California Sea Grant Strategic Plan
2001–2005

Looking Ahead

Contributors

Aquaculture
Ernest Chang, Fred Conte, Dennis Hedgecock, Ronald Hedrick, Gary Moberg, Paul Olin

Coastal Ocean Research
Paul Dayton, Libe Washburn, Richard Zimmerman

Fisheries
Louis Botsford, Chris Dewees, Dave Hankin, John Hunter

Marine Affairs
David Caron, Michael Orbach, Harry Scheiber, James Wilen

New Marine Products
Alison Butler, John Faulkner, Robert Jacobs, Herbert Waite

Ocean Engineering
Randy Ashley, E. John List, Richard Seymour

University of California Office of the President
Cathie Magowan, Carol McClain

California Sea Grant Communications
Marsha Gear, Gretchen Frederick, Joann Furse

California Sea Grant Extension
Kim Beaird, Jodi Cassell, Chris Dewees, Leigh Taylor Johnson, Deborah McArdle, Susan McBride, Paul Olin, Robert Price, Rick Starr, Jim Waldvogel

California Sea Grant Administration
Catherine Ashley, Nona Crampton, Melanie Guiang, Roslyn Johnson, Karen Lunkes, Norma Montes, Shauna Oh, Nicki Pyles, Georgia Ratcliffe, Carol Bailey-Sumber, Dolores Wesson, Clinton Winant

This publication is sponsored in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA66RG0477, project number A/P-1. The U.S. Government is authorized to reproduce and distribute for governmental purposes.

Sea Grant is a unique partnership of public and private sectors, combining research, education, and technology transfer for public service. It is a national network of universities meeting changing environmental and economic needs of people in our coastal, ocean, and Great Lakes regions.

Report No. R-045

Cover: Chromis being cleaned of parasites by a wrasse—the yellow Senorita. Photo by Eric Hanauer.

Introduction

The Marine Resources of the State of California

A remarkable 80 percent of California's 33.5 million residents live and work within the 20 counties bordering the Pacific Ocean and San Francisco Bay. California's coastal industries contribute more than $17 billion annually to the state's dynamic economy and support more than 370,000 jobs. Of the $17 billion, $10 billion results from coastal tourism and recreation alone. Another $6 billion comes from sea ports and shipbuilding activities.[1] A study by the State Lands Commission reported that 86 cents of each dollar spent on tourism in California was spent within coastal counties.[2]

California's fishing industry ranks fourth in the nation in total seafood landed.[1] Some of the commercial fisheries important to California include tuna, sea urchin, squid, groundfish, Dungeness crab, and salmon. This state's per capita consumption of seafood is higher than the national average. Commercial landings of fish and shellfish have an ex-vessel value (that paid to the fishers) of approximately $150 million annually.[3] The commercial fishing/seafood industry generates an annual income of $3.5 billion and an output of $8.3 billion annually.

Additionally, recreational fishermen annually take eight million marine sportfishing trips, catch over 40 million fish, and spend over $700 million in California. The recreational marine industry in California employs nearly 52,000 people in manufacturing, retailing, and other services and is the second largest marine recreational industry in the United States.

An estimated 184 million tons of cargo and more than three million passengers are transported by vessel each year, one of the largest volumes of waterborne trade and passenger transport in the world.[1]

"There's no other natural resource upon which we depend so much but about which we know relatively so little. Together, we must find new ways to protect and explore and harvest the oceans that are so critical to the fabric of life itself."
Vice President Al Gore, Monterey, California,

Marine-dependent industries and public resources in California include the following:

- ***six major seaports;***
- ***more than 200 coastal marinas and harbors;***
- ***1,000 coastal recreation areas;***
- ***more than 100 million visitors to the coast per year;***
- ***over 6,600 registered commercial fishing vessels;***
- ***14,600 commercial fishermen;***
- ***over 1,300 licensed seafood processors and dealers; and***
- ***more than 750,000 registered boats.***

More than 91 percent of California's historic wetlands, which serve as important nurseries for fish, shellfish and shore birds, have been lost to diking, draining or filling. While there are many steps that can be taken to reduce the impacts or deterioration of resources as a result of development, current restoration and mitigation strategies are not always successful nor a substitute for protection. Preserving and restoring California's remaining wetlands is a high priority.

It is estimated that 75 percent of the world's commercial fish species are either overfished or facing decline. A recent U.S. Geological Survey found that nearly six out of 10 California fish species have become extinct or are "on the road to extinction if present trends continue."[4] Total finfish and shellfish landings in California declined by almost half from 1970 to 1990, while total U.S. landings doubled over the same period. California's share of the U.S. harvest, which was 14 percent in 1970, declined to four percent in 1990.[3] In 1997, California closed its commercial abalone fishery in an effort to allow the severely diminished population to rebuild to a sustainable level.

The state's March 1997, "California's Ocean Resources: An Agenda for the Future" sets forth the first plan to "ensure comprehensive and coordinated management, conservation, and enhancement of California's ocean resources for their intrinsic value and for the benefit of current and future generations."[1] In this plan, the California Sea Grant College Program is identified as an important partner in the identification, development and dissemination of science, education and outreach efforts to assist the state and the nation in the rational management and conservation of its marine resources.

The Challenge

Managing and preserving the state's vast marine resources is a formidable challenge given the rapid growth of population in the coastal zone and the fast pace of

technological change affecting resource use and management. What were previously considered inexhaustible resources are increasingly recognized as finite and threatened. In 1994, the California State Lands Commission published a study of California's coastal zone resources that found over-development from increased population to be the leading threat to California's coastal zone and marine resources.[2]

A recent U.S. Geological Services survey found that nearly six out of ten California fish species have become extinct or are "on the road to extinction if present trends continue."

It is clear that the future of California is inextricably tied to the future of its coastal resources. Wise decisions with regard to coastal and marine-resource utilization by California's citizens, industries and policy-makers alike, rests on the high-quality of scientific information, on easy access to this wealth of information and on effective coordination of the academic sector with agencies with stewardship responsibilities, industry and other constituent groups.

The Role of Sea Grant in the State

The mission of the California Sea Grant College Program (CSGCP) is to maximize the contribution of universities and affiliated institutions to the wise use of the sea's resources and the meaningful defense from its hazards through research, education, and advisory services for the benefit of the state and the nation.

In the three decades since its inception, Sea Grant has been one of the principal sources of academic research on the coastal ocean, aquaculture, fisheries, seafood, marine biotechnology, ocean and coastal engineering, and ocean policy. The program has also become a major source of marine scientific and management personnel, having supported nearly

In the three decades since its inception, Sea Grant has been one of the principal sources of academic research on the coastal ocean, aquaculture, fisheries, seafood, marine biotechnology, ocean and coastal engineering, and ocean policy.

900 graduate and undergraduate students specializing in marine disciplines.

From the beginning, Sea Grant's solution-oriented focus made it multidisciplinary in approach and allied it with government and industry. These partnerships are maintained by a variety of mechanisms, notable among which are joint projects, industry advisory committees, communications programs, and the outreach activities provided by the extension arm to a wide variety of client groups.

The California Sea Grant Extension Program is made up of seven advisors and two marine specialists conveniently located throughout the coastal counties. Their role is to provide resource-relevant expertise to the communities they serve and a link to other university resources. Through the Extension program, citizens and other users gain access to the latest scientific information developed by the research arm of the program. Their role also includes providing the research community with a real-world assessment of current trends and information needs.

The following examples illustrate the role CSGCP has played in enhancing the marine resources of the state:

The California Sea Grant College Program catalyzed and supported the first major effort in the United States to identify new drugs from marine plants and invertebrate animals. This work continues to make remarkable contributions to California and the nation by keeping at the forefront of the ongoing revolution in marine biotechnology. Over the years, this program has benefited from a large number of industrial collaborators including large and small U.S. pharmaceutical and cosmetic companies.

Interdisciplinary groups of scientists including industrial partners have recently developed high-performance "bioceramic" materials using molecular biology techniques to duplicate the properties of natural materials found in the shells and skeletons of marine organisms like abalone and coral.

Basic biological research supported by the CSGCP has been critical to the creation and growth of several aquaculture industries in California, notably the sturgeon and abalone industries. Sea Grant scientists have described the chemical mechanisms that promote abalone reproduction and larval settlement, and they are presently exploring ways to enhance the growth rate of this valuable commercial species. The California sturgeon industry has thrived in large part due to Sea Grant-sponsored discoveries on reproductive biology and genetics.

In fisheries, the CSGCP has made important contributions to the management and conservation of California's fisheries resources. Ancient fish scales preserved in the Santa Barbara Basin have helped scientists understand how pelagic fish stocks in the California Current react to climate fluctuation over time, providing a long-term perspective that has been instrumental in managing these stocks.

In 1996, the CSGCP sponsored a workshop to assess the science and management needs emerging as a result of the spread of nonindigenous species throughout coastal and estuarine as well as fresh water systems. Researchers are now studying the fate and effect of many of these introductions, which have significant ecological and economic consequences. The invasion of *Spartina alterniflora* or smooth cordgrass in San Francisco Bay and its recently documented hybridization with the native species *Spartina foliosa* is a good example of a rapidly spreading species that threatens to radically alter its new habitat by encroaching on productive mudflats. Other on-going projects addressing this important priority include work on the Chinese mitten crab and a ballast water outreach and education program.

In 1997, the CSGCP Communications Office published a book addressing the management of a marine pest that threatened to destroy California's abalone culture industry and affect wild populations as well. This book, "Identification and Management of the Exotic Sabellid Pest in California Cultured Abalone," by Carolynn S. Culver, Armand M. Kuris, and abalone culturist Benjamin Beede, is a good example of how technical information is developed and delivered to the users.

In the area of ocean policy (marine affairs), the implementation of the United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks will result in major changes in the management of marine fisheries and of regional international fishing agreements. Sea Grant is studying the implications for the Regional Fishery Management Councils and for the interrelationships of American and foreign distant water fishing fleets.

In the area of ocean engineering, Sea Grant researchers have developed a new method of improved forecasting of wave height, intensity and duration that is likely to become the standard practice worldwide for agencies performing wave climate data collection and archiving.

The coastal ocean is enormously complex in its circulation and distribution of natural and man-made materials. Researchers are developing an integrated computational model of the physical, chemical, and biological processes that affect the fate and transport of materials in the Southern California coastal ocean. The model will be of primary use to fisheries scientists and to environmental managers responsible for the discharge of treated sewage.

Development Process for the Strategic Plan

The development of this strategic plan was designed to allow Sea Grant's constituencies an opportunity to provide their views on the needs and priorities for California Sea Grant in the next four years. Comments were solicited from the Sea Grant user community as a first stage. The responses were then provided to six scientific committees charged with the responsibility of addressing the different subject areas of the program: aquaculture, coastal ocean research, fisheries, marine affairs (policy and law), new marine products, and ocean engineering. The Sea Grant Extension Program, Communications, and Management have articulated their plans also.

The Sea Grant Advisory Board, which advises the Vice Provost for Research of the University of California, reviewed and revised the plan to ensure that it is reflective of state and federal needs, within the scope of the

program's mission, and that its goals are attainable with the resources available to the program. With the full endorsement of the Board, the plan was then forwarded to the University of California Office of the President.

Strategic Goals of the Program

This plan outlines a vision for the program for the next four years and seeks to build consensus among the diverse constituencies served by the program. It will provide a framework for determining the most relevant priorities to address and important goals that can be achieved through marine research, education and outreach in California.

While it is useful to prioritize the issues identified in this plan, prioritization might lead to the exclusion of innovative, high-risk, high-potential research. As a result, the strategic plan for each of the subject areas is not stated in terms of a strict prioritization, but rather includes a com-prehensive list of projects that are relevant to current needs.

The chapters that follow explain in detail the plans for each subject area (in alphabetical order), as well as the plans for the ex-

tension, communications and management components of the program.

---

[1] *California's Ocean Resources, An Agenda for the Future*, The California Resources Agency, Sacramento, 1997.

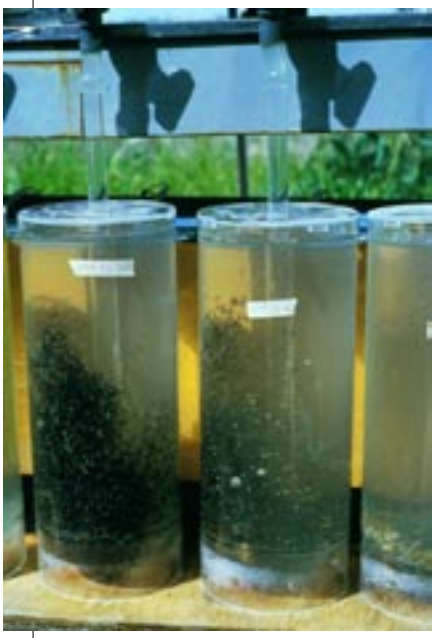
[2] *California Comprehensive Offshore Resource Study*, California State Lands Commission, Sacramento, 1994.

[3] *California's Living Marine Resources and Their Utilization*, California Sea Grant Extension Program, 1992.

[4] *Status and Trends of Our Nation's Biological Resources*, U.S. Geological Survey, Washington, D.C. 1999.

Aquaculture

Introduction



The California Sea Grant College Program (CSGCP) fosters university research in aquaculture with special emphasis on the needs of the California aquaculture industry, and with additional attention to the scope of regional, national and international problems. Aquaculture, defined broadly as artificial propagation and culture of aquatic organisms, mainly comprises commercial production of food for human consumption, with the inclusion of the culture of species for the enhancement or conservation of natural aquatic resources. The primary constituents of the CSGCP are the California and U.S. aquaculture industry; other constituents or stakeholders include municipal, state, and federal agencies and nongovernmental organizations with interests in regulating aquaculture or in enhancing natural resources. The CSGCP supports research primarily on aquatic species cultured in California and elsewhere for food (or nonfood) products and secondarily on new species for commercial cultivation or on candidates for enhancement of natural resources.

Problems in Aquaculture Research

Although public and private aquaculture constituents can identify particular needs and priorities for research on an annual basis, researchers can readily identify long-standing research problems in aquaculture. The ideal project is one in which a current industry need is addressed by an investigator or team of investigators with expertise in a general type of problem. The following list of research areas is neither prioritized nor exclusionary.

1. Development of economical diets for cultured species. Feeding represents a substantial part of production costs in aquaculture. Existing industries require both artificial feeds (e.g., for abalone, marine fish) as well as live feeds (e.g., brine shrimp or rotifers for larval marine fish, microalgae for filter-feeding bivalves). Research is needed on nutritional requirements, metabolism, least-cost diet formulations, and mass culture of food organisms.

2. Enhanced growth. Increasing growth reduces time to market and production costs, so enhanced growth appears on every industry list of needed improvements. The biology of growth can be understood through a variety of traditional disciplines (genetics, physiology, and nutrition), especially when coupled with well-designed selection or crossbreeding programs. There are few commercial breeding programs to improve growth of aquaculture species in California, although large-scale, USDA-supported, selection and crossbreeding programs to improve the yield of cultured Pacific oysters have substantial industry involvement. Modern biotechnology will increasingly offer new tools to enhance growth of aquatic species. For species with more advanced commercial brood stock management and breeding programs, genomic science provides powerful means for mapping major genes underlying growth, for accelerating the progress of selection programs, and for analyzing patterns of gene expression. Multi-disciplinary research will provide the greatest advances in this complex and difficult problem area.

3. Gamete quality. Highly variable survival in commercial aquaculture hatcheries is commonplace and is often attributed to variation in gamete "quality." Little is known about the biochemical, cellular, physiological, genetic, or nutritional factors underlying gamete quality. This extremely difficult problem will likely require multidisciplinary experimental approaches in which genotype and environment can be manipulated, creating contrasts for analyses at the molecular, cellular, and whole-organism levels.

4. Control over reproductive cycles and performance. High fecundity is one of the biggest advantages of culturing most aquatic species. At the same time, reproductive maturation can reduce yield by diverting energy to gametogenesis or spawning behavior, as in mixed-sex tilapia culture; or sexual maturation can reduce product quality and appeal, as in summer oysters. Nevertheless, we lack control over reproductive maturation, the timing of spawning activity, fecundity, gamete quality, and subsequent early survival for most aquaculture species. Sex can be determined in some fish by hormonal or even environmental manipulations. Some progress has been made in sterilizing both fish and shellfish through chromosome-set

manipulations resulting in triploidy, but much research remains for understanding the reproductive biology of other species. Like the study of growth, research on reproduction involves several disciplines, and it will benefit from applications of biotechnology, genomic science, and multi-disciplinary approaches.

5. Brood stock management and improvement. The vast majority of aquaculture is based on the cultivation of wild, undomesticated stocks. Aquaculture must develop domesticated strains with improved traits. Domestication primarily requires research in genetics and breeding, but the approach is greatly enhanced by inter-disciplinary work on physiology, behavior, engineering, and bio-eco-nomics. Development of closed populations requires pedigree control, as inbreeding is a severe risk in aquatic species with high fecundity and large variance in family size. Development of genetic improvement programs requires quantitative genetics research and development of commercial management programs, inventory control, and testing facilities. In many cases, basic research on quantitative genetics has yet to be done (e.g., abalone, marine fishes). In other cases, the basic research is done or in progress (e.g., Pacific oyster, rainbow trout), laying the groundwork for application of genomic science, but there remains a gap in the transfer of knowledge to industry.

6. Water recirculation, conservation, and quality. Recirculation in marine aquaculture enables the recapture of heat energy and affords greater control over water-quality parameters. Freshwater resources in the Western U.S. and especially in California are at a premium, so aquaculture must develop systems that conserve water. Wastewater discharge is a problem that should be addressed on site through engineering, before it becomes a downstream ecological impact.

7. Product quality. Aquaculture products are receiving increased scrutiny for hazards to human health (e.g., paralytic shellfish poisoning, coliform bacteria, *Vibrio* spp., Norwalk and other viruses). Research on best management practices to reduce health risks is needed. Novel approaches to identifying pathogens and measuring their concentrations are also needed. Product quality from the

standpoint of human nutrition or consumer acceptance should be addressed by food-science research.

8. Animal health and well being. Losses of aquaculture stocks to disease and stress represent a substantial cost to the aquaculture industry. While well-known diseases continue to plague the industry, additional diseases are constantly recognized, particularly as different culture approaches are developed or new species are raised in captivity. The detection, prevention, and control of the pathogens that cause well-known and new diseases are therefore critical to the successful culture of fish and shellfish. Basic and mission-oriented research that investigate the interactions between the host, pathogen, and environment are therefore a priority in any balanced aquaculture research program. The role of stress in reducing production efficiency and its effect on the immune response and susceptibility of the host to pathogens will involve multidisciplinary investigations (pathology, nutrition, physiology, genetics and behavior). Biotechnology will permit more rapid development of sensitive pathogen assays, increased understanding of phylogenetic relationships among pathogens, more rapid discovery of drugs, and new approaches to understanding immune mechanisms and vaccine development.

The detection, prevention, and control of the pathogens that cause well-known and new diseases are therefore critical to the successful culture of fish and shellfish.

9. Life-cycle closure. New species might be amenable to commercial culture, either as aquaculture species or as live food for aquaculture, if their life cycles could be closed. Research to close life cycles would generally be aimed at the early life history stages (e.g., spiny lobsters) and could involve a variety of disciplines (taxonomy, nutrition, physiology, behavior). Recent advances in probiotics, the manipulation of culture environments through microbial inoculation, are likely to accelerate closure of life cycles.

10. Ecological impacts of aquaculture. Scientific and media attention has focused on negative impacts of aquaculture (e.g., introductions, pests, diseases, wastewater discharge, and more recently, impacts on essential habitat for protected species of birds and fish), which should certainly be addressed through research. Remote sensing, geographical information systems (GIS), and bioinformatics could be used to assess ecological impacts of aquaculture.

Aquaculture can also have positive environmental effects. Because filter-feeding bivalves are critical links in pelagic-benthic food chains, restoring depleted shellfish populations through aquaculture may be the most environmentally friendly and economical way to improve water quality in the nation's estuaries. Aquaculture is also being used, for example, to enhance natural resources and to conserve aquatic biodiversity. As problems in this area are diverse and of varying degrees of complexity, so too will the scientific approaches be diverse. The relevance of ecological research to existing aquacultural enterprises must be clearly drawn in all proposals in this area.

Coastal Ocean Research

Introduction

Coastal ocean science is an integrated study of the stability and resilience of marine systems; areas of study include everything from wetlands to beaches and coastal bluffs through the intertidal zone to subtidal communities and the open ocean. Thus, the broad scope of coastal ocean science requires interdisciplinary research. Accordingly, the Sea Grant Program encourages new research initiatives closely linked to complementary programs funded by other sources. The ability to predict changes in coastal marine systems requires understanding ecosystem responses to natural physical and biological forces to appreciate the impact of anthropogenic activity including coastal development, watershed alteration, pollution, resource exploitation/protection, critical habitat protection/restoration, and introduction of exotic species.

A critical need is to train systematists capable of identifying and describing species.

The changes in the coastal ecosystems must be evaluated in terms of the species that are involved, which emphasizes systematics, or studying the evolution and maintenance of biodiversity on the planet. The importance of systematics to coastal studies cannot be overemphasized. The identification of species is fundamental to all biological and ecological research, yet the ability to identify species is badly eroded in all marine systems. The species diversity is poorly known and our ability to identify native vs. introduced species is often lost. Documenting the most obvious patterns of change is difficult since in most cases there are no taxonomists able to document even the most well-known species. The description of new species, genera, families, or even phyla is vastly reduced by the declining numbers of taxonomists and the poor dissemination of taxonomic information to other field and laboratory biologists. A critical need is to train systematists capable of identifying and describing species. Despite the fact that this need permeates most coastal issues, we have lost this expertise in systematics, and it is critical that this trend be reversed.

Much remains to be learned about how coastal physical processes affect transport, dispersion, transformation, and fate of contaminants in the coastal zone.

Examples of topical issues relevant for such integrated coastal understanding and study include:

1. Coastal physical processes. There exists a critical need for physical oceanographic studies addressing several key areas. Results from previous and on-going physical oceanographic research need to be incorporated into models and field studies assessing impacts of pollutant sources and pollutant discharges into the coastal environment, especially storm water inputs. Much remains to be learned about how coastal physical processes affect transport, dispersion, transformation, and fate of contaminants in the coastal zone. It is important to understand how physical processes acting over a broad range of space and time scales affect the cycling of pollutants, nutrients, and other materials in coastal ecosystems. The dynamics of many coastal marine populations are closely linked to poorly understood physical processes, particularly those acting to move organisms across the shelf. Studies are required to understand circulation processes in the coastal waters of large cities, especially in Southern California. Much remains to be learned about how storm-driven waves and currents lead to sediment movement and bluff erosion.

2. Natural variations in coastal ecosystem performance. Most environmental patterns have thresholds of irreversible change. We must grapple with the challenge of understanding and predicting these thresholds. For example, many cumulative impacts are small, within the range of natural variability. When do small impacts truly accumulate? When do such accumulations become significant to the sustainability of the systems? Efforts to define and scale those central components of the environment are of fundamental interest, but since everything cannot be measured, it is important that questions and parameters of study be prioritized with regard to how well they fit into the general problem and meaningful solutions. Sea Grant cannot be expected to fund interesting pure research that has low general applicability, and it is beholden upon the scientist to defend the general importance of the proposed research.

3. What parameters are most important for the understanding of ecosystem function, and how can we evaluate such questions? We need to understand coastal systems well enough to differentiate sensitive from robust parameters. How do we prioritize habitats and species of concern? Thresholds in demographic processes usually relate to age- specific life history factors. We can predict the consequences of various anthropogenic impacts only when knowledge of environmental processes related to environmental disturbances and recovery dynamics are understood. These are the parameters necessary for understanding the relative well being of ecosystems. Such questions focus on the role of natural systems and the need to develop and study marine reserves, which offer the only baselines of existing natural systems and the potential for large-scale experiments, including the ubiquitous alteration of wetlands, local impacts from outfalls, fishing, etc.

4. How do we evaluate the success of different management strategies? What criteria are needed to evaluate success? Managers are faced with paradoxical dilemmas because ultimate success is judged on the understanding of natural systems, which is necessarily incomplete. What parameters are available and how can they be identified and defined?

5. Environmental baseline information. Great effort has been expended in the last 50 years observing, monitoring, and experimentally manipulating coastal marine ecosystems in California, with much of this information relating directly to the study of natural variations in ecosystem performance. New technologies able to integrate meta-analysis and GIS databases become critical in utilizing this hard-won information. For example, the regional CalCOFI program is a gold mine of background data applicable to all aspects of the coastal zone. Many Mineral Management Service reports offering important baseline information could be better utilized. Long-term fishery data, outfall monitoring programs, and old environmental impact studies are unread. Published references with valuable data often are forgotten; and often journals reduce data to summary statistics (but the data and meta-data are sometimes available). Examples of environmental memory in sediment records, tree rings, long-term research projects and even old photographs can be utilized to detect trends, regime shifts, etc. Sea Grant can play a role in the recovery of such data by insisting that proponents incorporate them

into their proposals, thereby recovering important data and helping to focus on the important larger scales.

Problems in Coastal Resources Research

Human activities are a primary cause of significant perturbation in coastal environments...

1. Comparing anthropogenic effects and cumulative impacts. Human activities are a primary cause of significant perturbation in coastal environments; additionally, natural systems are also subject to great natural variability. The time and space scales of the variability are different in natural vs. human-induced change. The rate of change perturbation in coastal systems has increased drastically as a result of human use; areas most vulnerable to anthropogenic influence are:

(a) Fishing. Commercial and recreational fishing targets specific species but have unanticipated effects on bycatch species that are neither well monitored nor understood. Effects of gear on the habitat and other species are also of concern. Direct and indirect effects of fishing can have many cumulative and chronic effects on community structure and ecosystems that need to be understood.

(b) Land-based sources of marine pollution. Runoff and sewage outfalls provide a novel and significant input of contaminants and nutrients to coastal waters. Coastal eutrophication from agriculture, sewage, and runoff throughout the watershed can affect coastal bays, estuaries and nearshore areas. Eutrophication is linked to shifts in the composition of primary producer species and the proliferation of harmful algal blooms as well as causing many other important changes in the nearshore. Effects of contaminants on organisms are not understood. Little is known about tolerances, cumulative impacts and thresholds on specific life stages, populations, or pathways. Endocrine disruptive chemicals are a case in point that may have the potential to drastically affect many species.

2. Physical alterations of habitat and hydrology patterns. Development in coastal areas and upland watersheds has significantly altered habitat and associated hydrology. Physical barriers restrict movement and migration of propagules throughout estuaries, restricting their adaptation to climatic variability and sea level rise. Dredging,

filling of wetlands, construction of seawalls, jetties, and other armoring structures have altered coastal hydrology and habitats. The effects of changes in coastal erosion and sediment flows are not well understood. Delivery rates of sediments have been altered, and at the same time, coastal erosion continues to threaten human structures. The overall effects of these changes are not clear.

3. Invasion of exotic species. Another habitat-specific concern is that of better understanding the invasion of exotic species. Many of the ecological impacts and the dispersal vectors of exotic species are known, but what is poorly understood is the fact that many of the species have existed for years and sometimes decades as rare individuals. When populations appear to be released and become extremely abundant, such populations may or may not maintain the high abundance and exert community impacts. Moreover, native species that are extremely rare can also experience massive population explosions with important ecosystem and community consequences. An important priority is to understand what mechanisms control the distribution and abundance of populations and how these controls are breached such that populations are released to exert ecosystem impacts.

4. Marine reserves. Marine protected areas serve as necessary baseline references that allow study of such processes as the influence of physical oceanography on diffusion and dispersal, biological interactions, resource allocation, reproductive biology including spawning behavior, larval biology, nursery requirements, etc. While the baseline values of marine protected areas are obvious, there is a shortage of good documentation of their contribution to the enhancement of ecosystem performance outside the reserves. That is, the spillover of larvae and adults outside the reserves is important but poorly documented. The public enthusiasm for marine reserves is likely to result in the creation of such protected areas in the future, and it is essential that they receive appropriate scientific evaluation to ensure that baseline understanding is maximized and regional contributions are understood.

5. Large-scale experiments for ecosystem restoration, climate change and remediation studies. Experimental manipulation of ecosystems on a large scale is always difficult and often unwise from an environmental standpoint. Yet understanding the impacts of climate change on ecosystem function and possible remediation techniques require just such manipulations. By developing partnerships with municipal and industrial utilities, it may be possible to exploit existing operations to facilitate such studies. Examples include experimental studies of ocean temperature and elevated atmospheric CO_2 concentrations using power plant effluents and eutrophication studies associated with municipal sewage discharge facilities. Such topics could include impacts of climate change on natural populations and the development of restoration and remediation techniques in degraded habitats. Such large-scale disturbances are not experiments per se. They serve as experiments when used as hypotheses designed to answer specific questions. As such, they need explicit controls in time and/or space.

6. Critical habitats, risks and restorations. An issue of national concern is that of identifying and protecting critical or essential habitats. The definitions vary, but they are usually defined by the needs of a particular species or are charismatic habitats such as wetlands, kelp forests or rocky tidepools. Clearly, this view is too restrictive, as representative examples of all coastal habitats deserve protection and study. Under-represented habitats in this category include intertidal mudflats and offshore sand/mud habitats of the coastal shelf that are invisible or not attractive to the public eye, but nonetheless are vulnerable to a variety of disturbances, including draining, dredging, dumping, and trawling.

7. Habitat restoration must proceed with a clear understanding of the restoration goals. Many restoration projects fail to define a priori their long-range goals and they often fail to include meaningful criteria to evaluate the success of the restoration. In all cases, both the objectives and the evaluations should be based on an understanding of the natural situation. Again, this emphasizes the need for studies of relevant natural processes in appropriate natural systems.

California's coastal wetlands have been severely impacted by development in many cases. Their importance as biological resources for fish and birds makes them primary targets for remediation. In some instances this involves restoring a lagoon to a tidal inlet. There is a need to develop:

• Effective models for shoal formation in tidal inlets. Existing models, based upon tidal-flow-dominated inlets on the East Coast, are ineffective in the wave-dominated regime on the West Coast.

• Cost and risk models for remediation (pre- or post-construction) for the shoreline impacts of jetties used to stabilize inlets.

Summary

The problems of the coastal zone are complex, diffuse and so difficult that any attempt at meaningful prioritization likely results in simplistic short-term opinions. The priority of this review of the coastal ocean section is to define some of the most important gaps in our knowledge so that investigators might better focus their creative research. However, a recurring theme in this review is the need for representative natural systems to evaluate and compare anthropogenic and natural changes. Because the state has new and important legislation directed toward fishery management and marine reserves, there should be a general priority for Sea Grant programs to cooperate with state agencies to maximize progress on these fronts.

Introduction

Increasing demands on United States and California coastal fisheries resources by population growth, and the ensuing need for increased information and improved guidance for wise stewardship and management of these coastal resources, have not only increased apace but recently received unprecedented recognition at federal and state levels. At the state level, the Marine Life Management Act of 1998 (Keeley Bill) calls for development of formal management plans and stock assessments for nearshore finfishes, and acknowledgment of apparent serious declines in abundance due primarily to recreational and commercial fishing. At the federal level, recent revisions of the Magnuson Fishery Conservation and Management Act and vigorous implementation of the Endangered Species Act have placed new emphasis on restoration of over-harvested and/or threatened and endangered populations, identification of essential fish habitat and effects of fishing on this habitat, and reducing bycatch. Such statutory changes have been matched by an enormous growth in public awareness of the depleted status of coastal fishery resources and greatly increased participation of nongovernmental organizations in fishery-related legislative issues.

Such social and legislative changes necessitate more comprehensive assessments of California natural resources than in the past, thereby greatly increasing the demand for information and for innovative science that facilitate this process or reduce cost. More comprehensive assessments require the expertise of statistical fishery modelers and economists who must consider all biological and economic information to provide products needed for the decision-makers. Such “stock assessment” experts are in very short supply with American universities unable to meet the demand.

Against this backdrop, the California Sea Grant College Program has a critical role in providing the

education, training, and research needed for Californians to effectively respond to these recent statutory changes and to assure long-term viability of coastal fishery resources. Over the past 30 years, the CSGCP has provided a wealth of biological information useful for assessment and management of California fisheries. Perhaps its strongest sustained role in fisheries has been in support of invertebrate fisheries-Dungeness crab, urchin and abalone. Sea Grant has been the primary provider of long-range scientific information in this area. For example, Sea Grant scientists have developed modern meta-population models for sea urchin fishery management and greatly increased understanding of the dynamics and genetic relations among urchin and abalone populations. Sea Grant investigators have also made major contributions to finfish management and in virtually every relevant management topic ranging from genetic population structure, age determination, and recruitment processes, to ecological reserve management, and fishery economics.

Fisheries Research Issues

1. Nearshore fisheries. The Marine Life Management Act of 1998 (Keeley Bill) requires the California Department of Fish and Game (CDF&G) to develop management plans for nearshore finfish which shall be reviewed and implemented by the State Fishery Commission. Although this action has come in response to a widely-held belief that nearshore stocks of finfishes are severely overfished, it will be a formidable task for CDF&G biologists to provide accurate and comprehensive assessments necessary for development of fishery management plans because many species are involved, basic life history information and fishery-independent trends in abundance are lacking, and there is a shortage of modeling and economic expertise in the CDF&G. Strategic California Sea Grant-supported research and education should encourage completing data gaps on nearshore species, modeling, analyzing the genetic structure of nearshore fish populations that may have more complex stock structure than the large migratory populations, and, in the longer term, increased recruitment and training of fishery modelers and economists.

2. Marine reserves. A coastal-wide movement is building to implement area closures as a tactic for conserving marine resources and to provide underwater wilderness areas unaffected by fishing. The movement is driven by the concern of the public and nongovernmental organizations that current conservation methods are inadequate and resources are declining. Fishery agencies have long recognized the potential value of area closures as a management tool, but their use has been very limited due to major political and economic issues involved in closing areas large enough to be effective in management. Strategic CSGCP research should develop siting strategies for marine reserves (sources and sinks), and model the performance of area closures from a resource management standpoint (including assessment of reserve size and the response of commercial and recreational fishermen to creation of reserves and the economic and conservation implications of reserves). Lastly, with little understanding of the economic and social effects of marine reserve policies by the public and many marine scientists as well, CSGCP should sponsor a program involving objective analysis of reserve performance, a program critical for rational policy development.

3. Transboundary populations. Many of California's marine stocks are not confined to California's boundaries, but resource management depends upon assessments for entire stocks. Biological information (growth, age structure, abundance, genetic structure) needed by managers will be unreliable or incomplete if based only on local studies in California when a substantial fraction of the population lies outside California's borders. This problem is particularly acute for pelagic species such as sardines, mackerel, yellowtail, white sea bass, bonito, pelagic sharks and salmon, since their geographic location varies according to ocean climate and population size. Strategic CSGCP research on transboundary populations should encourage collaborative regional studies involving investigators in West Coast states (California, Oregon, Washington) and other countries (particularly Mexico and Canada).

4. Lower stock assessment costs. Less than ten percent of the marine fish stocks off California have been formally assessed and formal assessments have thus

far been limited to the larger and more valuable stocks. Many smaller, heavily fished stocks are of substantial economic importance to California's commercial and recreational fishermen, but data available for such stocks are often of very poor quality. Often these smaller stocks are not individually targeted as a species but instead are an entire species complex, occupying a specific type of habitat, and are fished as a group. Near-shore California finfish fisheries are an example of this situation. These small stocks require effective management (a requirement of the Marine Life Management Act of 1998), but expensive fishery-independent vessel surveys for monitoring abundance, and use of data-hungry assessment models typically used for large stocks are not feasible or economically justifiable. Strategic CSGCP research should encourage development of rational and effective management strategies and models that can be applied when information is limited, with particular reference to management of species "complexes." Strategic CSGCP research should also encourage development of low-cost fishery-independent monitoring strategies for detection of trends in abundance (e.g., based on power plant impingement data, stomach contents of commercially important predatory fish, contents of scats of marine mammals, etc.).

5. Long-term changes in productivity. Most stock assessments and fishery management plans do not account for long-term changes in stock productivity. Basing management strategy on average productivity of a stock over recent time is risky because many West Coast stocks show major shifts in productivity on decadal time scales. These shifts in productivity are believed to be driven by decadal shifts in ocean climate; in some cases (e.g., Pacific sardine) the evidence is strong. There is also increasing evidence that large-scale oceanographic influences have profound impacts on abundance of anadromous fishes such as coho and chinook salmon, steelhead, and possibly striped bass. Strategic CSGCP research should encourage the development of stock assessment models that incorporate environmental data to account for effects of ocean environmental factors on stock productivity in marine and anadromous fishes.

6. Essential fish habitat has been identified as an increasingly important element to be considered in devel-

oping fisheries management plans (MLMA of 1998, Magnuson Act reauthorization of 1996). While the habitats of most pelagic species are relatively safe from anthropogenic change, and habitat analysis often has no direct bearing on assessment of these species, this is not the case for anadromous and/or bay- and estuary-dependent species, or for coastal demersal species associated with specific topographic features such as reefs or kelp beds. For the latter, the identification and quantification of this essential habitat, along with fishery-independent density surveys, offers possibly the best "short term" hope for developing comprehensive population assessments for nearshore species. Such information is also highly desirable for designing, establishing and evaluating marine reserves as a management tool for nearshore species. Strategic CSGCP research should encourage study of essential fish habitat, especially for nearshore demersal species associated with topographic relief, and for anadromous and estuarine-dependent species.

Strategic California Sea Grant research should encourage study of essential fish habitat, especially for nearshore demersal species associated with topographic relief, and for anadromous, and estuarine-dependent species.

7. Fisheries policy. Resolution of many key fisheries issues requires a multidisciplinary approach combining resource economics and other social science disciplines. Improved understanding and objective analysis of policy issues related to the rapidly evolving management of California's fisheries will be critical to implementation of successful fisheries resource management. The California Sea Grant College Program is uniquely positioned to bring this multi-disciplinary approach to bear on fishery problems by encouraging collaborative, multi-disciplinary university research. Strategic CSGCP research should provide special support for collaborative, multi-disciplinary research on marine fisheries policy issues.

• ***Reduce fishing capacity***. A key component to biological and economically sustainable fisheries is reducing the amount of fishing effort. In California, too much fishing capacity is chasing too few fish. Various restricted access, harvest rights, and buyback systems have been proposed and could become a prominent feature of state and federal fishery management plans. Strategic CSGCP research should investigate the anticipated and actual outcomes of these policy options and provide recommendations for their implementation in California fisheries.

• ***Reduce bycatch.*** Discard of nontarget, unmarketable or prohibited fish species due to fisheries regulations and lack of gear selectivity is a major, worldwide issue; and the incidental catch of marine mammals, birds, and turtles is highly restricted, as is that of protected species, which is prohibited by federal law. These substantial "bycatches" are unacceptable for a variety of ecosystem, management, and political reasons and must be considered in any fishery management plan. Strategic CSGCP research should encourage development of more selective fishing gear that reduces bycatch, identification of oceanographic factors that contribute to greatest bycatch problems, and consideration of new regulatory policies that might reduce the magnitude of bycatches.

California Institute for Stock Assessment and Fishery Economics

The California Sea Grant College Program needs to take the lead in facilitating the development of a California Institute for Stock Assessment and Fishery Economics (CalSAFE) to support the Department of Fish and Game in the new stock assessments by providing modeling and economic expertise, training CDF&G biologists in these skills, and educating the next generation of stock assessment modelers and fishery economists.

The California Department of Fish and Game is ill equipped to use modern management techniques as required by the Marine Life Management Act of 1998. Few members of the CDF&G have modeling and stock assessment skills or expertise in fishery economics necessary to conduct modern stock assessments and to build modern fishery management plans. The situation is acute because there is a nationwide shortage of researchers with stock assessment modeling and fishery economic expertise. National demand is not keeping up with university production. Recognizing this problem, the National Office of Sea Grant has instituted a small nationwide fellowship program. This is a positive step forward, but is far from a solution since only a few national fellowships will be available. The California situation is particularly grave because very few universities in California offer courses in modern stock assessment of marine resources, having neither the mandate nor the funding. Unless strategic action is taken now, the next generation of California mod-

ern resource managers will not be educated in California.

Improving the overall management of California fisheries will require a statewide program of research and education. This program would combine the resources and expertise available throughout the state within academic institutions on the one hand and the CDF&G on the other to develop high-quality stock assessment and other fisheries modeling tools through a competitive, peer-reviewed process targeted to address CDF&G priorities.

To be effective, this program must be framed as a cooperative program of the two California university systems and the CDF&G. The program's mission would be to:

• Provide educational programs in fish stock assessment and fishery economics;

• Carry out research on fisheries management problems, particularly stock assessment;

• Advise the state in development and review of fishery management plans; and

• Provide training opportunities or mentor programs in advanced stock assessment methodologies for CDF&G biologists.

The gathering, archiving, and dissemination of information needed for stock assessment would continue to be the responsibility of the CDF&G.

Other valuable participants would be similar agencies at different levels of government such as the National Marine Fisheries Service and the Inter-American Tropical Tuna Commission. These agencies have similar interests and expertise in stock assessments, and could provide experience and expertise useful in training others.

The extent the institute would be a distributed or a centered entity within the California university systems is a strategic issue requiring further development. Training in certain core areas would be essential regardless of location, however. For example, training in stock assessment, applied statistics, and modeling are essential for developing modern fishery stock assessment scientists

and resource economics and econometrics for future fishery economists. In a distributed system, the extent of training in allied fields (oceanography, biology, applied statistics, applied economics, etc.) would vary, thereby taking on the theme of the individual campuses, thus adding strength and diversification.

As a statewide program, the California Sea Grant College Program would be an ideal partner, whose role would be to administer this institute as a competitive program open to researchers from the CDF&G and academic institutions statewide. Participating universities would serve as centers of expertise, with a strong focus on the development and use of statistical modeling techniques to assess the status of marine stocks. In addition, fishery scientists and policy analysts would collaborate with the Institute to develop management models capable of predicting the impacts of various potential policy options on the health of both the fish stock and the harvesting industry. The objectives of the stock assessment and fisheries management program would include:

- Educating graduate students in population dynamics and stock assessment, and related fields of fisheries science and economics;

- Offering training courses in these and related fields to further the education of future and current fisheries managers in California;

- Advising the CDF&G in the development of fishery management plans, and/or recovery plans;

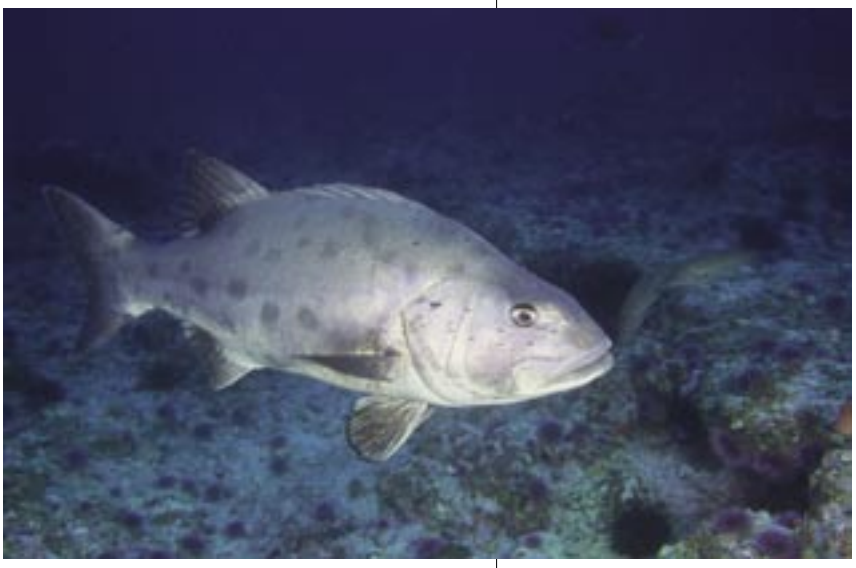
- Coordinating peer review of proposed fishery management plans;

- Carrying out research on population dynamics for key recreational and commercial species;

- Developing integrated models of fisheries combining population models with economic models of the industry;

- Providing legislators and the Fish and Game Commission with an objective view of marine resource policy issues.

A scientific committee composed of representatives from the CDF&G and scientists from throughout California and other states would guide the program. The responsibilities of the committee would include setting priorities for funding and evaluating proposals for their scientific merit. An advisory committee composed of a wide variety of representatives from the commercial and recreational fishing industry, and non-governmental organizations, would provide input to the review and selection process.



Marine Affairs

Introduction

The litany of why marine affairs is of crucial importance to California's governance, economy, and society is well known to the audience that will read this report: how the concentration of California's total state population is within the coastal region; how the ocean and coastal industries of the state that contribute so importantly to the state economy require expanded infrastructure, or pose problems of pollution and displacement, or are in complex relationships with user interests and regulatory agencies; and how ocean science and technological innovations in California are addressing ocean and coastal resource issues across a wide spectrum of concerns. In addition, dramatic changes in international law, multinational agreements and working arrangements for ocean resource management, concern with biodiversity protection, and the like, are now impacting and inevitably will continue to impact the California economy, law and policy, and the state's terrestrial physical environment, marine resources, and human settlement patterns, including urbanization processes, and problems of governance. All the foregoing prospects and problems, made familiar in numerous studies by the National Research Council and other agencies and institutions as well as in individual scholarly work, have to be kept in mind in assessing the urgency of the specific needs that California Sea Grant needs to address with its Marine Affairs program in the coming years.

The following list of areas in which CSGCP institutions' expertise and resources ought to be strengthened, and in which research should be encouraged, is not intended to be comprehensive and exclusive. Rather, it indicates some of the major areas in which research of distinction has been done in California from the social science disciplines, law, and policy studies; and areas of investigation in which there is a manifest need for more and better research now and in the time frame of this strategic plan's implementation.

Major Research and Programmatic Initiatives

1. Legal, institutional and policy-process studies. There is a vital need for information regarding international, national, state and substate local law and policy implementation affecting both natural resources and human population interaction with environment in the marine and coastal areas, as well as in the oceans beyond national boundaries of jurisdiction. The CSGCP should seek to support and increase its constituent institutions' capacity for monitoring important changes in law and policy, and for analysis of problems and processes of implementation.

There has been, and doubtless will continue to be, rapid change in the legal and policy framework for ocean and coastal governance. Concepts such as "sustain-ability" and the "precautionary principle" and "optimal use," in the new legislation and international agreements as in earlier law and policy, require continuous reappraisal in light of new mandates and normative standards and also in light of changing social, economic, and political developments such as shifting population distribution and concentration, changing abundance levels of resources, pollution of coastal and marine environments, etc.

In many other Sea Grant programs, a significant component of the budget for grants is allocated to maintaining university-based programs that systematically gather data on marine and coastal law and policy, and that are organized to undertake the analysis of the changing legal and policy framework in relation to management, conservation, and development objectives, as well as in relation to political, social, and economic change. Expertise is mobilized, for example, from the fields of history, geography, political science, anthropology and sociology, and psychology to augment the established trends of research in economics and policy analysis. A model of such interdisciplinary collaboration was provided by the University of California Institute of Marine Resources studies headed by Milner Schaefer in the 1960s, from which emerged a basic reconceptualization of coastal and ocean policy and management that has had enormous influence nationally and internationally quite apart from the way in which it sparked the

debate that led to the new coastal management structure in California at that time.

Lacking today the formal institutional structure of IMR, and pending new initiatives on that line by the University of California, Sea Grant should give high priority to support of research that brings the insights of law, policy, and social science disciplines to bear on the analysis of both the substantial content and potentialities of legislation and policy, on the one hand, and, on the other of implementation issues, performance, and impacts. Among the earliest CSGCP studies in marine affairs was an anthropological analysis of the tuna fishers of San Diego and their communities; this kind of cultural and social analysis should also be brought within the umbrella of studies of strong interest within the rubric of "marine affairs" but not strictly focused on specific legislation or policy, or the policy process, for it enriches the understanding of context when marine and coastal issues are confronted.

Analysis of legal, institutional, and policy issues is important in an immediate way to all of the CSGCP user constituents. But both historical studies and the study of contemporary policy process have proven useful as well in the training of resource managers and personnel of planning and development agencies, as well as to personnel in industry, for an improved understanding of their own activities and for insight into the potentialities of a variety of approaches to problem solving and policy formulation.

Analysis of legal, institutional, and policy issues is important in an immediate way to all of the California Sea Grant Program user constituents.

2. Economic studies of fisheries and habitat management. Economic analysis is subsumed in the approach to marine affairs issues involving the knowledge and methodology of social science, as described above; but in one special regard, the application of economic concepts to fisheries management, economics has played a role of special significance and is at the vital center of current-day debates of not only fisheries management but also of the approach to definition of habitats and their protection which is mandated by new legislation. The CSGCP has made significant contributions to the ongoing dialogue that has involved economists in fishery management development during the last decade, and

research on this line should continue to receive support. (Also, one CSGCP project has provided the only full analysis available in the literature of the history of economics in the debates of fishery management concepts both in international and national arenas.)

As an essential part of this effort, this committee joins with the working group on fisheries research to recommend support for an institute without walls, termed in this instance the California Institute for Stock Assessment and Fishery Economics, and endorses the specific objectives for research prioritization detailed in the Fisheries section of this document.

3. Coordination with SGEP and other institutions and agencies. Among the objectives of the Sea Grant Extension Program's draft Five-Year Plan is "collaboration with faculty members in identifying, conducting and extending marine and coastal policy research." The draft also stresses that the Extension personnel are "well positioned to identify marine affairs research needs and opportunities and to work with faculty in conducting and extending policy research results." Researchers in social science, law, and policy studies are no more receptive than are the best marine scientists in diverting their energies and resources to short-term projects, however responsive to perceived needs from important constituencies, if it is at the expense of their basic research of more enduring significance to the advancement of methodology and knowledge in their fields.

Nonetheless, the immediate needs of users and agencies often provide challenging opportunities for researchers to investigate implementation issues of larger significance; and there are many instances in the literature and in the history of California policy studies in which major research initiatives have resulted from a determination by the best research faculty to address problems of immediate concern to resource managers, industry, or elective officials. Even more important, the size of California's marine and coastal sector, its development potential, its management and conservation problems, its place in the global regimes for ocean uses, and its specific political and institutional contexts mean that many "California-specific" problems and research opportunities link

with, reflect directly, or offer insight into larger national and global issues of central concern to the marine community.

Hence the committee endorses as a general strategy the proposal that CSGCP seek to maximize productive contact between SGEP and faculty researchers on the lines that the SGEP draft plan suggests. The SGEP has specified certain priorities for attention in its own activities and in potentially expanded cooperation with faculty researchers. These priorities are not necessarily symmetrical with existing research competencies and interests in the marine affairs research community in California, however; and subject matter priorities from SGEP or any other source should not trump the criterion of researchers' demonstrated competence, and quality of the proposals as to promise of producing excellent analysis, in the allocation of research awards by the Sea Grant committee.

4. Some specific research subjects of special importance. The following list includes both California-focused studies and those of more general interest in law, policy, and social science. This is intended as exemplary and not as a set of priorities to the exclusion of other important topics that individual law/policy/social science researchers may present in the quest for CSGCP support. The basic principle for support of projects should be that the quality of the proposed research and the accomplishments of the grant applicants, work in law, policy studies, and social science is the foremost criterion for awards.

a. Sustainable development and resource management studies include analysis of ecosystem management, integrated coastal-ocean management, and other basic approaches to resource use and conservation; research on institutional structure and organization, agency effectiveness, and socio-economic-political context of management initiatives; studies of the applicability of theoretical ideas such as "co-management" in specific areas of marine resources and coastal resource use; and on the precautionary principle, sustainable use concepts, and similar concepts that are embedded in new legislation or proposals for long-term environmental planning.

b. Ocean and coastal governance: organization, dynamics, impacts includes analysis through application of social science methods and legal analysis of issues relating to ocean-coastal-watershed management and analysis of data bearing on the desirability and effectiveness of integration or coordination of basic environmental plans and of agency implementation; studies of the changing mix of user interests and activities, and implications for governance; studies of federal-state-local relations; and studies of regionalism in governmental organization and counterpart private-sector phenomena, especially in relation to such policy problems as nonpoint pollution and its control in the California coastal areas and in more general social science/legal/policy contexts.

c. Conservation and preservation issues include studies of Endangered Species Act implementation and its impact, past and present, as well as anticipated; rising issues of effects of EPA actions on areas of urban agglomeration (as recently in the Portland, Oregon region); legal issues relating to coastal and ocean users, "property" claims in law and the constitutional jurisprudence of regulatory law; analysis of preservationism and competing environmentalist or growth goals in relation to policy goals/legal mandates/economics/social impacts of mitigation plans in specific coastal-ocean areas, habitat preservation; and studies of the law and administration of marine reserves, and their relationship to other sectors of marine and coastal law, state and federal, as well as to emerging mandates in international environmental agreements.

d. Historical analysis of domestic and international policy process includes research on how state and federal laws—and also international commitments involving the U.S. as signatory or impacting on U.S. interests—have been implemented and have impacted marine user groups in the past, and how the public interest has been (and can better be) defined in a context of continuing user conflicts and basic legal-political differences over property rights and conservationist or management goals. Historical analysis can be supported as part of interdisciplinary cooperation with social science, natural science, and engineering researchers' proposals. The California

marine research community, and the larger international and national communities, require an institutionalized memory for perspective on the potentialities as well as past development of marine science, policy and law, as well as social change in coastal and marine communities.

e. Enforcement issues include research on social and political impacts, as well as on enforcement issues in the implementation of resource-use and environmental law, in marine and coastal areas; the entire range of Coast Guard activity, coastal and marine recreational safety agency activity, and the more comprehensive environmental planning and management programs in fisheries, beaches, pollution regulation, etc.

f. Ports and navigation include research on resources needed to respond effectively to rising shipping volume, new technologies, and new ship design in planning and support of port facilities; research on the management of ports and the relationship of environmental issues to port and navigational-improvement activities; and collaborative studies with marine engineers on policies for construction and management of both port and offshore physical structures, and the governance structures and policies for effective port operations and management.

g. User activities and conflicts include research, overlapping some of the above, that focuses more strictly on the economic, social, political and cultural aspects of ocean and coastal uses; marine industries and their operations; the roles of Non-Governmental Organizations in the politics of coastal and ocean governance; and the problems in regulation (by the state and federal environmental protection agencies, and by local and regional authorities) that impact the operations of both private-sector organizations, recreational uses, etc., on the one side, and standing governmental agency operations, on the other side.

Institutionalizing Research in Marine Affairs, Policy, and Law

The foremost problem that requires urgent attention from California Sea Grant and participating institutions in the opening years of the 21st century is the striking

inadequacy in the numbers of academics in California who are devoting their scholarly efforts to marine and coastal issues. There is a notorious shortage of trained personnel.

In the University of California itself, only a small number of faculty members now conduct active programs of research in the fields of ocean law and policy, coastal management, and marine resource regulations; only two or three campuses have a serious presence in those fields at this time. There is a dramatic deficiency in the amount of work being done by social scientists and students of policy, outside the field of economics; fisheries economics does have a strong presence at UC Davis. Only one campus, UC Berkeley, presently has a well-recognized presence, internationally and nationally, in ocean law, but the UCB program is now maintained by the efforts of only two faculty members, each of whom has teaching and administrative responsibilities in other parts of their law school's curriculum.

On the other UC campuses, and in the other distinguished private and public institutions associated with the California Sea Grant Program, there is a similar shortfall of faculty resources available to be devoted to (and interested in) the systematic study of coastal and ocean issues.

Small states such as Rhode Island and Delaware can boast of respectable research and degree programs that far exceed what any of California's institutions of higher learning devote to marine affairs. Among the larger states, Washington is preeminent with its concentration of social scientists, lawyers, and policy- or diplomacy-oriented scientists organized for collaborative teaching and research in a fine professional degree program.

Unfortunately, it is unlikely that the member institutions will respond effectively unless mechanisms can be developed for institutionalizing research in marine affairs, policy, and law. California needs to increase the numbers of graduate students obtaining advanced training in these areas of study; and the state, CSGCP and other institutions need to provide injections of critical funding where it will do the most to advance

the goal of building California's capacity for high-quality research in marine affairs to the level that the state's size and wealth, the quality of its academic institutions, and the urgency of the problems to be addressed all warrant.

A related objective to which resources of California Sea Grant should be directed is the more effective interaction between scientists and engineers, on the one hand, and marine affairs/law/policy scholars, on the other, in formulating research on specific issues of mutual concern, both in the process of responding to very specific state-based needs for increased knowledge and policy advice and in the process of advancing scientific, social-scientific, and legal research of a basic and long-term character. With respect to UC itself, the establishment of the new Marine Council and the possibility of its being funded for such purposes in future years opens the prospect that such goals may be pursued vigorously both within UC and sister institutions and among them in cooperative and collaborative arrangements.

An important result that can be anticipated, if such an effort is successful, is that the Sea Grant institutions will establish the collaborate structure for more effective efforts at foundation and other private as well as governmental funding of important projects in ocean and coastal policy, law, and social science.

New Marine Products

Marine Pharmaceuticals

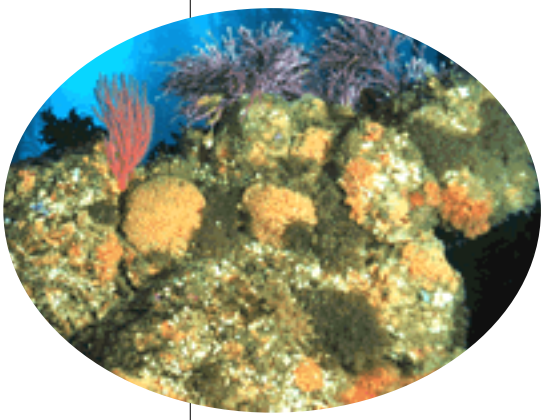


Photo by Eric Hanauer

The California Sea Grant College Program pioneered the discovery of new anti-inflammatory agents from marine organisms. Highlights include the discovery of the anti-inflammatory action of the sponge metabolite manoalide, a selective inhibitor of the enzyme phospholipase A_2 that was licensed for development as a treatment for topical inflammatory conditions such as psoriasis. Although manoalide proved ineffective during clinical trials, it remains the industry standard for phospholipase A_2 inhibition and has found a place in textbooks and fine chemical catalogues. This was followed by the discovery of the beneficial properties of the pseudopterosins, which were obtained from a Caribbean gorgonian. The gorgonians are now harvested commercially and an extract is incorporated into a variety of skin care products to which it imparts anti-irritant properties. To date, the pseudopterosins have generated nearly $2 million in royalties for the University of California.

The CSGCP projects were central to the formation of a biotechnology company that focussed on the development of marine metabolites for the treatment of osteoarthritis and wound healing. The pseudopterosins are currently in Phase I clinical trial for wound healing and have been licensed to another company for treatment of arthritis. The same collaboration also led to the discovery of debromohymenialdisine as a treatment for osteoarthritis, and again commercial development is anticipated. Other potential drugs from this program include the topsentins and related bisindoles, which are currently under preclinical evaluation by a major chemical company, and the scytonemins, which are another major class of anti-inflammatory agents that block neurogenic inflammation by a unique mechanism.

The marine natural products mentioned above serve a vital role as molecular probes used to unravel the complex physiological and biochemical processes underlying

the expression of pain and inflammation. They also serve as important templates used in combinatorial chemistry to define the phenotype of 'super drugs' to be developed in the future. At present there are eight distinct classes of anti-inflammatory marine natural products arising from this unique Sea Grant project that are currently at different stages of development. In all these cases, the uniformly repeating theme underlying success was the characterization of a unique biological mechanism of action and novel chemical structure for each marine natural product.

The California Sea Grant College Program tackled an area of pharmaceutical research, namely marine natural products and inflammation, in which each collaborator brought special unique talents to the team.

There is a lot to be learned from this success story. The CSGCP tackled an area of pharmaceutical research, namely marine natural products and inflammation, in which each collaborator brought special unique talents to the team. The CSGCP brought together a team of scientists who were on different campuses and otherwise might never have had the opportunity to work together. The program actively encouraged commercial development of potential pharmaceuticals well before such activities became fashionable. This resulted in the filing of dozens of patent applications. Many patents were awarded jointly among members of the team and others through special opportunities arising out of a network of evolving academic collaborations. Thus, the program developed a unique focus that spawned the formation of new companies, a unique research direction, and new collaborations. The success of the CSGCP was a major driving force behind the National Sea Grant Biotechnology Initiative, which has evolved into a very different program than that imagined by its early supporters.

Marine Biomaterials

Marine biomaterials are macromolecular structures, or components thereof, derived from marine organisms. Traditional biomaterials research has involved cursory biochemical and/or biophysical characterization of the materials, and the development of some useful application using these materials (by trial and error). Some successes that had part or most of their funding from the national or state Sea Grant programs include cnidarian fluorescent proteins, coagulogens, shell proteins, marine collagens, fish anti-freeze proteins, chitosans, adhesive proteins, and algal polysaccharides. All of these have

shown practical utility and are commercially available in one form or another. Others like coral and nacre implants and bioelastomers, though less thoroughly investigated, are revealing some exciting properties in recent research.

Marine Bioinorganic Chemistry

CSGCP has addressed marine bioinorganic chemistry and metallobiochemistry by funding exploratory research to elucidate the structures of siderophores (low molecular weight compounds that chelate and sequester iron, which are produced by marine bacteria). All bacteria require iron for growth. Iron has been shown to be a limiting nutrient in vast regions of the world's oceans, yet little is known about the molecular mechanisms of iron acquisition by marine microorganisms. The success of the initial Sea Grant funded research led to the establishment of a major new National Science Foundation institute called the Center for Environmental Bioinorganic Chemistry (CEBIC), located at Princeton University, which is comprised of investigators from the UC system, Princeton, Exxon, Rutgers and Montreal, to investigate iron limitation of primary production by phytoplankton and the mechanism of iron acquisition by other marine microorganisms.

Marine Products Research Issues

One current research effort in marine pharmacology is focused on the marine biosynthetic pathways essential or common to some of the pathways seen in the inflammatory response and its relation to the mechanism of action of natural products. This arises from the often asked question, "Why are there so many anti-inflammatory drugs found in marine organisms?" One hypothesis suggests that by incubating suitable substrates with marine organisms or their cell-free extracts, we may observe the formation of previously unidentified marine natural products. In effect, this experimental approach appears to be a way to up-regulate the production of extremely rare chemicals. For example, prostaglandins and fatty acids of unpredictable structure have been found in ancient organisms that preceded the evolution of terrestrial organisms and in fact lack organ and compartmental differentiation. A unicellular eukaryote that lacks the organismal components (neurogenic and hemopoietic) believed

necessary to produce the inflammatory response appears, however, to have much of the required biochemical and chemical pathway present. This raises the question whether evolution and adaptation may have altered the manner in which a pathway is expressed and perhaps its function, but not necessarily all the fundamental physiological chemistry. It is hypothesized that new important knowledge about the genesis of inflammation lies in the study of the primitive protists and other ancient marine organisms. Initial results support this hypothesis but the discovery of new pharmaceuticals awaits the unique investigational skills of natural product chemists.

Current Trends in Marine Materials Research

The last five years of marine biomaterials research have seen a dramatic shift in perception and method.

The last five years of marine biomaterials research have seen a dramatic shift in perception and method. The shift in perception has to do with understanding how marine biomaterials are adapted to function in a wide diversity of environmental conditions that include temperature, acidity, salinity, light, dehydration and turbulence. Such functional adaptations are of keen interest to materials design generally. Unlike marine enzymes, however, marine biomaterials are, more often than not, intractable, lacking both suitable assays for function and methods for the analysis of structure and macromolecular assembly. Several advances have radically changed this. Environmentally enclosed micromechanical testers are now available for routinely assessing the dynamic stress-strain properties of materials no larger than a few square millimeters. Indeed, atomic force microscopy can be used to reveal the mechanical properties of individual molecules. Chemical analysis of intractable proteins has also been catapulted forward by the discovery of new types of mass spectrometry for the femtomolar characterization of proteins and peptides. These methods have proven to be indispensable for detecting a broad spectrum of exotic and functionally important post-translational modifications. Use of partial peptide sequences for the synthesis of degenerate oligonucleotides to be used as primers for the DNA polymerase chain reaction and primer-based extension of cDNA ends has led to numerous breakthroughs in the otherwise impossible characterization of marine biomaterials.

An important strategy for the Sea Grant program will be to closely follow biomedical advances to determine which can be profitably applied to the marine environment. An example of this would be to adapt gene transfer techniques to capture the biosynthetic ability of unculturable symbionts to readily cultured microorganism. One of the acknowledged difficulties in developing marine natural products as drugs is to ensure a reliable supply of the chemical involved. For small molecules such as the osteoarthritis drug debromohymenialdisine, the best answer is a practical synthesis. For more complex molecules such as bryostatin, aquaculture is an attractive option. However, many of the most active marine natural products are found in very small quantities, often in uncommon or rare species. Fortunately, it appears that some of these compounds are produced by bacteria that enjoy a symbiotic relationship with the host invertebrate from which the compound was isolated. Current research has identified the genetic sequence responsible for polyketide biosynthesis, and vectors are being developed to transfer quite large bacterial DNA sequences into various *Streptomyces* species and over-express polyketide biosynthesis. The isolation and transfer of the biosynthetic gene sequences from symbionts to readily cultured bacteria will provide a cheap and reliable source of certain complex marine natural products. This technology will be developed within the next four years. The transfer of biosynthetic DNA from eucaryotes (invertebrates) to procaryotes (bacteria) will undoubtedly be accomplished in four to 10 years. This is just one example of technology transfer that could be beneficially adopted by marine science.

Understanding the biosynthesis, function and mechanism of action of marine natural products in truly unique marine organisms would lead to creation of a family of super drugs that will down regulate over-expressed complex biochemical processes underlying the symptoms of a variety of inflammatory disease states. In the future, the molecular knowledge of diseases will be further refined into narrow populations of disease phenotypes requiring special new classes of drugs. The recent new family of cycloygenase inhibitors that offer new health to arthritis sufferers is a powerful example of what to expect in the

An important strategy for the California Sea Grant Program will be to closely follow biomedical advances to determine which can be profitably applied to the marine environment.

future. Marine organisms are our most ancient genetic pool of living fossils and represent relatively undifferentiated sources in which to study the evolution and ecology of inflammation.

With the growing concurrent research into both the biomechanical/biophysical properties and biochemistry of marine biomaterials, a database of structure-function relationships is coming into existence. This is indispensable if we are to understand the molecular underpinnings of adaptation in biomaterials. Questions such as, "How do exoskeleton-derived proteins from sponges or oysters specify and direct mineral growth?" "How do marine organisms tailor adhesive secretions for different types of surfaces?" and, "How do antifreeze peptides bind to ice surfaces?" are changing the way we understand adaptation in marine organisms, as well as providing new insights for materials design.

Marine Products Research Future Goals

California is the home of many biotechnology companies, and, while it is not advisable to support research that could just as well be done within these companies, Sea Grant should support basic research that has a uniquely marine scope and yet is also of interest to industrial collaborators. In particular, working with whole cell bioassays that cannot be performed by robots, and studying mechanisms of action of marine natural products should prove to be valuable Sea Grant contributions to basic science.

Continued funding of research in marine bioinorganic chemistry is recommended. When compared with terrestrial environments, the oceans possess a unique elemental distribution, which is particularly reflected in the transition metal composition. In their adaptation to chemical environments, marine organisms have evolved new enzymes, often metalloenzymes, which are distinct from their terrestrial counterparts. Thus explorations of selective oxidation, halogenation and hydrolytic transformations can be expected to lead to the discovery of new metalloenzymes, many of which will have applications in the chemical and biotechnology sectors. This research might be best accomplished by teams consisting of chemists, marine biologists and microbiologists, who could give

broad attention to genetic techniques and manipulations to screen and engineer organisms.

Because of the costliness of biomaterials research, Sea Grant plays a vital role in nurturing or "nucleating" new ideas and educating graduate students in this area. Since the ultimate application for any particular biomaterial is rarely predictable from the outset, e.g., green fluorescent protein as a transcriptional reporter, coagulogen for detection of endotoxin, shell matrix proteins as anti-scaling agents, etc., Sea Grant's best strategy is to support the most innovative ideas coupled with the most rigorous science. Although the CSGCP funds a few centers of strength in marine biomaterials research, such as marine biomineralization and bioelastomers, these represent a much smaller investment than the state's potential would warrant. California universities are home to many world leaders in the molecular and biomechanical analysis of marine biomaterials.

Because of the costliness of biomaterials research, Sea Grant plays a vital role in nurturing or "nucleating" new ideas and educating graduate students in this area.

Priorities

• While a national Biotechnology competition is in effect, the California Sea Grant Program should give priority to proposals that directly impact California, either by exploring the potential of California's marine organisms or through close collaboration with California's biotechnology industry.

• Priority should be given to training graduate students in marine biotechnology, particularly where there is an opportunity for technology transfer from industry or academia to marine science.

• High-risk, high-reward projects have a special place in Sea Grant, which can act as a nursery for applying new research technology to the marine environment or marine organisms.

• Priority should go to creative investigator-initiated proposals that advance our knowledge of the formation, structure and function of marine natural products and biomaterials.

OCEAN ENGINEERING

Introduction

The California Sea Grant College Program (CSGCP) fosters university research in ocean engineering, with special emphasis on the needs of the state, but with attention also to regional, national or international needs. Ocean Engineering is defined broadly as the practice of classical engineering disciplines (mechanical, civil, environmental, etc.), often in an interdisciplinary mode, where the ocean provides significant influence on the result. Although Coastal Engineering is often recognized as a separate discipline, for purposes of this program it is included within the Ocean Engineering program. The beneficiaries of the Ocean Engineering research sponsored by CSGCP are broadly distributed. They include state, federal and local agencies responsible for ocean and coastal resource management and preservation; companies and individuals involved in ocean commerce, including users and managers of ports and harbors; engineering firms; and coastal property owners. Research into better understanding of the processes and better methods for conducting ocean engineering are vital to the prosperity of California, with its strong dependence on ocean-related activities.

Ocean Engineering Issues

The following nonprioritized, nonexclusive list of research areas has been developed.

Sediment processes. Sediments ranging from cobble- to mud-size particles are involved in a large and varied group of ocean engineering problems. The engineering research encompasses predicting transport of sediments, methods of moving and depositing them, and methods for retaining them. There are strong interdisciplinary links to such fields as hydrology, physical oceanography, civil and environmental engineering, chemistry and toxicology, and benthic and wetland biology. There is a need to develop:

• Methods for economical and environmentally benign disposal of dredged sediments on the sea floor, including appropriate capping techniques for contaminated material.

• Realistic models for the behavior of sediments or capping material during dumping and after settlement, including capabilities for the assessment of the risks of slumps, slides or turbidity flows.

• Methods for determining the stability of shelf and slope sediments under seismic excitation, especially when a tsunami is involved, including effective and economical means for assessing the strengths of sediment deposits and for modeling the slump potential.

• Regional scale models for nearshore sand transport. Existing models are ineffective in predicting long-term and large-scale trends that are critical to regional planning for the management of these sediments. Realistic methods for restoring the natural flow of sand onto the beaches.

• Improved models to estimate nearshore wave conditions from deepwater observations. Existing models predict wave height adequately but cannot predict direction accurately enough to allow sediment transport modeling. The existence of permanent offshore wave data makes long-term predictions of shoreline evolution potentially feasible.

Ports and harbors. California has one of the world's largest port complexes and several smaller, but important commercial ports. Although these typically enjoy deeper natural channels than ports in other parts of the country, dredging remains a major problem. Further, many California ports have large wave problems at entrances that do not occur in estuarine ports. Port structures are subject to accelerated structural degradation related to the coastal environment. In addition to ocean freight, harbors encompass facilities to support fisheries, offshore supply operations and recreational boating. There is a need to develop:

• Design or retrofit models for seismically susceptible structures. Existing models for seismic shaking of sheet-pile supported fills are inadequate because they do not consider the liquefaction of sandy fills. Failures of these structures have occurred on the West Coast and in Japan.

• Predictive models for severe seiching (surging) in harbor basins. The advent of effective forecast models for ocean waves will allow the development of advance warning of severe surging events allowing ship loading and transit schedules to be adjusted to avoid damaging conditions.

• Risk assessment models for port protection structures. Infrastructure within a harbor can be severely damaged if a breakwater or jetty fails during major storms. Existing models do not adequately assess the capabilities of rubble mound breakwaters that have been degraded by many large wave events.

• Economical methods for maintaining channel depths in small harbors that are no longer included in the federal dredging program.

• Methods for reducing the costs of maintaining up-to- date surveys of the depths of channels and harbor basins.

• Methods for mapping the extent of fog layers in the vicinity of harbors and predicting their short-term evolution.

Mineral resources. The major nonliving resources now being recovered along the California coast are hydrocarbons—oil and natural gas. Although a moratorium on further development is in effect, a large operation is still underway and will continue for many years. Many of the structures were designed before the experience of very large waves during the ’80s and ’90s. Others are still economically viable after exceeding their design lifetimes. The continental shelf, especially where it is quite broad in Southern California, contains a very extensive resource

of relict beach sands deposited as sea level increased over the last 15,000 or so years. There is a need to develop:

• Methodology for evaluation of the engineering aspects of converting platforms scheduled for removal to fish-attracting reefs or other public uses. The general distrust of the offshore industry by the public provides an important role for CSGCP to sponsor research leading to "honest broker" evaluation of the risks of proposed scenarios.

• Methods for economical and reliable assessments of the quantity and quality (sediment size ranges) of offshore sand deposits.

Ocean engineering data management. The availability of GPS, GIS and other computer-based technologies affords opportunities for ocean engineers to effectively exploit the glut of data collected by federal, state, local and commercial interests on the geophysical and infrastructure features of the California shelf. These data, if they could be readily obtained in a highly compatible form, could be combined into meaningful map overlays or other useful forms. This would facilitate better engineering decisions about what is being installed in the ocean and assist regulatory bodies in conflict resolution. Fiberoptics cables are rapidly replacing most other forms of communication, including satellites. Using the ocean floor as a right of way for these cables is proving more economical than acquiring land right of ways. In the future, this will become true for other commodities such as oil and gas lines. Without careful documentation of existing and planned infrastructure additions, California could eventually find itself in a situation similar to the Gulf Coast where haphazard oil and gas flowline installations have created a tangle of crossed pipes, some abandoned, that no one can sort out now. There is a need to develop:

• The technology, common formats, and types of geophysical and engineering data necessary to allow the integration of data from a variety of sources into statewide, regional, and project-scale databases on ocean floor utilization with particular attention to data that will help to resolve multiple-use conflicts.

The physics of plumes and outfalls. Several desalination plants are under design to meet the fresh water needs of Southern California cities. The process results in substantial flows of high salinity brines that must be disposed of in the ocean. Existing models for these negatively buoyant plumes are unvalidated and potentially misleading in predicting the mixing and interactions with bottom sediments. A similar problem exists with plumes of produced water (water separated from oil and gas recovery) from offshore platforms, where highly toxic elements may be present in the flows. There is a need to develop:

• Models for fate and effects of negatively buoyant plumes, discharging at or near the bottom and also at substantial distances above the bottom, with capability to predict mixing and entrainment.

Sea Grant Extension Program

The Sea Grant Extension Program mission is to apply research-based information to develop practical and acceptable solutions for marine and coastal resource concerns.

Introduction

Increasing demands on coastal and marine resources have led to unprecedented needs for dissemination and coordination of research-based information for management and wise stewardship of California's valuable coastal resources. Resolution of coastal resource issues often requires a blend of research information, new policies, and public education. The Sea Grant Extension Program (SGEP) is California Sea Grant College Program's (CSGCP) primary resource for helping Californians combine research, management, and education to solve resource problems. SGEP uses innovative research and extension approaches to address issues in marine fisheries, coastal and marine resources management, aquaculture, and seafood technology. As with the CSGCP research funding, the SGEP attempts to address a variety of coastal issues that have a time horizon ranging from less than one year to three to five years, or more.

SGEP program was established in 1972 and by 1980 consisted of eight county-based marine advisors and two campus-based specialists, one of whom serves as a half-time extension program coordinator. A combination of level funding and increasing costs led to a gradual attrition of program capabilities during the 1980s. Funding crises in the early 1990s contributed to the loss of five program professionals and the program coordinator. In 1992, the University of California Division of Agriculture and Natural Resources (UC DANR) provided significant new funding to assist California SGEP in refilling five program professional positions. At that time, SGEP was integrated with the land-based UC Division of Agriculture and Natural Resources, Cooperative Extension (UC DANR CE), a move that proved to be an effective way to conduct marine extension programs. In 1997, the National Sea Grant Office provided emergency funds that enabled SGEP to maintain current program effort. This emergency funding ends during 2000. As the year 2000

approaches, SGEP continues to face increasing demands and increasing operating costs within a level-funding environment. If the situation is not resolved, severe reductions in the SGEP work force and activities will occur.

The CSGCP recognizes that a state the size of California would benefit by a much larger SGEP staff size, but plans to maintain the SGEP program at its current size to emphasize CSGCP priorities for research funding. To maximize effectiveness of a small staff, SGEP hires people with diverse expertise so that campus specialists and marine advisors each have different but complementary subject area specialties. This enables SGEP to provide leadership on statewide and national as well as local issues, while satisfying research and publication requirements for university academics.

Extension Program Mission and Approach

The SGEP mission is to apply research-based information to develop practical and acceptable solutions for marine and coastal resource concerns. This is done with a team of seven coastal county-based marine advisors and two campus-based specialists who work on local, state, and national issues. Locally, marine advisors work directly with the very diverse marine community, conduct educational and applied research programs, and help identify community needs for university and agency research. SGEP staff also regularly meet to discuss important state and national issues that will affect most Californians, and identify ways to work together to provide leadership for resolution of these larger issues. Approaches that are commonly used by SGEP to resolve problems include:

Consensus and conflict resolution approaches. SGEP staff attempt to build consensus on controversial issues by utilizing objective, nonadvocate approaches to resolving conflicts. Frequently, SGEP staff are asked to identify groups affected by an issue, collect information about the topic, host workshops and public meetings to discuss the issues, and work with affected groups to collectively resolve issues.

Mission-oriented research that addresses critical current needs. This collaborative research with university

faculty and resource users has proven to be an effective extension education tool and gives SGEP staff credibility with university and agency researchers.

Public education and outreach. Educational techniques include one-on-one consultations, use of listservers and websites, newsletters, radio and television interviews, printed publications, videos, public displays, and workshops.

Important California Coastal Issues

The SGEP regularly discusses issues of concern with coastal residents, meets with state and federal agency staff to identify resource concerns, and gathers ideas for future work from university faculty. Semi-annually, the SGEP meet to discuss ways to provide a coordinated effort to solve coastal problems. In 1997, the SGEP also formed an official advisory committee to help identify major issues that would provide the basis for a programmatic work plan. Recently, the CSGCP decided SGEP will have a Director who serves as a member of the CSGCP management team to ensure integrated approaches to solving critical coastal issues. This decision was made to improve the integration of the research and outreach components of CSGCP. Based on the input from local communities, state agencies, universities, the SGEP advisory committee, and the CSGCP, the SGEP has chosen to work on the following issues in the next four years.

Fisheries Management

As in most other parts of the world, many of California's marine fisheries resources are in jeopardy. Concerns include population declines of some species, such as abalone, rockfishes and endangered salmon; coastal and inland habitat loss; water quality degradation; user conflicts; and a need to maintain both commercial and recreational fishing opportunities. Thus, a strategic goal of SGEP is to help California by focusing SGEP attention on nearshore fisheries, essential fish habitat, and public education.

Nearshore fisheries are now receiving greater attention in California. The Marine Life Management Act (MLMA) of 1998 created a fundamental change in how

California marine fisheries will be managed, and the California Fish and Game Commission now has broad mandates to improve management and conservation of nearshore species. SGEP plans to work closely with the California Department of Fish and Game to provide suggestions for appropriate collaborative management, help provide peer-review for the scientific component of the MLMA, help produce a revised version of the Sea Grant publication, "California's Living Marine Resources and Their Utilization," help focus university research on management issues, and provide training to agency staff about fisheries management alternatives. In the next four years, SGEP will also help solve problems with the emerging live fish fishery and declining rockfish populations by conducting research and providing leadership in conflict resolution and stakeholder involvement, by providing information and evaluations about management alternatives, and continuing to assist in formulating ideas for management of the nearshore dive fisheries.

Essential fish habitat issues are becoming increasingly important in the United States. There is a direct correlation between habitat quality and population abundance of valuable marine species. In the next four years, SGEP will provide leadership and guidance for anadromous salmonid fishery habitat restoration and enhancement in Northern and Central California watersheds, help resolve conflicts between agricultural uses and the state and federal endangered species acts, and provide guidance and leadership in helping define and identify essential marine fish habitats. This will be done in collaboration with researchers, stakeholder groups, and agency staff, and will likely be a part of a new National Sea Grant Program initiative.

Public education work conducted by SGEP in the next four years related to fisheries will include publishing information in the form of books, pamphlets, videos, the internet, and other media that help marine resource users and the general public understand issues and alternatives for achieving the state's objectives of conservation and sustainable use of California's marine fisheries resources.

Coastal and Marine Resources Management

California's coastal and marine resources support valuable tourism, recreation, shipping, and food production industries. These critical resources are affected by population growth, development, degradation of habitats and water quality, and by direct utilization. SGEP will make a difference on this diverse set of issues by focusing on watershed management, nonindigenous aquatic nuisance species, and marine protected areas.

Watershed management that integrates scientific, economic, and social factors has been shown to effectively solve problems in coastal watersheds. Some of the numerous factors affecting watershed management in California include incorporation of the diverse environmental and water-quality laws, coordination of state and federal agency programs, implementation of the state and federal endangered species acts, interactions between private land practices and multiple habitats and species, flood control, and sustainability of outdoor recreation. In the next four years, SGEP will work in selected areas to provide research and educational information for watershed and nonpoint source pollution policy analysis, planning, and management. SGEP will also provide information for upland and coastal endangered species habitat management, reducing contamination of coastal harbors and marinas by metals in vessel anti-fouling paints, and resolution of watershed and water-quality issues related to coastal aquaculture, recreation, tourism and binational coastal water-quality management.

Nonindigenous aquatic nuisance species (ANS) introductions are dramatically affecting West Coast ecosystems and causing significant environmental and economic costs. Ballast water discharges are a major cause of introduced species and have been recently linked to dredging issues. In the next four years, SGEP will continue to serve as a leader at the state, regional and national levels to coordinate, facilitate, and implement applied research, management, and outreach on ANS issues. Specifically, SGEP will lead a Pacific Coast outreach program to help resolve ballast water management issues. The ballast water project is a coordinated effort which involves all the Pacific Coast Sea Grant Extension

programs, as well as ports, agencies, and industry and environmental groups. Additionally, SGEP will work with the aquaculture industry to reduce and manage ANS introductions, conduct public outreach and education on ANS issues and management, work with government and private partners to develop regional management programs for the Chinese mitten crab, and lead and coordinate national and regional intergovernmental groups, such as the National ANS Task Force and the Western Regional Panel on ANS.

Marine Protected Areas (MPAs) have been used widely around California and the world as a management tool. Properly designed MPAs have the potential to sustain populations of organisms and habitats that attract coastal and marine tourists, as well as support sport and commercial fisheries, but have been established in California with little coordination and research design. In the next four years, the SGEP will continue to help organize and participate in forums that discuss MPA issues among the wide range of those interested and potentially affected by MPAs, encourage and participate in applied research which helps California and the region understand and evaluate MPAs, and assist California with developing science-based approaches to MPAs.

Aquaculture

California's aquaculture industry produces over 50 species that collectively contribute $83 million to the state economy, and can contribute significantly towards fulfilling the national aquaculture policy objective of expanding U.S. domestic production from the present $900 million to $5 billion annually.

California's aquaculture industry produces over 50 species that collectively contribute $83 million to the state economy, and can contribute significantly towards fulfilling the national aquaculture policy objective of expanding U.S. domestic production from the present $900 million to $5 billion annually. SGEP will help achieve this goal by working to increase production of the state's diverse aquacultural products through support of integrated research and outreach efforts that address constraints in nutrition and production technology.

Nutrition and diets of cultured species are currently limiting aquaculture production. SGEP will encourage research on nutrition of striped bass, sturgeon, white sea bass, and other species to improve production and develop diets that result in improved effluent water quality through reductions in nutrient loading. Further improvements in water quality will be achieved through research

on recirculating filtration technology. The development and evaluation of artificial diets for cultured abalone will remove farmers' reliance on kelp that is limited during El Niño years. Coupled with continuing successful collaborations to manage and control the sabellid parasite, cultured abalone could also be used in recovery programs for the endangered white abalone and to enhance the depleted fisheries for red, pink, and green abalone. SGEP will help encourage the development of an artificial diet that would stabilize production, allow expansion of this industry, and reduce the environmental conflicts associated with harvesting of kelp beds.

Production technology currently limits the scale of aquaculture activities in California. In the next four years SGEP will assist researchers with ongoing efforts to develop genetically improved oyster broodstocks. To promote sustainability, SGEP will document the environmental benefits and risks of estuarine and offshore shellfish culture and work with the industry in developing codes of conduct for responsible aquaculture. SGEP staff will also continue working closely with the aquaculture industry as an integral link between researchers and commercial producers to help increase and diversify California aquaculture production.

Seafood Technology

Seafood safety, quality, and marketing are key statewide and national issues. Implementation of strict new federal safety regulations, increasing consumer demand for high-quality seafood, and the need to add value to a finite seafood supply guides SGEP's seafood technology program, which focuses on adaptive research and extension of technical information on seafood safety and quality.

Hazard Analysis and Critical Control Point (HACCP) seafood safety regulations were promulgated by the U.S. Food and Drug Administration. SGEP will concentrate on assisting the California seafood industry with implementation of these recent federal regulations. This includes conducting basic and "Encore" HACCP courses, training trainers, and conducting national "Sanitation Standard Operating Procedures" short courses. Short

courses will be a cooperative effort of SGEP, the California Department of Health Services and the U.S. Food and Drug Administration. In cooperation with these agencies, SGEP will produce a "Compendium of Seafood Processes, Hazards, and Controls."

Seafood research conducted by SGEP will focus on the development of histamine in albacore tuna, the microorganisms responsible for histamine development, methods to prevent histamine formation, and studies on the effectiveness of crab and shrimp cooking processes.

Seafood extension education conducted by SGEP will include a publication on direct marketing for commercial fishermen, produced with assistance and cooperation from the California Department of Fish and Game, California Department of Food and Agriculture, harbor-masters, and city and county administrators. SGEP will also expand its efforts to extend information using computer technology. The popular and widely respected SGEP seafood technology web site (60,000 hits/month) will be updated and enlarged to include additional seafood safety and quality information. SGEP will continue to manage a seafood technology Internet mailing list with about 850 subscribers from 48 countries.

Communications

Introduction

The Communications Office advises and assists CSGCP management and Extension personnel with communications planning and implementation. The office also frequently prepares material to satisfy information requests from the National Sea Grant Office and other Sea Grant programs. The Communications Office interprets, prepares and distributes Sea Grant publications to the program's user communities and fills numerous requests for information and publications from a variety of audiences throughout the year. Key audiences include: federal, state and local legislators, resource managers and administrators concerned with marine resource issues; industry people such as fishers and seafood processors; members of nongovernmental and conservation organizations concerned with marine resource issues; researchers, faculty and students; reporters and editors of mass media and electronic media; staff of other Sea Grant programs; recreational users of marine resources, and the general public.

The major functions of the Communications Office are (1) production of Sea Grant publications (educational, reference, and technical series); (2) public information activities; (3) dissemination of reprints and other technical publications produced by the program's researchers; (4) development of content for the CSGCP's web site; (5) high school outreach; and (6) miscellaneous program support activities (graphic displays for conferences, etc.).

The goals of the California Sea Grant College Communications office are:

• To educate key audiences and users about critical marine resource issues;

• To counsel and support the communications needs of program management and Extension, thereby contributing to Sea Grant's visibility and effectiveness; and

• To increase program recognition and support by informing key audiences and users about the activities and accomplishments of the state, regional, and national Sea Grant programs.

Communications Goals, Objectives and Plans

The goals of the CSGCP Communications Office are:

• To educate key audiences and users about critical marine resource issues;

• To counsel and support the communications needs of program management and Extension personnel, thereby contributing to Sea Grant's visibility and effectiveness; and

• To increase program recognition and support by informing key audiences and users about the activities and accomplishments of the state, regional, and national Sea Grant programs.

Short-Term Communications Goals

During the next four years, the CSGCP Communications Office will expand its focus to:

• Make increasing amounts of CSGCP information and print materials available on the program web site as text and photos. At the same time, the staff will set in place systems to routinely collect e-mail addresses from key audiences in order to communicate more quickly and inexpensively. Eventually, it is anticipated that web publication may partially or entirely replace printing of some CSGCP materials.

• Use current projects to develop ongoing narrative feature stories with photos on the web as an educational outreach tool for high school science students. It is anticipated that students and principal investigators will discuss questions posed by the students via the internet.

• Begin using video and audio clips on the CSGCP web site to enhance information about marine research as an educational outreach to the public.

• Hire freelance science writers on a project basis to develop materials to inform the general public about marine issues and Sea Grant projects.

The Communications staff will prioritize its activities to reflect the priorities identified by the CSGCP, NOAA Research, the National Sea Grant Office, the Sea Grant Association and the Resources Agency of the state of California. These include the Sea Grant National Strategic Investments and Theme Team topics.

The Communications staff will maintain and expand its interactions with the news media to increase public understanding and discussion of important marine and coastal issues. Specifically, the communications coordinator will begin attending local meetings of the San Diego Science Writers to elicit their individual interests in marine science topics.

Long-Term Communications Goals

The Communications Office has these major long-term goals:

(1) Inform a wide spectrum of audiences about the mission and activities of the state and national Sea Grant programs;

(2) Inform public, scientific, federal and state legislative, and other audiences about findings arising from Sea Grant-sponsored research and outreach projects;

(3) Educate a wide spectrum of audiences about state, national, and international marine-resource issues;

(4) Advise and support the communication needs of program management and Extension personnel;

(5) Systematize and increase follow-up efforts to report on program accomplishments as requested in the Program Assessment Team review by the National Sea Grant Office of September 1998;

(6) Increase the use of electronic technology to maximize communications resources and reach the widest audience;

(7) Provide information about marine education opportunities by updating and web publishing the "Directory of

Academic Marine Programs in California," last published in 1993 (Third Edition); and

(8) Expand CSGCP's educational outreach to high school students via the Internet.

Time Line

In fall, 1999, the CSGCP Communications Office will produce and distribute the CSGCP new Strategic Plan and Implementation Plan. The Communications Office will also produce a new Program Directory of research, outreach and communication projects to be funded for 2000–2001. The Directory will also include the proposals funded by the National Sea Grant Office through the National Strategic Investment call for proposals.

Production of the Program's Annual Report will begin at the end of each fiscal year in February and take approximately four months depending on other program priorities.

Production and distribution of research project results will be on an on-going basis, as will the writing and distribution of news releases, story ideas and public service announcements. Certain projects, such as administering the Isaacs Scholarship competition and the State and Knauss Fellowships, each have specific time lines based on the dates of the competitions. It is anticipated that the proceedings from the Sea Grant Extension Program workshops on nearshore fisheries and sea urchins, held in June 1999, will be produced during the year 2000 in cooperation with the Associate Director for Extension, Chris Dewees.

Dewees also anticipates funding from the California Department of Fish and Game to prepare an updated version of the book, "California's Living Marine Resources and Their Utilization" that was last published in 1992. The Communications Office will assist with that project.

The production time line of CSGCP publications, especially books and proceedings, is dependent upon a number of factors out of the office's control, such as the timing of the author in getting the material to the

Communications Office, the availability and speed of scientific editing services, and current program priorities.

Anticipated Outcomes

Current trends show increasing numbers of people using electronic media, personal computers, e-mail and the Internet at home and at work in the conduct of their professional responsibilities and personal interests. The CSGCP Communications Office will increase its use of electronic technology to make information available in a more timely manner to audiences and to reduce the cost of printing and mailing literature. The resulting savings will be applied to developing other communications methods, such as audio and video production, that can reach larger and more diverse audiences with information about Sea Grant accomplishments.

The Communications staff will use mail and e-mail surveys, informal information gathering during telephone calls with key audience members, and seek input from its advisory committee to evaluate communications results and make improvements and additions to its strategic and implementation plans. As each communication is initiated, the Communications staff will provide an easy-to-use response mechanism for information users to provide feedback.

The Communications staff will change the format and distribution of research completion reports, formerly called the *Biennial Report*. The new format will feature individual reports that are organized topically. This will allow the more timely distribution of information to marine resource managers and other scientists.

The Communications staff will track expenses and compare those with previous years to identify areas of change. This information will be analyzed at the end of each fiscal year and used to modify and plan future communications.

Management and Planning

Introduction

The mandate of the California Sea Grant College Program (CSGCP) is to encourage the sustainable use and conservation of the marine resources of the state of California, by identifying important problems and opportunities, by supporting solution-oriented research that addresses these issues, and by communicating the results to the community. To fulfill this mandate, CSGCP management must identify the different constituent communities and provide good communication channels between these groups. An important function of the CSGCP management team is to ensure the existence of these channels, to facilitate the communication between the constituents of the Sea Grant community, and to provide an efficient and fair way to select the most effective research in support of the marine community. CSGCP management also keeps the National Sea Grant Office informed of the activities of the CSGCP, and maintains close communication with other Sea Grant programs and the national and international marine communities.

Reportage

The management of the CSGCP reports to the Vice Provost for Research of the University of California for programmatic purposes and to the Director of the Scripps Institution of Oceanography, where the CS-

GCP office is located, for administrative purposes. The California Sea Grant Advisory Board, which represents the marine community of the state of California, advises the President of the University of California and the Director of the CSGCP on the research, education and outreach activities of the program.The Sea Grant Committee (SGC), constituted by a rotating body of eminent marine scientists, is the body charged with deciding which proposals to support. The state of California interacts with the CSGCP through the Resources Agency Sea Grant Advisory Panel (RASGAP). RASGAP prioritizes the CSGCP research in terms of the needs of the Agency. The Marine Resources Committee (MRC) represents industry, the state and other constituents. The role of the MRC is to identify needs, develop problem statements, and communicate research priorities.

The commitment of resources to research, education and outreach is an investment process.

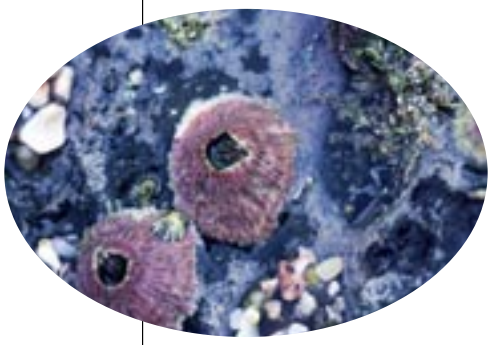
Decisions

The process by which research proposals are selected for support provides a good example of how CSGCP management integrates the various elements of the community to achieve the goals of the program. Relevant research issues are continually identified by the research community and by the Sea Grant Extension Program (SGEP), whose advisors remain in frequent communication with California's marine community. RASGAP provides CSGCP with an annually updated list of research areas of importance to California. These areas, along with other issues identified by the SGEP and issues suggested directly to the program by the marine community, are considered by program management for inclusion in the call for research proposals. When the call is issued, the CSGCP will conduct meetings to articulate the various needs expressed by the marine community. The research community responds to this call with preliminary proposals, some of which are focused on specific issues and others which address fundamental issues in the marine sciences. The MRC and the SGC review the preliminary proposals and request formal proposals in areas of interest. These proposals are sent out for review. The SGC meets after the reviews have been returned and ranks all the proposals according to their scientific merit. In this process, the role of the Sea Grant management team is to ensure that there is effective communication between the SGEP, the MRC and the SGC, and that the review pro-

cess is both fair and transparent. The management team is also responsible for communicating the results of the decisions reached by the SGC in a rapid and constructive way.

The commitment of resources to research, education and outreach is an investment process. In analogy with financial investments, CSGCP believes in the importance of maintaining a diversified portfolio of investments, and seeks to diversify in four directions. One dimension of diversification is to maintain consistent support for the six traditional research areas. As research needs vary, there is always a tendency for one area to come forward, and CSGCP must encourage that growth while at the same time ensuring that the other areas continue to develop at a sustainable rate. A second dimension in which the program seeks to maintain diversity concerns the balance between fundamental and application-oriented research. While the CSGCP is solution-oriented, experience demonstrates that support for fundamental research can lead to the development of entirely new areas, such as was the case for Marine Pharmaceuticals. Another dimension in which the program seeks diversity is the length of commitment to any given research endeavor. CSGCP must always retain the capability of funding new and exciting research. At the same time, experience shows that in order to develop ideas to the point of commercial viability, some projects need to be supported for periods of up to 10 years. Finally the program needs to maintain a balance between traditional and modern scientific approaches: for example, in Biology, there is a need to support research in Molecular Biology while also supporting research in Natural History and Systematics.

The program needs to maintain a balance between traditional and modern scientific approaches...



Community Involvement

The success of CSGCP depends on the extent to which the constituent communities participate in the program. For example, while the research community is anxious to participate in formulating research proposals and carrying out the research, that community is also responsible for identifying, with the SGEP and California's marine community, the research issues which are likely to benefit the state. The research community is also responsible for deciding which research proposals should be sup-

ported. That community, therefore, bears the responsibility for providing written reviews of proposals and staffing the SGC, the decision-making body.

Planning

The National Sea Grant Office, the state of California, and the grantee institutions provide a total of $7 million each year to support the CSGCP. In order to ensure the effective investment of this resource, there has to be a plan that provides a direction for the program. As required by the National Sea Grant Office, the CSGCP management maintains two plans, a Strategic Plan, which forms the content of this document, and an Implementation Plan, which describes how the goals set forth in the Strategic Plan will be achieved. Together these documents articulate a medium term direction for CSGCP. While the plans are formally reviewed every five years, they are regularly updated by the Sea Grant Committee.

Sea Grant
California

Gary P. Moberg (1941–1999)

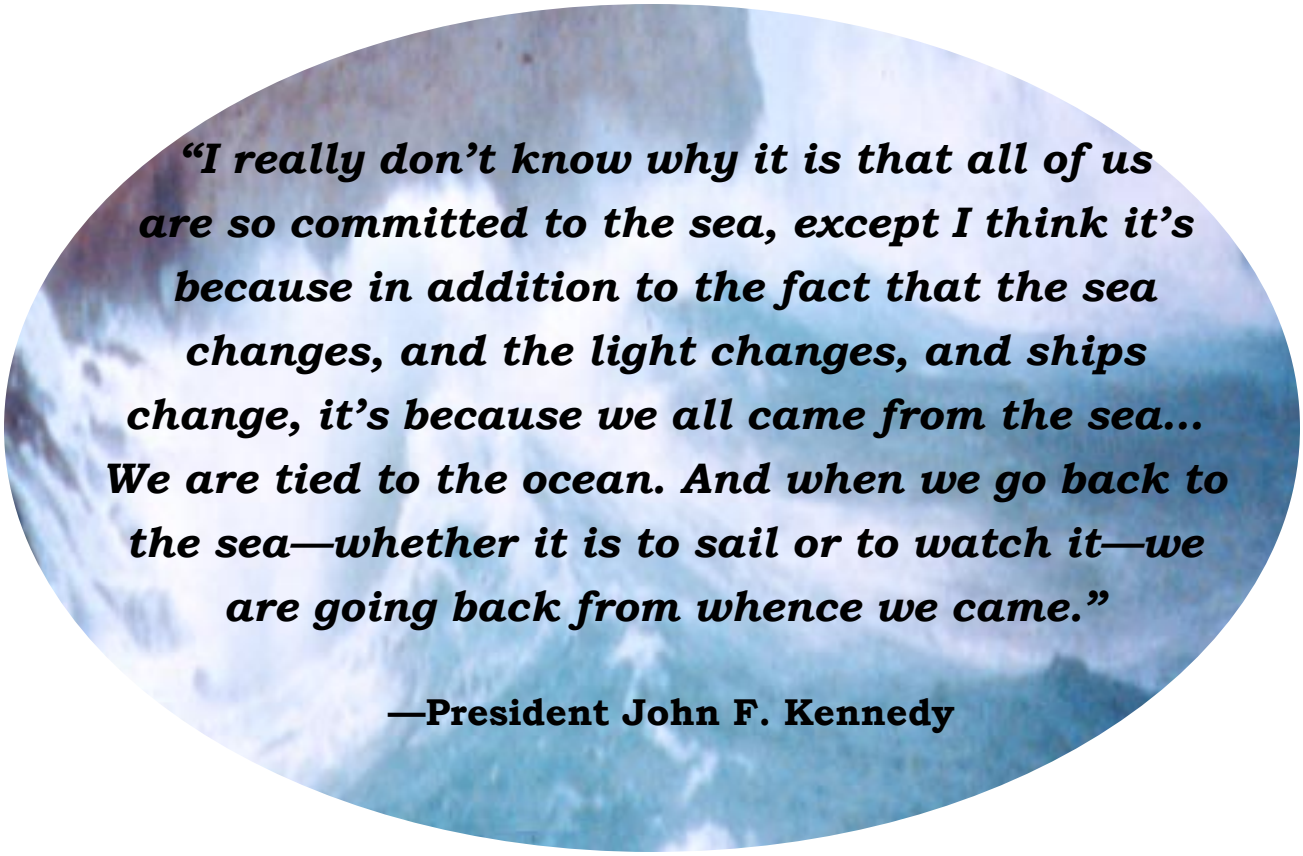
Gary P. Moberg joined the faculty of the Department of Animal Science, UC Davis in 1970. He served with distinction as an Associate Dean of the Division of Animal Biology in the College of Agricultural and Environmental Sciences from 1993 until the spring of 1999 when he left that post to become Director of the Center for Aquatic Biology and Aquaculture at UC Davis. Dr. Moberg was internationally recognized as an expert in animal stress and welfare; research in his laboratory focused on such topics as the endocrine control of reproduction in white sturgeon, the biological response of finfish to stress, and the impact of environmental stress on shellfish.

His long and valued association with the California Sea Grant College Program began in 1988 with the funding of his project, "Endocrine Stimulation and Regulation of Sturgeon Female Maturation." This association continued with a series of research projects dealing with hormonal control of reproduction and gamete formation in cultured sturgeon until his sudden and untimely death last August. Most recently, he served on the Aquaculture Committee for California Sea Grant in the development of a strategic plan for future aquaculture research.

Dr. Moberg's wisdom, dedication, accomplishments, and contributions will be sorely missed by all at California Sea Grant and his colleagues throughout the scientific community. Our deepest sympathies go out to his family.

Clinton D. Winant
Director

Sea Grant
California



"I really don't know why it is that all of us are so committed to the sea, except I think it's because in addition to the fact that the sea changes, and the light changes, and ships change, it's because we all came from the sea... We are tied to the ocean. And when we go back to the sea—whether it is to sail or to watch it—we are going back from whence we came."

—President John F. Kennedy

California Sea Grant College Program
9500 Gilman Drive
La Jolla, CA 92093-0232
(858) 534-4440
www-csgc.ucsd.edu