abnormally high sea levels along the coast, abnormally warm inshore coastal water, and depleted zooplankton abundance. The data also provide the basis for development of a prognostic model capable of detecting early the onset of El Niño-type processes.

Lawrence Badash, "Radioactivity at Sea: Marine Science and the Development of Pollution Abatement Policy, 1946-1972," R/NP-1-12J.

The objective of this project was to investigate the public and scientific history of the debate on the disposal of radioactive materials in the sea. The study looked at the attitudes and motivations of the marine scientists who had an opportunity to influence disposal policy and public perception of the issue.

Dennis M. King, "The Economic Impact of California Ports and Harbors," R/NP-1-12B.

This project was designed to collect and evaluate economic information about California seaports and to develop a simple method of assessing their economic impacts on the California economy. Data on port usage, revenue sources, major inflows/outflows, planning and investments, and economic impacts were collected and published for each of California's major seaports.

Gary B. Griggs, "An Assessment of Shoreline Protection Measures along the Central California Coast," R/MA-22.

The durability and effectiveness of various coastal protection works in different coastal environments was the focus of this study. The researchers collected historical and present-day information on over 100 seawalls and revetments—when and where each was built, and when it was damaged, destroyed, repaired, augmented, or rebuilt. The nature of and reasons for damage to coastal structures by storms were also investigated.

James F. Case and Richard K. Zimmer-Faust, "Chemoreceptive Behavior and Physiology in the California Spiny Lobster, *Panulirus interruptus*, and Other Crustaceans of Fisheries Interest," R/NP-1-12M.

These researchers identified the chemical attractants and suppressants that naturally reside in the preferred baits used by commercial lobster and crab fishermen.

Joy B. Zedler, "The Impact of Hydrological Modification on Estuarine Ecosystems," R/NP-1-13B.

This project responded to a need to identify effects of wastewater (fresh water and nutrients) on coastal wetlands. Researchers demonstrated that soil salinities are substantially reduced, that vegetation is sensitive to the timing of salinity reductions, and that plant growth is nitrogen limited. The data were used to test hypotheses that had been developed during a 6-year monitoring program for salt marsh vegetation.

Robert S. Jacobs, "Marine Natural Product Chemistry and Pharmacology Advisory Program," R/NP-1-13H.

This project sought to establish an effective mechanism for integrating pharmacological data on marine natural products between the drug industry, the University, and principal investigators working in the marine chemistry and pharmacology subject areas.

Judith E. Hansen and Keith Arnold, "Mariculture of Red Algae: Heterotrophy," R/NP-1-13F.

The major goal of this project was to determine whether a unique agarophyte such as the red alga *Gracilaria* could obtain part of its maintenance and growth requirements from the uptake and assimilation of environmentally available dissolved organic matter. A total carbon budget has been quantified for purposes of predicting and modeling production.

Ronald P. Hedrick, "Detection of the Infectious Stage of the Parasite Causing Proliferative Kidney Disease in Pacific Salmon," R/NP-1-13G.

This project investigated the source of the infective stage of the protozoan parasite (PKX) that causes proliferative kidney disease (PKD) in salmonids, a parasite that appeared for the first time at the Mad River Hatchery in 1983, causing severe mortalities among chinook and coho salmon and steelhead trout.

David G. Hankin, "Chinook Salmon Spawning Behavior," R/NP-1-13A.

Chinook salmon caught today are far smaller and thus less valuable than they once were or could be. In addition, smaller chinook may be less "fit" as natural spawners. This project characterized chinook salmon spawning behavior in terms of the behavioral dominance of larger males.

Theodore H. Kerstetter, "An Investigation of the Physiological Cause of Parr Reversion in Coho Salmon (*Oncorhynchus Kisutch*)," R/NP-1-13E.

The two major goals of this project were to measure the blood pH of stunted and normal seawater coho salmon in order to determine whether acid–base regulatory problems were a cause of stunting and to measure levels of sodium and potassium in muscle to determine whether these electrolytes were abnormally high or low in body tissues of stunted fish. It was determined that both sodium and potassium are abnormally high in the muscle of stunts, a strong indication that electrolyte regulation in stunts is impaired.

Samuel H. Logan, "An Economic Analysis of Hatchery and Commercial Production of Sturgeon," R/NP-1-12A.

A quantitative systems model of hatchery production was developed to reflect the biological functions associated with growth, feed conversion, mortality rates, and stocking densities. Through computer simulation, the basic model was used to analyze the effects on costs of changing sizes of plant, increasing stocking densities, and changing the proportions of fish marketed at various stages of growth.

Gregor M. Cailliet, "Age Determination and Verification of Native and Cultured White Sturgeon in San Francisco Bay," R/NP-1-13D.

The researchers have documented that numerous hard parts of sturgeon (fin-ray sections, cleithra, operculi, otoliths) have growth increments that may be useful in age determination. They have also conducted studies of growth in juvenile white sturgeon using tagging techniques in combination with injections of tetracycline to mark growth zones.

Marc Mangel and Richard E. Plant, "Stock Assessment in Aggregating Fisheries," R/NP-1-12C.

In many fisheries, catch occurs only when fish are found in dense schools or aggregations. In these cases, it is unlikely that standard methods can be used to estimate stock size accurately. This project investigated an alternative procedure for population estimation using recent developments in search theory.

David S. Reid, "Freezing-Induced Changes in Fish Tissue," R/NP-1-12D.

The major goals of this project were to develop new methods for looking at fish tissues during freezing and frozen storage in order to identify the changes that take place as quality deteriorates. The researchers have developed new microscopy techniques of high value. In particular, "isothermal freeze fixation SEM" produces very detailed pictures of fish tissue structure. Progress has also been made toward miniaturizing biochemical assays so that less fish tissue need be used.

Robert E. L. Taylor, "Improved Larval Diets for *Macrobrachium rosenbergii*," R/NP-1-12K.

This project evaluated the efficacy of commercially available synthetic feeds for *Macrobrachium* larval culture. The researchers developed a larval rearing system that enabled them to compare the growth and survival of freshwater prawn larvae fed a variety of diets. They also quantified the ascorbic acid requirement of *Macrobrachium* larvae and determined the stability and effectiveness of commercial diets with respect to this nutrient.

David M. Ogrydziak, "Seafood Science: Basic Understanding of Technological Problems and Their Solutions," R/NP-1-13C.

This project sought to determine whether different methods of handling tuna at sea would yield different results in terms of salt content and "press cake" yield after processing. The researchers found that extensive penetration of salt into tuna occurred even after the tuna was frozen. Thus, extended holding in refrigerated seawater resulted in the highest salt concentrations. Such handling practices also seem to adversely affect final product yield after processing.

William N. Shaw, "Natural Setting of Purple-Hinge Rock Scallop, *Hinnites multirugosus*, in Northern California, R/NP-1-13K.

The major goal of this project is to provide potential scallop culturists in northern California with guidelines for the placement and removal of spat collectors in order to maximize the collection and survival of juvenile purple-hinge rock scallops.

Marine Advisory Program

"Despite its importance, the commercial fishing industry is in trouble. Inadequate and deteriorating on-shore support facilities, too few berthing spaces, rising operational costs, several poor fishing seasons, and conflicts with recreational boaters and off-shore oil exploration threaten the livelihood of commercial fishermen and the future of the commercial fishing industry."

Joseph E. Petrillo
The California State Coastal Conservancy

Part of Sea Grant's mission is to move marine-related research results out of academia and into the hands of people who face practical, real-world problems.

This "linking" function is one of the most important roles provided by Sea Grant's Marine Advisory Program (MAP), which serves as a communications channel among those who earn their living or gain enjoyment from the ocean, such as fishermen, marine industry representatives, government, and members of the public. The Marine Advisory Program, coordinated by Robert J. Price, Food Science and Technology Extension, University of California, Davis, includes specialists in marine fisheries, seafood technology, and aquaculture in addition to seven marine advisors who are spread out along the length of California in order to adequately service all of the state's coastal regions.

In the past year alone, MAP worked closely with more than 200 cooperating organizations in industry, government, and academia to provide educational and advisory services wherever they were needed. The following examples represent only a small sample of their activities.

- Offshore oil drilling is a big issue in central California, and the Santa Barbara marine advisor helped to establish and continues to advise both the Fisheries/Offshore Oil Joint Committee and the Seismic Steering Committee in order to reduce conflicts between the fishing and oil industries. For example, the laying of oil and gas pipelines between the Grace and Hope Oil Platforms had disrupted shrimp trawling operations in usually productive shrimp grounds in the Santa Barbara Channel, and consequently 14 trawlers experienced financial loss. In 1980, the marine advisor had initiated meetings between the trawl fleet, Chevron Oil Company, the Minerals Management Service, and the California Department of Fish and Game. Ultimately, some safe trawling areas were identified and published in MAP oil and fisheries newsletters. Since the project was completed last year, fishermen have slowly begun to fish the Grace–Hope trawl area.
- At the request of California State legislators, the Assembly Office of Research, impacted agencies, and industry, the aquaculture specialist hosted workshops to develop compromise legislation important to the developing aquaculture industry. Two pieces of legislation resulted from these efforts in 1984: the first redefined the regulatory authority of the state on matters of shellfish sanitation and certification of shellfish growing areas and transferred direct authority from the Department of Fish and Game to the Department of Health Services, and the second redefined and reestablished the mechanism of indemnification for losses of diseased aquaculture animals destroyed by the state.
- Marine advisors have worked with Vietnamese fishermen in the state to increase their understanding of commercial fishing regulations and boating laws, particularly those related to safety, and to increase their participation in the legislative process, especially as it affects gill-net regulations and fishing gear.
- In Eureka, the marine advisor moderated a meeting co-sponsored by the MAP, the Humboldt Fishermen's Marketing Association, and a local congressman on the proposed Gorda Ridge Offshore Mining Project. The meeting prepared local residents, fishermen, and governmental agencies for a public hearing on the project.
- The San Francisco Bay area marine advisor sponsored a conference to provide research information on the controversial herring fishery, and to open communication among conservation groups, sport and commercial fishermen, and the California Department of Fish and Game.
- The Monterey Bay marine advisor cosponsored a wetland restoration workshop with the Elkhorn Slough Foundation. Sea Grant wetland researchers and local university and government agency researchers met to critique a 200-acre wetland restoration project and to plan a 125-acre restoration.
- Improving the quality and variety of seafood products being delivered to the consumer is a priority of the National Sea Grant College Program. This requires that accurate information be provided to the seafood industry on improved sanitation and quality-control techniques. For example, holding dressed Pacific salmon in chilled water systems on commercial trollers became popular in 1981 and 1982, but little information existed on proper use of these systems. The quality of fish was often low because of poor handling techniques and the use of improper seawater/freshwater mixtures and temperatures. To provide needed technical information to commercial fisheries, MAP advisors presented data and recommendations from a two-year MAP study of different systems at numerous workshops and conferences in California and Oregon.
- Increased use of local Pacific whiting could mean an additional $50 to $100 million annually to the West Coast seafood industry. A project to develop suitable whiting products and to assist processors in developing markets for these products was completed this year. From Pacific whiting filleted and frozen at sea, three new whiting-in-sauce products were created, and potential markets for these products were identified. Presently, 12 California

hospitals are testing a whiting-in-sauce product prior to its distribution throughout the western United States.

- To find out about the use of innovative technology by fishermen, a major survey has been mounted covering such devices as sonar, track plotters, personal computers, and survival suits. When all the data have been collected, correlations will be made to gain an improved understanding of fishermen's decision making about technology. This knowledge can be applied to refine MAP programs.

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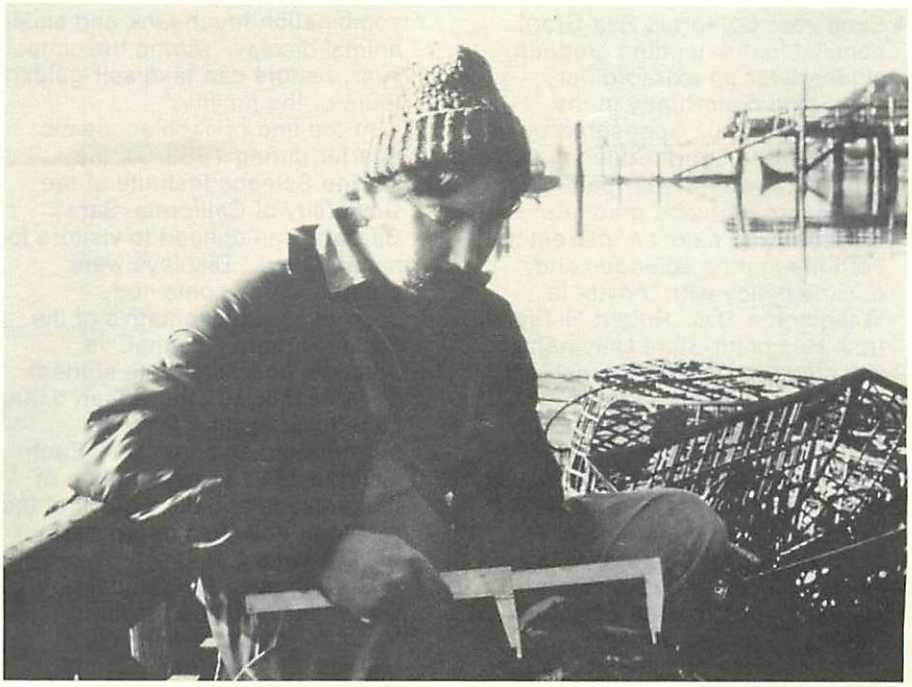

Advisor Christopher Toole has been working jointly with the National Marine Fisheries Service and cooperating fishermen to establish a rock crab fishery in Humboldt Bay.

Training Future Generations of Talent

California Sea Grant's educational activities reach people of every age and with enormously different degrees of "sea savvy."

- The **graduate trainee program** remains the primary vehicle through which California Sea Grant encourages and trains a new generation of students to enter marine-related professions. Since 1973, nearly 500 graduate trainees have worked with Sea Grant project leaders throughout the state. This new talent will be responsible for maintaining America's scientific and technological leadership in coming years.
- In order to encourage even younger students to consider careers in the marine sciences, California Sea Grant offers the **John D. Isaacs Memorial Scholarship**. The $10,000 award, allocated over a four-year period, recognizes superior research in marine science or technology by a California high school senior and seeks to encourage that student to pursue further excellence in marine science in a California university. The 1984 winner, Mwenda Kudumu from Gompers Secondary School in San Diego, is completing her freshman year as a biology major at Stanford University.
- Each year California Sea Grant nominates outstanding graduate students for an extraordinary internship opportunity in the nation's capital. Sponsored by the National Sea Grant College Program, the one-year paid **Internship** matches graduate students who have an interest in both the marine sciences and oceans policy with "hosts" in Washington, D.C. Robert H. Diebel from Humboldt State University, selected for a 1983 Internship, served on the staff of the Subcommittee on Oceanography in the Merchant Marine and Fisheries Committee of the House of Representatives. Victoria J. Fabry, a doctoral student in biological oceanography at the University of California, Santa Barbara, spent part of her 1984 Internship on the Senate Subcommittee on National Ocean Policy Study, a subcommittee of the Senate Committee on Commerce, Science, and Transportation, and later moved to the office of Representative Barbara Boxer (Marin County).
- California Sea Grant's **Ocean Education for the Public** program has supported education activities at five university-based marine facilities throughout the state.

  At the University of California, Santa Cruz, a field trip and slide show program led by student interns provided marine education to nearly 9,000 people last year. In addition, the program developed outreach presentations for special education classes, communication-handicapped children, young adults in continuation schools and probation programs, and residents in senior citizen centers.

  The educational programs at Moss Landing Marine Laboratories (MLML) last year reached over 14,000 people through tours and an annual Visitor Days program. MLML staff presented information about marine research and career opportunities to approximately 7,000 students at neighboring schools.

  During the past year over 3,000 people attended slide shows at the Fred Telonicher Marine Laboratory at Humboldt State University or used a new combination touch tank and small animal display. During the school year, visitors can take self-guided tours of the facility.

  At the end of each academic quarter during 1983-84, the Marine Science Institute of the University of California, Santa Barbara was opened to visitors for several days. Displays were created which contained organisms representative of the Santa Barbara Channel. In addition, undergraduate student docents met with more than 5,000 scheduled visitors from surrounding communities. Each visit included an explanation of the displays and discussion of the research activities in progress at the laboratory.

  More than 38,000 students visited the Thomas Wayland Vaughn Aquarium-Museum at UCSD's Scripps Institution of Oceanography last year to learn more about the marine world. In addition, docents from the aquarium went out to schools to teach ocean science to another 9,000 youngsters. The state-mandated Gifted and Talented Education program again requested that the Aquarium teach 12 one-week classes on the interactions between man and the ocean ecology. The aquarium was also asked both to teach marine science in an elementary magnet school and to "adopt a school"—in this case Crown Point Elementary School, a K-6 school in San Diego, which also includes classes for the trainable mentally retarded. The aquarium equipped an oceanography laboratory for the school and taught 15 classes daily for four days. During the summer the aquarium offers more intensive classes, attended this past year by 600 elementary and high school students. For teachers, the aquarium offered two weekend workshops and an annual environmental symposium. (D. W. Wilkie et al., "Ocean Education for the Public," A/PE-1.)

Classes, crafts, and field experiences are all used to introduce students to the marine environment in Sea Grant's Ocean Education for the Public program. This youngster will eventually sport a T-shirt on which is printed the design he is shown preparing, using a preserved fish and acrylic paint.

Communications and Publications

The communications office of the California Sea Grant College Program responds to requests for information from marine-related industries, government agencies, special interest groups, educational institutions, nonprofit organizations, and the general public. Many requests are for publications produced in the Sea Grant educational, reference, and technical report series.

In FY 1982-84, the following publications were produced by the communications office (listed in order by Sea Grant number):

Sea Grant Reference Series

Anderson, Kelly E., Editor. 1983. Making Waves, 5-Year Report: 1977-1982, California's Sea Grant Program. Sea Grant Publication No. *R-CSGCP-010*, 75 pages, California Sea Grant College Program: La Jolla, California.

Davenport, Riley T. 1983. California Sea Grant 1983-84 Program Directory. Sea Grant Publication No. *R-CSGCP-011*, 28 pages. California Sea Grant College Program: La Jolla, California.

Anderson, Kelly E. 1983. California Sea Grant College Program Annual Summary 1981-82. Sea Grant Publication No. *R-CSGCP-012*, 40 pages, California Sea Grant College Program: La Jolla, California.

California Sea Grant College Program. 1984. California Sea Grant 1980-1982 Biennial Report: A Report on the California Sea Grant College Program from October 1, 1980 to September 30, 1982. Sea Grant Publication No. *R-CSGCP-013*, 309 pages, California Sea Grant College Program: La Jolla, California.

Anderson, Kelly. 1984. California Sea Grant 1984-85 Program Directory. Sea Grant Publication No. *R-CSGCP-015*, 28 pages, California Sea Grant College Program: La Jolla, California.

Sea Grant Technical Series

Luyendyk, Bruce P., Earl J. Hajic, Robert E. Crippen, and David S. Simonett. 1983. Side-Scan Sonar and High-Resolution Reflection Maps of the Santa Barbara Channel Seafloor. Sea Grant Publication No. *T-CSGCP-006*, 17 pages plus 7 maps, California Sea Grant College Program: La Jolla, California.

Josselyn, Michael, Editor. 1982. Wetland Restoration and Enhancement in California. A proceedings of a workshop held in February 1982. California State University, Hayward. Sea Grant Publication No. *T-CSGCP-007*, 110 pages, California Sea Grant College Program: La Jolla, California.

Anderson, Kelly E., Editor. 1983. Recent Innovations in Cultivation of Pacific Molluscs: Abstracts from the International Symposium, December 1-3, 1982. Sea Grant Publication No. *T-CSGCP-008*, California Sea Grant College Program: La Jolla, California.

Zedler, Joy B. 1984. Salt Marsh Restoration: A Guidebook for Southern California. Sea Grant Publication No. *T-CSGCP-009*, 46 pages, California Sea Grant College Program: La Jolla, California.

Educational Series

Zedler, Joy B. 1982. Salt Marsh Vegetation: Examples from the Tijuana Estuary. Sea Grant Publication No. *E-CSGCP-003*, 36 pages, California Sea Grant College Program: La Jolla, California.

Other

Morse, D. E., K. K. Chew, and R. Mann. 1984. Recent Innovations in Cultivation of Pacific Molluscs: Proceedings of an International Symposium Sponsored by the California Sea Grant College Program and the Pacific Sea Grant College Programs in Alaska, Hawaii, Oregon, and Washington. Vol. 14, Developments in Aquaculture and Fisheries Science, 14. Elsevier Science Publishing Co. New York.

Pacific Sea Grant College Program

Five Sea Grant college programs in the Pacific states—Alaska, California, Hawaii, Oregon, and Washington—are working cooperatively to achieve sound management and utilization of the vast resources of the Pacific. The ocean area covered by their activities exceeds the landmass of the continental United States.

The formalized network organized by these programs, which is known as the Pacific Sea Grant College Program (PSGCP), grew out of earlier cooperative activities going back some 15 years. The present objective of PSGCP is to provide coordination and support for major regional activities in education, research, and advisory services.

Among recent activities are the following:

- In the autumn of 1983, over 300 people from 10 countries met in Seattle at the International Symposium on Salmonid Reproduction. This symposium, focused on the scientific basis for salmonid enhancement, was the major meeting of the past decade involving those scientists, industry, and government officials who are concerned with the enhancement of troubled salmon stocks. The meeting was organized by the University of Washington with support from the other PSGCP institutions and held in cooperation with the National Marine Fisheries Service and the Department of the Interior.
- In June of 1984, PSGCP sponsored a workshop in Guam on the taxonomy of selected economically important algae of the Pacific. A small group of leading taxonomists from the United States, Guam, the People's Republic of China, Australia, Taiwan, Chile, and Japan spent four days conducting comparative assessments of different specimens. A proceedings with photos and taxonomic keys is being produced as an aid to algae identification; the publication will also contain suggestions for needed follow-up activities. The California Sea Grant College Program planned and conducted this workshop.
- A workshop on Biological Interaction Among Marine Mammals and Commercial Fisheries in the southeastern Bering Sea was held in Anchorage, Alaska in October 1983. Sponsored by PSGCP, the Marine Mammal Commission, and the North Pacific Fishery Management Council, the workshop, which attracted 81 participants, consisted of 15 major presentations and four working sessions on marine mammals and groundfish, salmon, herring, and shellfish. Workshop proceedings were published by Alaska Sea Grant.
- The Oregon State University Sea Grant College Program organized a two-day conference for PSGCP on small boat fisheries as part of the seminar series at Fish Expo '83 in Seattle. Fish Expo involved 16 sections with 48 speakers and 3,000 participants.
- The markedly increased volume of debris in the world's oceans was the topic of concern at a workshop held in November 1984 in Honolulu for scientists, technicians, and members of the marine community. The presence of marine debris, such as lost fishing gear and nets, has created concern over entanglement of marine mammals, reptiles (turtles), seabirds, and fishes, and may result in fouling of vessel propulsion systems. The meeting was co-sponsored by the University of Hawaii in cooperation with other PSGCP institutions, the National Marine Fisheries Service, regional fishery management councils, and several other organizations.
- A five-day training workshop was held in December 1984 in Honolulu to bring together more than 60 marine advisors, specialists, and communicators from the Pacific Sea Grant colleges. The workshop addressed both highly focused topics, such as fisheries oceanography and seafood quality, and topics of broader scope, such as mediation and conflict resolution and long-range planning.

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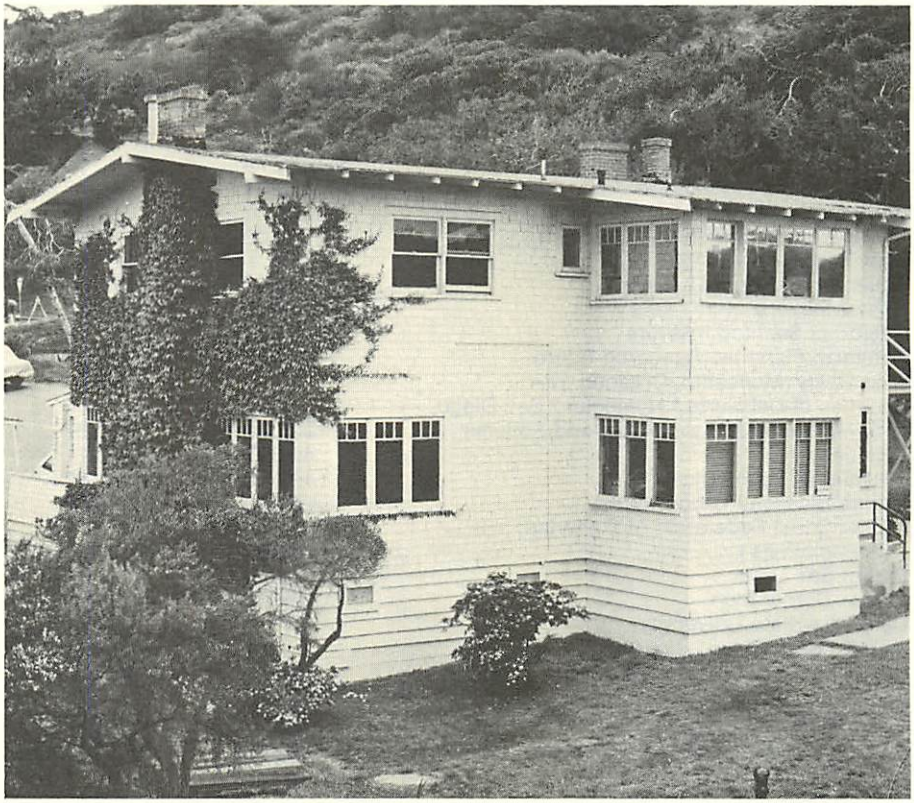

The headquarters of California Sea Grant, a statewide, multiuniversity program, is located at UCSD's Scripps Institution of Oceanography in La Jolla.

Activity Budget

	1982-83		1983-84	
	NOAA Grant Funds	Matching Funds	NOAA Grant Funds	Matching Funds
Marine Resources Development				
Aquaculture	$ 477,643	$ 381,122	$ 551,738	$ 400,705
Living Resources, other than Aquaculture	249,874	189,888	275,585	197,264
Marine Biomedicinals and Extracts	242,922	108,949	234,399	134,952
Socioeconomic and Legal Studies				
Marine Economics	33,969	38,786	—	—
Ocean Law	16,812	7,479	—	—
Sociopolitical Studies	32,367	24,621	16,048	12,309
Marine Technology Research and Development				
Ocean Engineering	129,674	223,910	111,420	57,687
Resources Recovery and Utilization	78,328	80,190	78,487	69,965
Marine Environmental Research				
Research and Studies in Direct Support of Coastal Management	5,527	18,288	—	—
Environmental Models	145,543	62,787	131,403	94,200
Marine Education and Training				
Other Education	436,440	63,468	421,875	40,625
Advisory Services				
Extension Programs	558,086	162,696	535,499	208,178
Other Advisory Services	177,619	103,891	196,305	99,167
Program Management and Development				
Program Administration	317,696	150,633	363,203	206,612
Program Development	247,500	14,770	184,038	32,771
Total	$ 3,150,000	$ 1,631,478	$ 3,100,000	$1,554,435

Matching Funds Sources

	1982-83	1983-84
State of California:		
California Resources Agency	$ 308,774	274,750
Department of Fish and Game	81,201	1,955
State of Washington:		
Department of Fish and Game	2,400	—
American Heyer-Schulte	—	27,880
Aquarium-Museum Docents	29,560	17,150
Bristol-Meyers	13,000	11,152
California Seafood Institute	5,000	—
Canadian Fisheries Research Board	2,400	2,892
Ciba Geigy, Monsanto, Organon, RIA	—	10,613
Counties of Del Norte,* Humboldt,* San Diego, Santa Barbara, Santa Cruz, and Sonoma,	30,000	23,167
Donations	49,892	65,211
Fleischman Foundation	149,550	19,127
Marine Bioassay Laboratories	5,000	6,360
Pacific Coast Federation of Fisheries Associations	5,000	—
Port of San Diego	2,600	—
Syntex Corporation	3,500	2,902
California State University, Long Beach	—	11,396
Humboldt State University	19,070	6,370
San Diego State University	22,446	32,316
San Jose State University	37,044	32,472
University of California	814,941	986,841
University of Oregon	2,400	—
University of Southern California	7,479	—
Central University of Venezuela	23,600	21,881
University of Sao Paulo	10,320	—
Total	$1,625,177	$1,554,435

*Counties of Del Norte and Humboldt provided matching funds only in 1982-83.

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