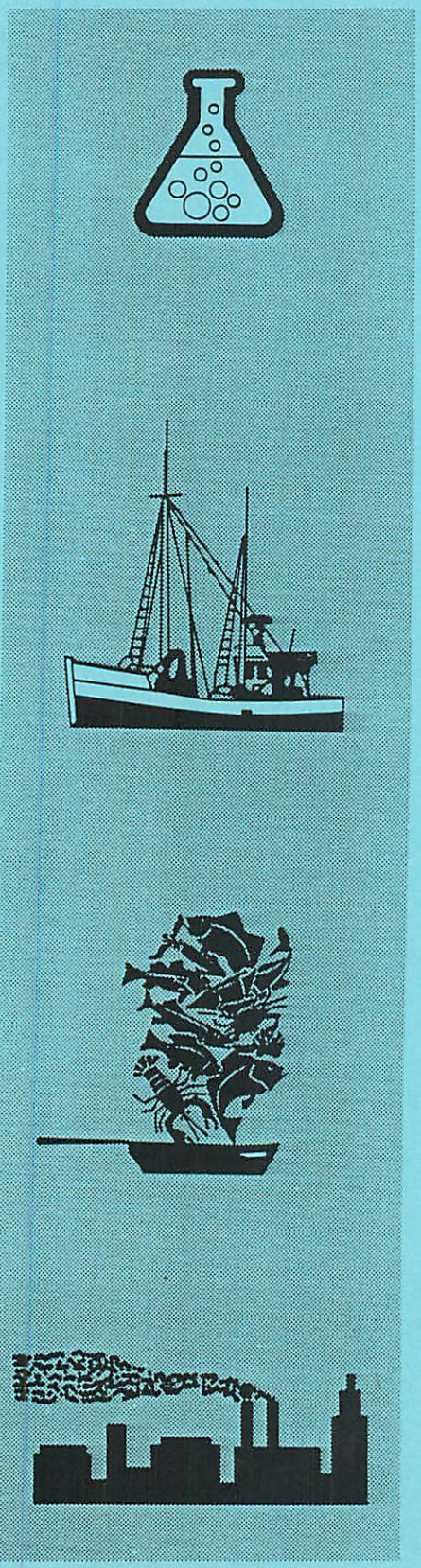

The National Sea Grant College Program Annual Report FY 89

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

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Introduction

The staff of the National Sea Grant College Program has prepared annually, since 1978, a series of reports which include for each program area a discussion on the status of the program, descriptions of major achievements and opportunities, problem areas or weaknesses and a listing of projects receiving funding in the last fiscal year. This volume constitutes the National Sea Grant College Program 1989 Annual Report.

The subjects of the individual reports overlap somewhat--some projects listed under one subject, such as social science may also appear under another such as economics or law. Thus the numbers of projects and monies spent for activities in each subject give a total that exceeds the expenditures in fiscal year 1989 of $36,108,137 in Federal Sea Grant funds and $28,223,388 in matching funds. These funds supported 654 projects at approximately 130 academic institutions. All but a few of the projects were components of one of the 29 state or regional Sea Grant programs whose directors are listed below.

The Sea Grant Directors shape the local and regional programs to exploit the strengths of their individual participating institutions, to focus on issues in advisory service and education that are of regional importance and often of national significance, and to comply with priorities set for research areas, education, and service by the National Sea Grant Office. Decentralized day-to-day management results in effective cooperation among federal and state or local governments and academic institutions in marine affairs. The research programs, while normally dealing with local, state, or regional species, environments, and processes produce results of generic importance in advancing science, solving problems and exploiting opportunities in wise use and development of marine and coastal resources. Peer review is the basis of the process for selecting projects and for reconciling proposals with budgets. Successful proposals have an applied bent even if application relates to the very long term. The melding of research, education, and advisory service in a single program makes planning for technology transfer more nearly routine. Researcher, educators, and advisory personnel are encourage to work across institutional and program lines. Such cooperation and collaboration have proven successful.

Summaries of Reports by Technical Specialists

Environmental Studies

The FY 1989 Sea Grant Environmental Studies Program included 168 projects conducted at 29 Sea Grant institutions. Over $6.3 million in federal support and $4.0 million in matching funds were provided for these efforts. This support represents a 10 percent increase in total funding for and an 2 percent increase in the number of Sea Grant environmental projects, compared to FY 1988.

Sea Grant environmental studies are grouped into seven areas of emphasis: environmental characterization, nutrient and carbon dynamics, habitat studies, particulates and toxic substances, human health, environmental management, and special projects. Of these, nutrient and carbon dynamics was the largest in FY 1989, representing 27 percent of total funds. Research relating to particulates and toxic substances, and environmental management were the next largest categories, accounting for approximately 22 and 20 percent of funds awarded respectively.

Sea Grant environmental research for FY 1988 spanned a variety of habitats, from freshwater creeks draining into watersheds of the Great Lakes to benthic oil-seep communities of the northern Gulf of Mexico continental slope. Estuarine studies were carried out in a variety of coastal areas, including the Great Lakes, and on embayments of all sizes, including Boston Harbor/ Massachusetts Bay, Delaware and Chesapeake Bays, Pamlico-Albemarle Sound, Mississippi Sound, and the Mississippi-Atchafalaya River complex.

Marine Economics

Sea Grant economists, both through research and extension, are providing a more complete understanding of the organization, conduct, and performance of the marine sector of the economy. By focusing on the efficient use of America's marine resources, Sea Grant is helping to improve the competitiveness of the nation's marine economy, that part of the economy dependent upon ocean and Great Lakes resources.

The Fiscal Year 1989 marine economics program includes 36 projects, with total funding of $1.7 million, of which federal funding amounted to $826 thousand. Eighteen Sea Grant institutions currently participate in the marine economics research program, and at least 12 institutions have an economics specialist on their Marine Advisory Service staff.

Marine Recreation and Tourism

The National Sea Grant College program in Marine Recreation and Tourism responds to the legislative mandate to promote the efficient use and development of marine resources. Coastal recreation is very important to the economic base of coastal communities and the nation in general. It is also a major catalyst in making recreation and tourism one of the fastest growing industries in the United States.

Sea Grant conducts both a research and extension program in marine and coastal recreation. The research program is interdisciplinary involving economists, legal scholars, social scientists, engineers, and specialists from many of the natural sciences. Technology transfer and education is emphasized through the network of marine advisory and extension programs nationwide.

Sea Grant's program in Recreation and Tourism in Fiscal Year 1989 consisted of 22 research projects. Funding for the Recreation and Tourism research amounted to $489 thousand, with another $527 thousand contributed in matching funds. This is approximately the same funding level as in Fiscal Year 1989. In addition, most Sea Grant universities conduct a recreation advisory effort to provide educational and technical assistance to the industry.

Ocean Engineering

Competitiveness is directly linked to improved productivity, which in turn is dependent on improved technology. It is the goal of the ocean engineering program to provide the technology needed by the marine sector of our economy.

In FY 89, 85 projects were supported in ocean engineering at a Federal funding level of $3,884,780 with an additional $2,398,180 in non-Federal match. Projects are grouped in 18 subprogram categories in order to better indicate the problem orientation of the various studies. Several examples of effective focusing of activities are given, including fisheries engineering and underwater work vehicles. Program leadership continues to be shown by the Massachusetts Institute of Technology Sea Grant College Program, which had 18 projects at a Federal funding level of $1,268,870.

Marine and Coastal Transportation Systems

This analysis of the National Sea Grant College Program in Marine and Coastal Transportation Systems is based on the listing of current projects as of October 1, 1989. There has been no attempt to avoid multiple listing with other reports being prepared at this time, and the choice of including or excluding projects represents the subjective judgment of the author. A total of three projects is listed, representing the efforts of three institutions. The total Federal funding level is $68,784 and the non-Federal match is $32,196.

Aquaculture

The funding level for support of aquaculture projects during FY- 89 declined slightly over preceding years. Sea Grant supported 94 projects at a level of $3,640,000 with $2,861,000 in matching funds for a total of $6,501,000. This represents 9 less projects than last year and $460,000 less in Federal funding. This reduction is probably within the normal variation to be expected in the dynamics of the grant process. No deliberate reductions have been made.

There was a continuing trend to support more projects in the genetics/biotechnology and physiology/endocrinology subject areas. Nutrition and disease/parasites projects remained about the same.

Almost all categories of projects received less funding this year but the ratio of funding remained the same in terms of program emphasis. Species receiving the greatest emphasis were salmon, rainbow trout, hybrid striped bass, red drum, marine shrimp, hard clams, oysters and algae. Marine shrimp projects, however, declined from last years total. The high number of oyster projects centered around the need for disease control in this group. We did see a clearer focus on projects dealing with marine viruses as these are becoming more of a problem for several cultured species.

Hawaii, Texas, Washington, and California had the largest aquaculture programs in terms of dollars and projects. Texas continued it's shift away from more applied research to more basic research in order to stay ahead of the developing shrimp industry. Hawaii continued it's program to assist the Pacific Islands with their aquacultural development plans. California maintained it's emphasis in more basic research and Washington focused on salmon and oyster related projects.

The National Office participated in the Joint Subcommittee on Aquaculture activities and contributed time to several information service project. The UJNR Aquaculture Panel (Japan–U.S. technical exchange) meetings were held in the U.S. this year and the National Office Aquaculture Director served as Program Chairman for the meeting. The National Office also participated in two workshops on rejuvenating the oyster industry on the East Coast, and one workshop on the use of Artificial Intelligence in Aquaculture. The Aquaculture Program Director also attended meetings for the creation of the Pacific Aquaculture Association and Pacific Island Network. A new project funded by the Dept. of Interior, through the University of Puerto Rico, was developed to create an underwater park in the Virgin Islands with an aquaculture, fishery enhancement theme.

Recent significant research advances include the further refinement of recombinant DNA vaccines for the prevention of virus diseases in fish; continued development of techniques for inserting fish growth hormone genes into bacteria and then extracting the hormone for administering to fish to increase growth; successful insertion of genes for growth into the genome of a commercially important fish; successful cryopreservation of shrimp gametes (sperm only) and demonstration of increased commercial production for marine fish, shrimp and mollusks in ponds provided with increased aeration; demonstrated improvements of growth rate in hard clams due to selective breeding procedures; demonstration of resistance to MSX disease in oysters from a selective breeding program, and improved diagnostic procedures for determining the presence of several shrimp viruses. An improved water filter (fluidized bed) was introduced to soft shell crab and crayfish recirculating systems that allows a forty–fold increase in holding capacity. Many other results were documented in publications published in peer reviewed journals and were submitted to the Sea Grant Depository in Rhode Island.

The next two decades will see a dramatic change in the way we obtain our seafood products. An increasing proportion of our seafood supply will come from aquacultural production, especially for those products of high market value. Today many underdeveloped countries in tropical areas are gearing up for aquaculture production, primarily through shrimp culture. In 1988 approximately 22% of the shrimp placed on world markets was produced on shrimp farms. This production was valued at $2.5 billion at wholesale prices. In 1988 the total hectares devoted to shrimp aquaculture was estimated at 765,500 and the United States only had 500 hectares in production (World Shrimp Farming, 1988).

Fisheries

The Fisheries Research Program focuses on a large number of topics falling within the major categories of fisheries biology and management, and fishing and sampling gear technology. This year the program consists of 142 project funded at $4.97M in Federal funds, $3.84M in state matching funds, and $0.64M in pass through funds. All programs support at least one project in fisheries research, and all support advisory activities associated with fisheries. Only 21% of the projects funded comply with the National Sea Grant Office Annual Guidance, thus resulting in an evaluation of the guidance and its revision. Research associated with recruitment fisheries oceanography continues to receive substantial attention from the research community. This topic was funded at $1.05M this year.

Research planning on the topic of recruitment fisheries oceanography continued this year with the completion of the NOAA program development plan and the drafting of a technical development plan for a South Atlantic Bight recruitment study. A number of opportunities in related research sponsored by NOAA and other agencies are identified. Additional research opportunities are identified.

Following practice begun three years ago the report includes abstracts of a number of publications submitted to the Sea Grant Depository. These address the research priorities Developing New Techniques for Assessment, Recruitment and Fisheries Oceanography, Habitat Fish Productivity Interactions, Integrating Biological and Economic Information into Management Strategies and Plans, an Promising Areas of Research.

Marine Biotechnology

Research in support of marine biotechnology continued to be an important component of the National Sea Grant College Program in fiscal year 1989. The research, which is largely fundamental in nature, is providing the scientific basis for using marine organisms or their components to provide goods and services. During the last year $2,325,000 in federal funds and $1,793,000 in matching funds supported 59 projects in four categories including biochemistry and pharmacology, molecular biology, biochemical engineering, microbiology and phycology. Notable advances were described in more than 90 recent papers. For example, procedures for genetic engineering of fish were demonstrated, recombinant vaccines for viral diseases of fish were successfully tested, a potent mammalian immunohormone was isolated for the first time from a plant, and a novel bioreactor for studying high pressure–high temperature relationships in bacterial growth and productivity was designed, constructed, and used to study biochemical processes of a methanogenic bacterium from a deep–sea vent.

Seafood Science and Technology

The United States has enormous fisheries within its zone of extended jurisdiction along its marine coasts, yet a large proportion of the seafood sold domestically is imported. Fuller development of fisheries by U.S. fishing fleets and processors depends on stronger competition in international markets. Enhancement of their competitive position depends in part on enhancing the quality of seafood, improving the technology and efficiency of processing and handling seafood, including dealing satisfactorily with organic wastes, developing acceptable products from non–

traditional species and for non-traditional markets, and assuring safe products of high quality. The 49 Sea Grant projects dealing directly or indirectly with seafood technology in fiscal year 1989 focused on these issues and helped prepare students for careers in industry and academe through advanced training. Federal funding in the amount of $1,662,000 and $1,202,000 in matching funds supported these projects. This report discusses some of the recent issues and Sea Grant advances in this field. For example, the recent rapid growth of the increasingly important soft shell crawfish industry in domestic and foreign markets results from research on intensive culture systems in the early 1980s at Louisiana State University.

Communications

The Sea Grant communications network experienced a period of transition accompanied by a maturation of regional efforts during Fiscal Year 1989. As it continued to fulfill Sea Grant's mandate for the "broad and prompt dissemination of knowledge and techniques," the network for the first time saw one of its own members become an official representative to the Council of Sea Grant Directors and proudly unveiled its first-ever regional magazine *Nor'easter*, published by the Northeast Sea Grant programs.

For the National Office, the transition to a new Administration presented a chance to introduce Sea Grant to new officials not only through the printed word but also through a visual medium. With the creative assistance of the communications programs in Texas, North Carolina and Georgia, the documents *Oceans of Opportunity* and *The National Sea Grant College Program Economic Impact--1987* as well as a new national insignia were produced, thus helping to bring further visibility to Sea Grant.

So that the results of Sea Grant research, education, and advisory/extension work flow into the hands of users in both the public and private sectors, NOAA Sea Grant supported communications projects at all 29 Sea Grant programs during Fiscal Year 1989. Federal funds of $3,141,481 were matched by $2,012,632 in state funds for a total of $5,154,113. In terms of overall program funding, the amount for communications comprised 7.5 percent of the total.

Education and Training

This year's report on the education and training program of the National Sea Grant College Program follows the past year's format in describing projects in the areas of Course Development and Student Projects; Research Assistantships; Pre-College Education and Teacher Training; Non-Formal Education; Technical and Vocational Education; Sea Grant Fellowship Program; Sea Grant Fellows Program; International, and other. It also describes the thrusts that are being developed nationally by NOAA and National Science Foundation.

Marine Advisory Extension Services Program

Core funding for the Sea Grant Marine Advisory Services Program has been maintained at relatively stable levels during the last 6 years; however individual programs have continued to mature and even expand through cooperative programming and leveraging resources in recent years. A national meeting of Program Leaders was held in 1989 and was an effective tool for promoting interaction and planning for the increasing opportunities and challenges of the future. The entire network is becoming an integrated program in its own right; no longer is it just the local agent working on the docks with fisherman or in a fish plant with the local processor. Progressive long term planning on the regional and national level has resulted in ongoing program development for educational programming and information transfer on such issues as global climate change, vessel safety, oil spill prevention and preparedness, natural hazard preparedness, water quality, economic development of the marine community and resource conflict resolution. MAS is also beginning to focus on transferring information as appropriate from NOAA/OAR laboratories to managers and resource agency decision-makers.

Fishing Vessel Safety Training Program - 1989 Update

Commercial fishing is one of the most dangerous industries in the United States. On average, 84 fishermen and 250 vessels are lost each year; and the number of injuries and disabilities, and the damage to vessels probably are just as alarming. Each year, the United States Coast Guard responds to approximately 3000 offshore search and rescue cases and investigates 1100 marine casualties involving commercial fishing vessels. Commercial fishing is the only major marine commercial industry for which inspection, licensing, operation, and equipment regulations, other than basic safety equipment, are essentially non-existent.

The United States approach to the fishing vessel safety problem has been to promote the acceptance and use of voluntary safety standards by the industry. In 1989, Sea Grant supported the voluntary safety standards program by making available a variety of multi-media training materials; providing sea survival and vessel safety instruction to fishermen; and providing safety and survival training curricula, materials, and courses for a growing cadre of providers of such instruction. Also, Sea Grant and the National Council of Fishing Vessel Safety and Insurance examined the feasibility of establishing a national network of fishing vessel safety programs.

During the last two years, a much higher level of vessel safety and sea survival programming has been made possible by the Saltonstall-Kennedy (S-K) financial assistance program. Institutions having Sea Grant ties received S-K awards totalling approximately one-half million dollars for establishing or continuing fishing vessel safety programs. Unfortunately, S-K funding priorities no longer include fishing vessel safety education and training programs. Without this funding, the level of effort in response to commercial fishing vessel safety issues may decline sharply, and progress to establish a national network of fishing vessel safety programs will slow considerably.

Marine Policy and Social Sciences

Sea Grant's program in Marine Policy and Social Science is based on the recognition that most resource management issues have sociocultural dimensions and policy implications. Sea Grant Research provides information to help manage marine resources more wisely in concert with local and national concerns, knowledge, and planning capabilities. Marine Policy and Social Sciences draw on many disciplines for methods and theories. In FY 89, total Sea Grant funding for Marine Policy and Social Science was about $2.16 million, slightly less than FY 88. Relative proportions of research in each of the topical areas has shifted slightly over the last two years, with studies in the area of commercial fishing slipping to 26% of the social science and marine policy funding, and policy and resources management studies increasing to about 60% of the Sea Grant funding (see Table II).

Marine policy research accounts for about sixty percent of FY 89 funding. It includes studies on options for managing coastal growth, estuarine governance and planning, identification of areas vulnerable to sea level rise and policy alternatives, and projects on Great Lakes water policies (see Table I). The social sciences emphasize research on aspects of commercial fishing, ranging from sociocultural effects of fishery management regimes, to studies of risk communication regarding contaminated fish. The more traditionally defined social sciences account for about 40% of the total funding in the Marine Policy and Social Sciences Program. Underrepresented are social and political aspects of aquaculture development, biotechnology, and coastal growth; coastal archaeology; and micro and macro structural changes in the fishing industry.

Ocean and Coastal Law

Total for legal programs and projects in FY 89 decreased significantly from the FY 88 level of $915K and the FY 87 level of $1.1M. Federal funding amounted to $255K compared to $317K in FY 88 and $481K in FY 87; matching funds were $344K versus $598K in FY 88 and $624K in FY 87. However, the decrease in matching funds was attributable to a sizeable reduction in the large overmatch provided by the University of Hawaii's Law of the Sea Institute in FY 88, which accounted for almost half the matching funds that year.

Coastal and Ocean Processes

Coastal and Ocean Processes research and development are conducted in the following five broad areas, with the number of FY89 projects and the total funds expended in each area parenthesized: sediment transport (7/$331,464), tidal inlets and estuaries (7/$626,406), coastal oceanography (10/$656,775), coastal protection (12/$787,473), and technology development (5/$294,975). During FY89 about $1,265,000 in Federal funds, matched by more than $1,100,000 from non-Federal sources, supported research in coastal oceanographic processes, and the resulting form, manner and rate of change of the coastal and seafloor.

Much of America's shoreline is eroding. Louisiana is losing coastal wetlands at a rate of tens of square miles per year, Great Lake's shorelines experience severe erosion during periodically high lake levels, and open ocean and bay coasts in every coastal state experience erosion at varying rates. Although the most dramatic erosion

occurs when hurricanes and "northeasters" strike the Gulf and Atlantic coasts, and intense storms move inland over the Pacific coast, day-to-day wave and current processes also contribute significantly to erosion. However, a capability to provide solutions to this problem is limited by our lack of knowledge and understanding of the physical forces and interactions that produce these changes. An added complication is that if sea levels rise, as many scientists concerned with global climate change believe, increased erosion and other potentially deleterious effects will result. Over half of the Sea Grant Coastal and Ocean Processes program, therefore, is directed toward enhancing our understanding of the forces that impinge on coastlines and the resulting sediment movement. In addition, some research into improved coastal protection structures is being conducted.

Marine Geological Resource

Research related to marine geological resources is supported by six institutions involving 22 projects. Topics include improving our understanding of the formation of heavy mineral deposits, pursuing studies related to evaluating potential mining of cobalt-enriched manganese crusts on Hawaiian seamounts, and evaluating the economic and political implications of various mineral resources within the EEZ.

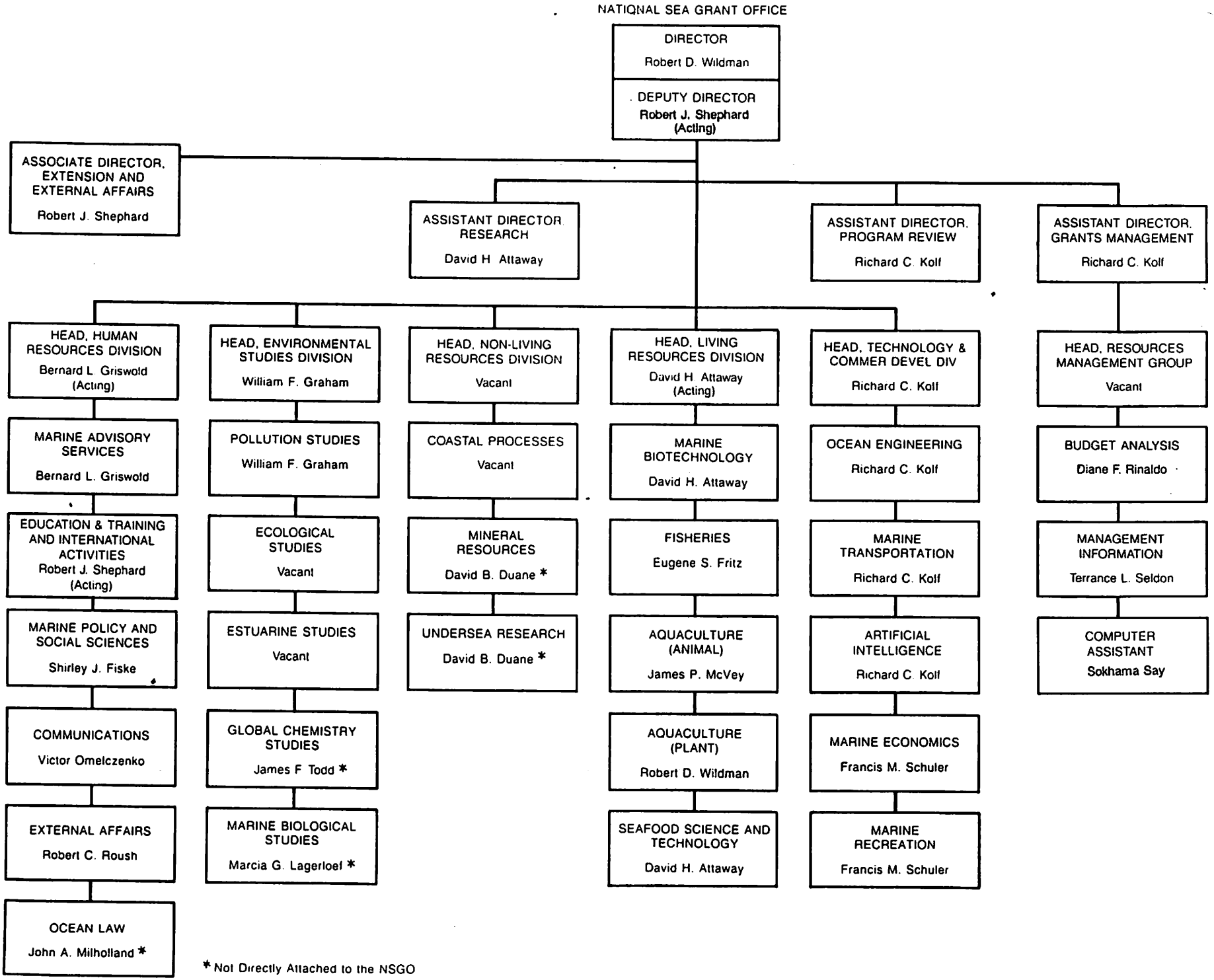
Significant developments resulting from recent Sea Grant research include addressing the environmental considerations related to the potential mining of cobalt-enriched manganese crusts on the Hawaiian seamounts. Through these studies, baseline information will be gathered of the geological setting, physical oceanography, chemistry, and water quality to assess any mining impact on the environment. The University of Hawaii's follow-on program on the geology, geochemistry, and economies of crust deposits is major, comprehensive, and strongly supported by the state.

The polymetallic sulfide deposits found in conjunction with ocean spreading centers is being addressed through Sea Grant supported research. These studies include determining the long-term behavior of the vent systems, and the technology for sampling which will aid economic determination of the significance of these deposits.

Diving Physiology and Technical Development

To ensure that NOAA remains in the forefront of diving research providing scientists with state-of-the-art undersea capabilities and ensuring maximum safety, an emphasis within Sea Grant must be placed on new diving related research, both of a fundamental and applied nature.

Six research projects addressing different aspects of diving were conducted FY '89 by Sea Grant institutions using Federal funds which totalled $431,238. In addition, the supporting organizations provided more than $132K in matching funds.



* Not Directly Attached to the NSGO

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* Sea Grant Colleges (total 26)
(ME/NH=1)
** Institute

Division of Environmental Studies

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Environmental Studies

Summary

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Introduction

Environmental studies conducted under the aegis of the National Sea Grant College Program during Fiscal Year (FY) 1989 included 168 investigations undertaken at 29 Sea Grant institutions. The overall objectives of these studies were: (1) to describe and understand more fully the functioning of the nation's marine, estuarine, and Great Lakes ecosystems, (2) to gain greater awareness of the implications of human activities to the well-being and future use of these environments, and (3) to apply improved ecosystem understanding to management of the nation's coastal and oceanic resources. The total cost of the Sea Grant environmental studies program for FY 1989 was $10,430,327. Of this, $6,334,372 was furnished by federal sources. Matching funds of $4,035,955 were provided by participating Sea Grant institutions.

A significant fraction of Sea Grant's environmental investigations relate to estuaries. In FY 1988, such studies were undertaken at 24 programs in the Sea Grant system. This level of effort reflects the nationwide interest in estuarine and coastal ecosystems. Of special concern are conflicts among potential uses of estuarine environments and the disruption or irreparable alteration of estuarine habitats as a result of human activities.

Environmental Studies Division research meshes closely with that of other divisions within Sea Grant. Greatest commonality occurs with fisheries-related studies conducted under the auspices of the Living Resources Division. For the purpose of this report, fisheries research is differentiated from environmental studies because the latter focuses on community- and ecosystem-level concerns, while the former focuses on the biology of economically important species for the purpose of enhancing exploitation. An analogous standard has been applied to potentially overlapping Sea Grant studies in physical, chemical, and geological oceanography/coastal processes.

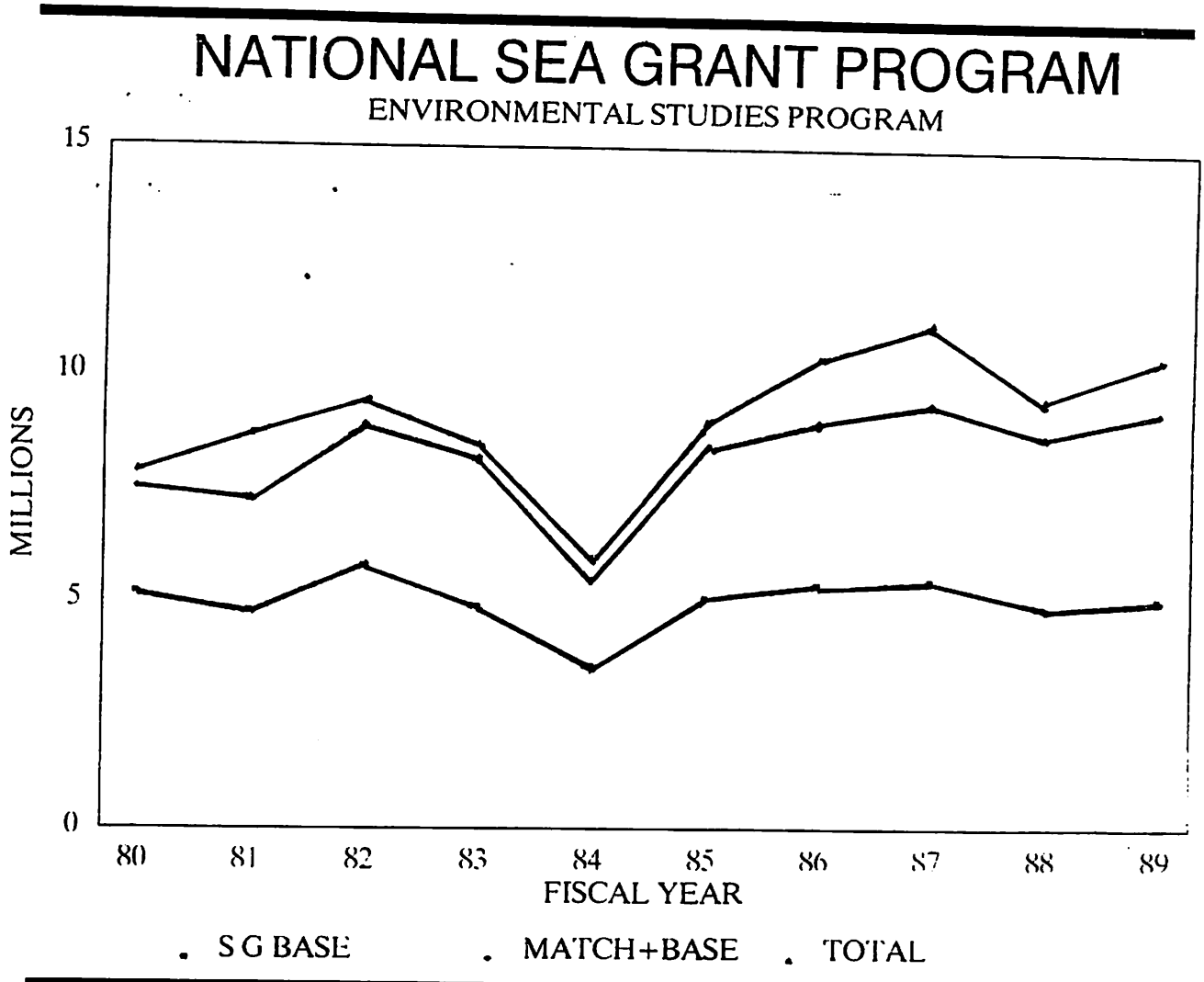

Figure 1. History of Sea Grant Environmental Studies Funding

Environmental Studies Program

Characteristics and Trends

Fiscal Year 1989 saw a modest increase in funding for environmental projects over FY 1988. Funding in 1988 had experienced a decline which departed from the steady growth experienced by Sea Grant environmental activities between 1984 and 1987 (Figure 1/Table 1). In 1989, the number of projects in the program increased modestly from 164 to 168.

After suffering a sharp decline in 1988, pass-through funding for environmental research increased modestly in 1989. From a high in FY 1987 of 31 projects valued at over $ 1.8 million, pass-through activity for environmental studies dropped in FY 1988 to 18 projects supported at approximately $785,000 (Table 1). In 1989, number of pass-through projects increased to 25 with a total funding of $1,240,0085. While it is difficult to predict the future levels of pass-through activity, $1 to $1.5 million annually appears to be a reasonable estimate. Strong cooperatively-funded activities exist with several elements of NOAA, including the National Undersea Research Program (NURP), the Estuarine Programs Office (EPO), and the National Ocean Service (NOS). FY 1989 extramural pass-through funds for environmental research were received from the U.S. Army Corps of Engineers, the Environmental Protection Agency, and the U.S. Navy.

TABLE I

FUNDING FOR SEA GRANT ENVIRONMENTAL STUDIES

Fiscal Total	No. of Project	Funding (x1,000) Sea Grant	Match	Passthru	Total	Average Funding/Grant (x1,000) Federal*	Match	
80	147	$5,189.7	$2,354.9	$ 365.7	$ 7,910.3	$ 37.8	$16.0	$53.8
81	190	4,752.5	2,541.3	1,396.0	8,689.8	32.4	13.4	45.7
82	182	5,756.2	3,183.5	466.6	9,406.3	34.5	17.5	51.7
83	158	4,936.3	3,228.5	360.2	8,525.0	33.5	20.4	54.0
84	109	3,576.4	1,908.5	517.8	6,002.7	37.6	17.5	55.1
85	176	5,062.3	3,346.3	630.3	9,038.9	32.3	19.0	51.4
86	197	5,375.1	3,567.9	1,502.9	10,445.9	34.9	18.1	53.0
87	184	5,522.4	3,876.0	1,837.5	11,235.8	40.0	21.1	61.1
88	164	4,862.0	3,806.8	785.9	9,455.7	34.4	23.2	57.7
89	168	5,094.3	4,036.0	1,240.0	10,370.3	37.7	24.0	61.7

*Sea Grant + Passthrough

Previous and present pass-through activities reflect the relevance of the Sea Grant environmental program and the willingness of Sea Grant scientists to participate in cooperative undertakings. As is the case with all Sea Grant research, pass-through efforts must stand the test of peer review and must fit within the research framework established by individual Sea Grant programs. Pass-through awards provide Sea Grant institutions with a means to extend the scope of on-going environmental investigations or to initiate relevant new studies that otherwise could not be undertaken because of fiscal constraints. In an era of diminishing resources and increasing research costs, Sea Grant's ability to assist federal agencies gain access to high-quality, academic scientists has been critical to the maintenance of dynamic environmental research programs.

Matching funds furnished by Sea Grant programs in support of environmental investigations in FY 1989 (approximately $4.0 million) continue a record high levels. Over the last decade matching funds have grown from 32% of total program funds (excluding pass-through funds) to 43-44% of total funds. This high level of matching support has been a crucial factor maintaining a strong environmental program in an era of level or declining Federal support. The magnitude of the matching support is a striking reminder of the commitment by member programs to the Sea Grant concept and to the constituents they serve.

The overall effect of the shifts in funding described above was to increase average federal support slightly in FY 1989 to $37,700 per grant, while average matching support increased very slightly to $24,000 per grant. The average total award per project increased from FY 1988 levels to $61,700. While this figure is the highest of the decade, it contains a decline of $2,300 in Federal support compared to the previous high year of 1987. This decline in Federal support has been more than offset by a $2,900 increase in matching support (Figure 1; Table 1).

All but one Sea Grant institution supported some environmental studies in FY 1988. Table 2 summarizes the total federal and matching funds and number of environmental projects sponsored by Sea Grant programs last year. Effort is unevenly distributed. The number of projects range from 2 to 12 per program, while total funding ranges from $93,880 to $1,069,587.

Areas of Emphasis

Sea Grant environmental studies are grouped into seven topical areas: environmental characterization, nutrient and carbon dynamics, habitat studies, particulates and toxic substances, human health, environmental management, and special projects. The level of effort, both in terms of financial support and number of projects, varies considerably across the categories (Table 3). Environmental characterization, nutrient and carbon dynamics, particulates and toxic substances, and environmental management are the four largest segments of the program, constituting approximately 80 percent of the number of FY 1989 studies and 84% of the total FY 1989 environmental research expenditures.

Despite fluctuations in the funds available for Sea Grant environmental research between FY 1985 and FY 1989 (Table 1, Figure 1), the relative distribution of these resources among the topical areas has remained remarkably stable (Table 4). In most cases, support has oscillated approximately within a three percent range over the past four years. Among the exceptions are growth in environmental characterization studies due to inclusion of a series of studies a Hawaiian sea mounts in this year's report. The relative allocation of Sea Grant environmental funds for human health-related research has declined for the fourth year, as have resources for special products.

Area of Emphasis--Environmental Characterization: Studies that describe or model the physical, geological, or biological attributes of marine systems generally are of low priority and are not recommended for funding unless they are components of larger, interdisciplinary efforts. The inclusion in this year's report of a major multi-disciplinary effort to characterize the mineral resources and ecosystems of Hawaiian sea mounts has resulted in this area now accounting for 16.3% of total funds.

Area of Emphasis--Nutrient and Carbon Dynamics: Wide-spread concern remains within the Sea Grant network over the implications of nutrient and carbon dynamics to the health of the nation's coastal and estuarine waters and to the food webs they support. In FY 1989, such studies were carried out by approximately 60% of the Sea Grant programs and accounted for approximately

TABLE 2: SUMMARY OF FY 1989 SEA GRANT ENVIRONMENTAL STUDIES BY INSTITUTION

GRANTEE	NO. OF PROJECTS	MATCHING FUNDS	FEDERAL FUNDS
UNIVERSITY OF CALIFORNIA SEA GRANT COLLEGE PROGRAM	6	$ 154,328	$ 111,827
UNIVERSITY OF SOUTHERN CALIFORNIA SEA GRANT PROGRAM	3	$ 113,428	$ 113,148
UNIVERSITY OF CONNECTICUT SEA GRANT PROGRAM	3	$ 184,108	$ 41,295
DELAWARE SEA GRANT COLLEGE PROGRAM	8	$ 186,862	$ 261,300
FLORIDA SEA GRANT COLLEGE PROGRAM	7	$ 340,400	$ 146,000
GEORGIA SEA GRANT COLLEGE PROGRAM	4	$ 230,100	$ 43,100
HAWAII SEA GRANT COLLEGE PROGRAM	12	$ 246,646	$ 222,864
ILLINOIS/INDIANA SEA GRANT PROGRAM	2	$ 92,386	$ 76,730
LOUISIANA SEA GRANT COLLEGE PROGRAM	10	$ 279,713	$ 245,210
MAINE/NEW HAMPSHIRE JOINT SEA GRANT COLLEGE PROGRAM	8	$ 351,562	$ 119,620
MARYLAND SEA GRANT PROGRAM	12	$ 595,400	$ 212,750
MASSACHUSETTS INSTITUTE OF TECHNOLOGY SEA GRANT COLLEGE PROGRAM	4	$ 197,500	$ 57,645
WOODS HOLE OCEANOGRAPHIC INSTITUTION SEA GRANT PROGRAM	6	$ 214,805	$ 79,599
MICHIGAN SEA GRANT COLLEGE PROGRAM	3	$ 92,389	$ 78,990
MINNESOTA SEA GRANT PROGRAM	3	$ 74,230	$ 19,650
MISSISSIPPI/ALABAMA SEA GRANT CONSORTIUM	3	$ 99,125	$ 72,369
NEW JERSEY MARINE SCIENCES CONSORTIUM SEA GRANT PROGRAM	4	$ 134,000	$ 140,600
NEW YORK SEA GRANT INSTITUTE	8	$ 334,302	$ 231,797
UNIVERSITY OF NORTH CAROLINA SEA GRANT COLLEGE PROGRAM	10	$ 239,550	$ 111,054
OHIO SEA GRANT PROGRAM	6	$ 228,671	$ 138,532
OREGON SEA GRANT COLLEGE PROGRAM	2	$ 110,700	$ 41,300
RHODE ISLAND SEA GRANT COLLEGE PROGRAM	8	$ 473,975	$ 595,612
SOUTH CAROLINA SEA GRANT CONSORTIUM	3	$ 141,700	$ 67,300
TEXAS A&M UNIVERSITY SEA COLLEGE PROGRAM	6	$ 253,369	$ 109,055
VIRGINIA GRADUATE MARINE SCIENCE CONSORTIUM SEA GRANT PROGRAM	9	$ 340,257	$ 129,974
WASHINGTON SEA GRANT COLLEGE PROGRAM	2	$ 59,000	$ 31,000
WISCONSIN SEA GRANT INSTITUTE	11	$ 340,257	$ 322,785
UNIVERSITY OF PUERTO RICO SEA GRANT PROGRAM	4	$ 69,000	$ 116,500
GRAND TOTALS	168	$ 6,334,372	$ 4,035,955

TABLE 3: CATEGORIES OF SEA GRANT ENVIRONMENTAL RESEARCH FOR FY 1989

CATEGORY	NO. OF PROJECTS	SG FUNDS	MATCHING FUNDS	P/T FUNDS
I. ENVIRONMENTAL CHARACTERIZATION	27	$ 764,806	$ 745,278	$ 43,100
II. NUTRIENTS AND CARBON DYNAMICS	48	$1,358,316	$1,054,048	$ 376,000
III. HABITAT STUDIES	20	$ 604,683	$ 367,782	$ 25,125
IV. TOXICS	33	$1,248,195	$ 917,331	$ 73,835
V. HUMAN HEALTH	9	$ 292,956	$ 172,354	$ 161,886
VI. ENVIRONMENTAL MANAGEMENT	28	$ 825,331	$ 774,052	$ 106,000
VII. SPECIAL PRODUCTS	3	$ 0	$ 5,110	$ 92,000

27 percent of environmental program funds. As in years past, this remains the largest category of environmental research.

Area of Emphasis--Habitat Studies: Sea Grant habitat-related research falls into three categories--studies of the role played by physical factors (e.g., hydrology) in shaping and maintaining coastal and estuarine systems, investigations of the manner in which organisms use estuarine and coastal habitats, and the development of method and techniques to rehabilitate and restore estuarine habitats. While the number of projects in habitat studies remained about the same in FY 1989 compared to 1988, the total funding declined by about 25 percent.

Area of Emphasis--Particulates and Toxic Substances: The transport, cycling, and fate of toxic substances, as well as their effects on marine and freshwater biota, often are mediated by nteractions among sediments and particles in the water column of coastal, estuarine, and Great Lakes ecosystems. In FY 1989, research in this area rose to 22 percent of the Sea Grant environmental program on the basis of funding. Only 12 percent (4 of 33 projects) of this research was focused on effects.

Area of Emphasis--Human Health: FY 1989 human health research focused on two areas: hazards to humans as a result of diving in polluted waters or consuming seafood tainted with pathogens or toxic pollutants, and causes and effects of toxic algal blooms (e.g., red tides). Human health studies continued their decline in FY 1989, decreasing from 14 projects in 1988 to 9 in 1989 and in funding from $753,878 to $469,310. Given the growing number of environmental health issues, this is a trend that bears watching.

Area of Emphasis--Environmental Management: Four areas are encompassed under the umbrella of environmental management: environmental quality assessment,coastal and wetland management, waste disposal, and development of improved instrumentation/environmental observation techniques. Of particular note is the reduction in the number of

projects in the latter category. The number of projects declined to 4 from 11 in 1988, while funding declined from 6.6 percent to 1.8 percent of total program dollars.

Area of Emphasis--Special Projects: In 1989, this program area consisted of 3 projects, all focused on publications.

Extramural Interactions

NOAA Estuarine Programs Office

The Environmental Studies Division has interacted with other NOAA and federal components in the areas of estuarine, coastal, and pollution research. In this regard, the Division maintained a close working relationship with the NOAA EPO during FY 1989. The Division participated in periodic meetings held under the auspices of the EPO. It assisted in organizing EPO estuarine seminars, documented Sea Grant-sponsored projects in estuaries of concern to the EPO, and contributed to EPO-sponsored briefings and newsletters. It also worked closely with the EPO and the Maryland and Virginia Sea Grant Programs to develop and fund coordinated research efforts on Chesapeake Bay anoxia and environmental quality. The Estuarine Program Office was abolished in January, 1990. Its responsibilities have been given to the new NOAA Coastal Ocean Program Office.

NOAA Coastal Ocean Program Office.

The Environmental Studies Division works very closely with the new NOAA Coastal Ocean Program Office (COPO). The Division Head serves as OAR's representative on the COPO Coastal Ocean Council and as the focal point for the development of new OAR programs as part of NOAA's COP. The Environmental Studies Division has had the lead role in the development and startup of the two new Coastal Ocean programs described below.

A Estuarine Habitat Research Program

In 1989, work continued on the development of a NOAA inter-line office cooperative research program on estuarine habitat productivity to be initiated in 1990. The initial program emphasis was determined to be:

1. The effect of water turbidity and disease on seagrasses and their ecosystems.

2. The effect of altered hydrology on salt march accretion, chemistry, and biology and on the organisms that utilize the marsh.

3. The development of new techniques and methodology for the restoration and construction of seagrass and salt marsh habitats.

An implementation plan was prepared and submitted to the COPO for the anticipated release of funds in 1990 to initiate the program. Major participants in the program are expected to be Sea Grant scientists and the laboratories of the National Marine Fisheries Service.

NOAA Research on Coastal Productivity

A program to study the impact of anthropogenic nutrients on the productivity, water quality, and carbon transport in the nation's coastal waters is another part of the NOAA Coastal Ocean Program. The interaction of the Mississippi River with the Louisiana shelf has been chosen as the initial study site. In recent years, anoxia has occurred on the shelf in summer months. The program is scheduled to begin in FY 1990. As is the case for the estuarine habitat productivity effort described above, investigators are to be drawn from NOAA laboratories and Sea Grant academic scientists.

Future Efforts

Estuaries, coastal habitats and environmental pollutants will continue as focal points for the Environmental Studies Division in FY 1989. Staff will assist in defining plans for research activities and will continue to promote cooperative interactions among NOAA components, other federal agencies, and Sea Grant institutions. Foremost among these will be efforts to implement the NOAA Coastal Ocean Program.

Efforts also will be made to develop and implement a program on toxic pollutants that focuses on effects at the population, species, and

TABLE 4. COMPARISON OF SEA GRANT ENVIRONMENTAL PROGRAMS

	PERCENT FY 1985 TOTAL FUNDS	PERCENT FY 1986 TOTAL FUNDS	PERCENT FY 1987 TOTAL FUNDS	PERCENT FY 1988 TOTAL FUNDS	PERCENT FY 1989 TOTAL FUNDS
Environmental Characterization	11.0	12.3	11.3	8.1	16.3
Nutrients/Carbon Dynamics	29.4	30.8	28.8	30.5	27.0
o Primary Production/ Nutrient Cycling	5.6	5.8	7.8	8.9	6.8
o Trophic Dynamics	12.1	16.9	14.4	15.5	11.2
o Eutrophication	11.7	7.9	6.6	6.1	9.0
Habitat Studies	9.1	9.9	13.2	13.1	9.6
Toxic	18.4	17.4	17.2	19.5	22.2
Human Health	12.7	9.1	8.8	8.0	4.5
Environmental Management	15.9	18.3	19.4	19.7	19.5
o Environmental Quality Assessment	5.1	6.1	5.8	4.4	7.4
o Coastal Wetland Management	3.3	2.4	2.0	3.0	5.9
o Waste Disposal	6.0	7.0	5.3	5.7	4.4
o Instrumentation/Environmental Observation Techniques	1.5	2.7	6.3	6.6	1.8
Special Products	3.5	2.1	1.3	1.1	0.9

systems levels, and permits enlightened discussion of the effects of complex mixtures of pollutants, as well as cumulative effects of exposure over time. The development of a new program addressing the research issues relative to the understanding and prediction of noxious and toxic algal blooms either as part of the Coastal Ocean Program or as a separate Sea Grant program is also of high priority.

PROJECTS

A. ENVIRONMENT CHARACTERIZATION

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. Physical		
Numerical Modelling Nearshore Hydrodynamics I.A. Svendsen 26 Delaware Sea Grant College Program	5,460	43,455
An Analysis of the Hydrodynamic Regime in Delaware's Inland Bays K.C. Wong 46 Delaware Sea Grant College Program	15,478	28,777
Directional Wave Collection and Analysis - Kings Bay, Georgia H. Wang 25 Florida Sea Grant College Program	0	17,000
Lake-Level variation in Lakes Michigan and Huron: Magnitude and timing of past and future fluctuations. N.C. Hester 46 Illinois/Indiana Sea Grant Program	0	58,130
Evolution of Wave Spectra in Bays - Calculation of Wave Conditions in Bays V. Panchang 46 Maine/New Hampshire Joint Sea Grant College Program	35,862	8,586
Numerical Analysis of Tides, Mixing, and Three-Dimensional Flow-Structure in the Gulf of Maine F.E. Werner 50 Maine/New Hampshire Joint Sea Grant College Program	9,700	0
Circulation and Sediment Transport in a Shallow Inlet-Estuarine System: Pettaquamscutt River J. Boothroyd 46 Rhode Island Sea Grant College Program	50,000	145,265
Assessment and Modeling of Estuarine Flow and Transport Processes in Response to Changing Freshwater Discharge B. Kjerfve 46 South Carolina Sea Grant Consortium	67,200	32,900
Predictive Methods for Salinity	31,548	18,597

Intrusion in Galveston Bay G.H. Ward 46			
Texas A&M University Sea Grant College Program Modeling Tidal Circulation and Transport in Central Puget Sound W.S. Chu 46 Washington Sea Grant College Program		29,600	16,200
	SUBTOTAL:	$244,848	$368,910
	PASSTHROUGH:	128,700	

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
2. Geological/Chemical			
Black Smoker: Vents for Ocean Thermal Power V. Anderson 22 University of California Sea Grant College Program		65,537	16,137
Biostratigraphy to Date Crust E.H. De Carlo 09 University of Hawaii Sea Grant College Program		21,414	11,898
Stratigraphic History of Crusts A. Malahoff 09 University of Hawaii Sea Grant College Program		24,938	13,041
Geology of Hydrothermal Systems A. Malahoff 09 University of Hawaii Sea Grant College Program		25,006	15,001
Isotopic Stratigraphy J. Mahoney 09 University of Hawaii Sea Grant College Program		37,755	29,223
Geochemistry of Vent G. McMurtry 09 University of Hawaii Sea Grant College Program		25,118	15,000
Stable Isotope Studies of the Cobalt-Rich H. Yeh 09 University of Hawaii Sea Grant College Program		18,405	11,266
Crusts Magnetic Materials G. Andermann 10 University of Hawaii Sea Grant College Program		9,705	24,698
Microbiology and Chemistry of Vents D. Karl 32 University of Hawaii Sea Grant College Program		22,000	21,652

Water Mass Evolution and the Circulation and Nutrient Environment of the Gulf of Maine W.S. Brown 50 Maine/New Hampshire Joint Sea Grant College Program	53,000	27,411
Estimation of Supply Rate of Heat and Metals to Black Smoker Vent Fields J.R. Cann 09 Woods Hole Oceanographic Institution Sea Grant Program	25,000	15,400
Seismic Strategraphy and Depositional History of the Tidal Delta–Shore Attached Ridge Complex, Barnegat inlet, New Jersey G. Ashley 39 New Jersey Marine Sciences Consortium Sea Grant Program	29,700	30,400
SUBTOTAL:	$394,378	$249,727
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
3. Biological		
Microbial Geochemistry J.P. Cowen 09 University of Hawaii Sea Grant College Program	25,354	18,213
Petroleum Seeps Program: Continuing Investigations of Louisiana Continental Slope R.S. Carney 07 Louisiana Sea Grant College Program	24,322	25,602
The Long–term record of community structure in Chesapeake Bay G.S. Brush 40 Maryland Sea Grant College Program	37,800	18,400
Paleoclimatic Implications of Late Holocene Lake Level Fluctuations in the Lake Michigan Basin E.F. Stoermer 39 Michigan Sea Grant College Program	14,904	38,907
Continental Shelf Hardbottom Environments: Distribution, Classification and Biology W. Schroeder 40 Mississippi/Alabama Sea Grant Consortium	60,000	44,119

SUBTOTAL:	$162,380	$145,241
PASSTHROUGH:	0	

B. NUTRIENTS & CARBON DYNAMICS

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. Primary Production and Nutrient Cycling		
Controls on Phosphorus Chemistry of an Urban Estuary, the Delaware J.H. Sharp 30 Delaware Sea Grant College Program	22,620	23,718
Coastal Outwelling and Nutrient Cycling: Determining the Fate of Nitrogen Remineralization in Sediments and Identifying Source C.S. Hopkinson, Jr. 40 Georgia Sea Grant College Program	63,000	16,000
Enhancement of Coastal Productivity Associated with Processes in the Atchafalaya Bay Ecosystem: V. Stable Isotope Ratios and J.W. Day 39 Louisiana Sea Grant College Program	40,904	24,853
Enhancement of Coastal Productivity Associated with Processes in the Atchafalaya Bay Ecosystem: V. Stable Isotope Ratios and R.R. Twilley 39 Louisiana Sea Grant College Program	52,820	24,948
Regulation and Utilization of Planktonic Primary Production H. Pearl 40 University of North Carolina Sea Grant College Program	7,700	23,324
Significance of Dissolved Phosphorus Compounds to Phytoplankton and Bacterioplankton in Western Lake Erie R.T. Heath 47 Ohio Sea Grant College Program	25,868	23,008
O/R Processes in the Pyconocline of Stratified Coastal Waters J. Sieburth 40 Rhode Island Sea Grant College Program	66,745	41,616
Estuarine Nutrient Dynamics & Water Quality Interactions: Relation to River Flow, Land Use & Wetland Exchanges	37,700	15,800

H.N. McKellar 46 South Carolina Sea Grant Consortium		
Nutrient Flow from Seagrass Detritus to Food Webs in the Laguna Madre Estuary R. Benner 40 Texas A&M University Sea Grant College Program	40,108	20,054
Loss of Seagrass Habitat & Its Management in Texas Estuaries: Photosynthesis Production Along an Estuarine Gradient K.H. Dunton 40 Texas A&M University Sea Grant College Program	32,350	16,800
Isotopic Determination of Nitrogen Sources and Processing in Estuarine Environments J. Zieman 39 Virginia Graduate Marine Science Consortium Sea Grant Program	62,508	30,229
SUBTOTAL:	$452,323	$260,350
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
2. Trophic Dynamics		
Balance Between Oxygen Production and Consumption in Estuarine Waters R.J. Geider 40 Delaware Sea Grant College Program	17,160	21,872
Macrobenthic Production in Natural and Restored Seagrass Beds S.S. Bell 40 Florida Sea Grant College Program	29,500	21,100
Coral Reef Ecosystems R. Grigg 07 University of Hawaii Sea Grant College Program	16,704	36,389
Fishing Impact on Coral Reefs R. Brock 07 University of Hawaii Sea Grant College Program	10,454	23,463
Petroleum Seeps Program: Evaluation of Marine Microbial Chemoorganotropha/Chemolithoautotrophs for Contributions to Benthic H R.J. Portier 11	15,001	14,769

Louisiana Sea Grant College Program		
Atchafalaya System Synthesis R. Carney 39 Louisiana Sea Grant College Program	0	29,265
Enhancement of Coastal Productivity Associated with Processes in the Atchafalaya Bay Ecosystem: VII. Zooplankton Feeding and M.J. Dagg 39 Louisiana Sea Grant College Program	31,140	32,338
Enhancement of Coastal Productivity Associated with Processes in the Atchafalaya Bay Ecosystem: VIII. Ichthyoplankton Flux Al R.F. Shaw 39 Louisiana Sea Grant College Program	50,996	29,686
Production and Fate of Phytoplankton Biomass in the Mesohaline Reach of Chesapeake Bay T.C. Malone 40 Maryland Sea Grant College Program	51,500	58,700
Assimilation of Organic Aggregates by Bay Scallops (Argopecten irradians) I. Valiela 03 Woods Hole Oceanographic Institution Sea Grant Program	35,700	19,934
Causes and Consequences of Cladoceran Dynamics in Lake Michigan: Implications for Recruitment Success of Forage Fish Species J.T. Lehman 40 Michigan Sea Grant College Program	23,871	58,512
Competition for Food Among the Major Predators in Saginaw Bay J. Diana 40 Michigan Sea Grant College Program	35,949	13,219
Primary Production Dynamics and Trophic M. Sullivan 40 Mississippi/Alabama Sea Grant Consortium	30,825	28,250
Control of Production in Eelgrass Communities: Interactions Between Nutrient Enrichment and Food Web Cascades J. Burkholder 40 University of North Carolina Sea Grant College Program	54,750	6,200
Dynamics of Zooplankton–Fish Interactions: Impact of the Introduction of Bythotrephes	25,766	15,554

Cederstroemi into Lake Erie D.W. Garton 40 Ohio Sea Grant College Program			
Effect of Microbial Predators on Lake Erie Blue-Green Algae in Laboratory Tanks and Outdoor Pool Ecosystems J.C. Burnham 40 Ohio Sea Grant College Commission Program		26,738	15,414
Biological Invasions in Estuaries Studies on Introduction of Exotic Species by Seawater J.T. Carlton 39 Oregon Sea Grant College Program		65,100	18,800
Response and Stability of Eelgrass Communities Subject to Variable Water Quality Regimes: Mesocosm Studies R. Wetzel 39 Virginia Graduate Marine Science Consortium Sea Grant Program		35,474	17,490
Plankton Size Spectrum Shifts and Food Web "Bottlenecks" Accompanying the Invasion of the Lake Michigan by the Predatory Clad C.D. Sandgren 40 Wisconsin Sea Grant Institute		56,832	13,342
Light and Zooplankton Effects on Phytoplankton Production in Lower Green Bay P.B. Sager 40 Wisconsin Sea Grant Institute		58,327	20,687
	SUBTOTAL:	$671,787	$494,984
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
3. Eutrophication		
Nonpoint Source Pollution S.J. Dollar 30 University of Hawaii Sea Grant College Program	9,793	13,020
The Production and Fate of Phytoplankton Biomass in the Mesohaline Reach of the Chesapeake Bay D.J. Conley 07 Maryland Sea Grant College Program	0	32,175
Trophic Dynamics in Chesapeake Bay: Ecological and Biochemical Approaches to the Study of Flows of Carbon H.W. Ducklow 07 Maryland Sea Grant College Program	0	17,040
Plankton trophodynamics in Chesapeake Bay: Bacterivory and Herbivory by Nano- and Microzooplankton G.B. McManus 07 Maryland Sea Grant College Program	0	4,425
Plankton Trophic Dynamics In Chesapeake Bay: Models and Budgets of Carbon Nutrient Coupling W.M. Kemp 07 Maryland Sea Grant College Program	0	13,600
A Nitrogen Budget for a Eutrophic Coastal Salt Pond: The Relative Importance of Benthic Regeneration and Groundwater Inputs B.L. Howes 45 Woods Hole Oceanographic Institution Sea Grant Program	48,700	24,740
Continuation of Studies of the Effect of Increased Nitrogen Loading in coastal Lagoon Ecosystems: Denitrification as a Sink f S. Seitzinger 40 New Jersey Marine Sciences Consortium Sea Grant Program	54,400	25,400
Effects of Increased Nitrogen Loading on Estuarine Primary Productivity and Nitrogen Cycling J. Boyer 40 University of North Carolina Sea Grant College Program	17,624	8,596
Contribution of Benthic Community	12,676	10,769

Metabolism to Water Quality W. Rizzo 40 University of North Carolina Sea Grant College Program			
Methods to Predict Pollutant Loading from Poorly Drained Soils Adjacent to Coastal Waters C. Reynolds 46 University of North Carolina Sea Grant College Program		41,278	6,384
The Dry Deposition of Nitrate to Narragansett Bay and Its Watershed B. Huebert 45 Rhode Island Sea Grant College Program		49,735	80,608
Chronic Effects of Seasonally Low Dissolved Oxygen R.J. Diaz 07 Virginia Graduate Marine Science Consortium Sea Grant Program		0	10,803
Effect of Low Dissolved Oxygen on Ability to Metamorphose R. Mann 07 Virginia Graduate Marine Science Consortium Sea Grant Program		0	19,186
The Role of Dissolved Oxygen Constituents from Anaerobic L.K. Blum 07 Virginia Graduate Marine Science Consortium Sea Grant Program		0	15,018
The Impact of Oyster Abundance on Water Quality in Sub-Estuaries R. Jonas 07 Virginia Graduate Marine Science Consortium Sea Grant Program		0	0
Passive Artificial Ventilation of Hypoxic Estuaries L.D. Wright 24 Virginia Graduate Marine Science Consortium Sea Grant Program		0	16,950
Chesapeake Bay Environmental Effects Research: New Project Initiatives W.L. Rickards 81 Virginia Graduate Marine Science Consortium Sea Grant Program		0	0
	SUBTOTAL:	$234,206	$298,714
	PASSTHROUGH:	404,980	
C. HABITAT STUDIES			

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. Wetland Dynamics		
Wastewater Wetlands: Pulsed Discharges to Protect J. Zedler 39 University of California Sea Grant College Program	27,265	20,092
Soil Aeration and Salinity as Factors in the Competitive Ability of the Weedy Marsh Species Phragmites Australis J.L. Gallagher 39 Delaware Sea Grant College Program	7,020	28,320
The Degradation and Restoration of Wetland Vegetation: The Relative Role of Saltwater Intrusion and Chronic Soil Waterlogging I.A. Mendelssohn 40 Louisiana Sea Grant College Program	33,872	22,070
Comparison of Marsh Vertical Accretion Rates Under Altered Hydrologic Conditions in Saline D.R. Cahoon 40 Louisiana Sea Grant College Program	11,980	11,635
Analyzing Stress in Coastal Marsh Ecosystems: Field, Laboratory and Modeling Studies T. Loder 47 Maine/New Hampshire Joint Sea Grant College Program	64,000	0
Physical Processes and Inlets and Effect on the Transport of Immature Fishes J. Miller 46 University of North Carolina Sea Grant College Program	48,247	8,358
Intertidal Wetland Responses to a Changing Salinity Gradient South J.T. Morris 40 Carolina Sea Grant Consortium	36,800	18,600
Nutrient Retention and Transformations in Tidal Wetlands as Influenced by Subsurfaces Hydrology and Internal Biogeochemical R W.E. Odum 39 Virginia Graduate Marine Science Consortium Sea Grant Program	40,595	20,298
SUBTOTAL:	$269,779	$129,373
PASSTHROUGH:	0	
TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS

2. Habitat Utilization

The Importance of Competing Sessile Species to the Survivorship of Juvenile Oysters R.B. Whitlatch 06 University of Connecticut Sea Grant Program	41,771	22,572
Toward the Development of Probabilistic Scenarios of Sealevel Vulnerability Along the Connecticut Shoreline G.W. Yohe 38 University of Connecticut Sea Grant Program	21,337	18,723
Use of the Vegetated Intertidal Marsh by the Young of Estuarine-dependent Fishes and Crustaceans R.T. Kneib 40 Georgia Sea Grant College Program	51,700	11,200
Ecology and Control of Larval Biting Midges Culicoides spp. (Diptera: Ceratopogonidae) in the Salt Marsh Intertidal Zone D.V. Hagen 42 Georgia Sea Grant College Program	50,200	0
Trophic Coupling Between Juvenile Demersal Fishes and the Benthos in Sheepscot Bay L. Watling 06 Maine/New Hampshire Joint Sea Grant College Program	31,000	11,804
Human Influences on the Dispersal of Living Organisms and Genetic Material into Aquatic Ecosystems A. Rosenfield 74 Maryland Sea Grant College Program	0	0
Evaluation of Salinity as a Variable for Use in Habitat Evaluation Procedures (HEP) Applied to Estuarine and Marine Habitats C.D. Veal 77 Mississippi/Alabama Sea Grant Consortium	0	0
Habitat Specific Recruitment Patterns in Estuarine Dependent K. Able 07 New Jersey Marine Sciences Consortium Sea Grant Program	49,900	60,600
Habitat Requirements of Molting and Mating Blue Crabs T.G. Wolcott 06 University of North Carolina Sea Grant College Program	28,547	2,230

Maximizing Shellfish by Manipulating Their Environment C.H. Peterson 06 University of North Carolina Sea Grant College Program		4,669	16,484
	SUBTOTAL:	$279,124	$143,613
	PASSTHROUGH:	28,300	

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
3. Habitat Restoration and Rehabilitation			
Improving on Nature: Stress-Tolerant Plants from the Marine Estuarine Environments for Ecosystem Restoration and Agriculture J.L. Gallagher 05 Delaware Sea Grant College Program		21,060	47,996
Plant Tissue Culture Technology for Marine Angiosperms Used in Habitat Restoration K.T. Bird 05 Florida Sea Grant College Program		34,700	46,800
	SUBTOTAL:	$55,760	$94,796
	PASSTHROUGH:	0	

D. PARTICULATES & TOXIC SUBSTANCES

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
1. Transport, Cycling, and Fate			
Toxic Metal Sources and Fates in the Delaware Estuary T.M. Church 44 Delaware Sea Grant College Program		36,557	57,946
Production and Microbial Transformations of ignocellulose-derived Dissovled and Particulate Organic Matter in Estuarine and Coastal Water R.E. Hodson 45		65,200	15,900

Georgia Sea Grant College Program		
Light, water and the photoinduced toxicity of complex mixtures of hydrocarbon pollutants R. Davenport 49 Illinois/Indiana Sea Grant Program	48,686	28,514
The Control of Trace Element Toxicity in the Chesapeake Bay in Dominant Phytoplankton J.G. Sanders 44 Maryland Sea Grant College Program	25,000	18,600
Characterization of Coastal Colloids F.M. Morel 39 Massachusetts Institute of Technology Sea Grant College Program	47,500	0
Bed-Water Exchange of Toxic Organic Compounds P.M. Gschwend 39 Massachusetts Institute of Technology Sea Grant College Program	50,000	0
Seasonal Changes in Particle Residence Times and Scavenging Rates in Massachusetts Bay G.T. Wallace 44 Massachusetts Institute of Technology Sea Grant College Program	50,000	35,430
Effects of Maternal Exposure of Rainbow Trout to 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD)on Reproduction J. Giesy 45 Michigan Sea Grant College Program	41,536	26,864
Causes and Mitigation of Toxics Contamination of the Fishery in the St. Louis River/Duluth-Superior Harbor, Fishery Nursery A G. Rapp 44 Minnesota Sea Grant College Program	24,000	5,790
Innovation Studies of Organic Contaminant-Particle Interactions in Large Lakes S.J. Eisenreich 46 Minnesota Sea Grant College Program	26,380	8,010

Bioaccumulation of PCB and PCDF in Lake Superior Phytoplankton D.L. Swackhamer 47 Minnesota Sea Grant College Program	23,850	5,850
Assessment of Atmospheric Deposition of Trace Metals to Western Long Island Sound J.K. Cochran 44 New York Sea Grant Institute	24,843	20,211
Bioaccumulation and Toxicity of Lead and Silver in Estuarine Microzooplankton M. Levandovsky 44 New York Sea Grant Institute	29,998	76,284
Volatizing Toxic Chemicals in the Estuarine Environment: Surface Gas Transfer Experiments in a Tilting Wind-Water Tunnel C.H. Jirka 45 New York Sea Grant Institute	43,165	38,735
Disposition and Metabolisms of Polychlorinated Dibenzofurans in Fish H.C. Sikka 45 New York Sea Grant Institute	50,568	26,745
The Role of "Marine Snow" Vertical Flux and Accumulation of Sediments in an Estuary J. Wells 48 University of North Carolina Sea Grant College Program	12,544	23,457
An Ecosystem Approach to Lake Erie Coastal Wetlands: Sediment, Nutrient, and Pesticide Budgets W.A. Krieger 42 Ohio Sea Grant College Program	39,000	20,454
Sunlight Induced Photochemistry in Lake Erie: Formation of Reactive Species W.J. Cooper 45 Ohio Sea Grant College Program	0	38,107
The Response of Near Bottom Sediment Fluxes and Distributions to Time-Varying Flows K.W. Bedford 46 Ohio Sea Grant College Program	46,199	25,995
Pollutant Metal Removal & Release Via Reactions with Sedimentary Pyrite J. Morse 44 Texas A&M University Sea Grant College Program	44,891	23,604
The Persistence of Organic Pollutants in a Great Lakes Estuary	79,479	51,396

D.N. Edgington 45 Wisconsin Sea Grant Institute		
Dechlorination of PCBs in Sheboygan Harbor W.C. Sonzogni 45 Wisconsin Sea Grant Institute	16,828	13,948
Dechlorination of PCBs in Sheboygan Harbor W.C. Sonzogni 45 Wisconsin Sea Grant Institute	16,828	13,948
Particle Dynamics Residence Times and a Be-7 Budget for Green Bay J.V. Klump 48 Wisconsin Sea Grant Institute	29,344	22,925
The Sedimentary Sink Term for Biogeochemical Mass Balance in Lake Michigan J.V. Klump 48 Wisconsin Sea Grant Institute	31,428	28,764
Molecular Properties and Fate of Organic Chemicals in Aquatic Environment A.W. Andren 48 Wisconsin Sea Grant Institute	46,762	39,068
Rates and Mechanisms of Contaminant Uptake and Release by Suspended Sediments in Lake Michigan D.E. Armstrong 48 Wisconsin Sea Grant Institute	51,281	42,111
Ecology and Etiology of White Band Disease in Elkhorn Coral Acropora Palmata (Lamarck) E.H. Gladfelter 08 University of Puerto Rico Sea Grant Program	12,000	17,400
The Evaluation of Long Term Effects on Coral Reefs from Terrigenous Sedimentation J. Morelock 09 University of Puerto Rico Sea Grant Program	26,900	33,300

Extreme Wave Heights for Puerto Rico and the U.S. Virgin Islands A. Mercado 25 University of Puerto Rico Sea Grant Program	25,100	65,800
SUBTOTAL:	$1,049,039	$811,208
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
2. Effects		
Influence of Complex Biofilms and Absorbed Pollutants on Oyster Set and Survival R. Weiner 30 Maryland Sea Grant College Program	60,000	33,000
Microbiological Hazards Associated with Diving in Polluted Waters: An Epidemiological Study R.R. Colwell 32 Maryland Sea Grant College Program	0	0
Toxic Halogenated Aromatic Hydrocarbons in Lake Trout Gametes as a Factor in Fry Survival R.E. Peterson 45 Wisconsin Sea Grant Institute	63,151	54,091
Predatory-Prey Linkages in Great Lakes Food Webs J.F. Kitchell 47 Wisconsin Sea Grant Institute	76,005	19,032
SUBTOTAL:	$199,156	$106,123
PASSTHROUGH:	151,100	

E. HUMAN HEALTH

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. Pathogens and Toxic Pollutants		
Detection and Survivability of Some Pathogenic Enterobrac I. Radolfo 45 University of Southern California Sea Grant Program	43,639	40,642
Develop of DNA Probes - Pathogenic	39,574	37,113

Marine Bac H. Shizura 45 University of Southern California Sea Grant Program		
Risk Perception and Communication Regarding Chemically Contaminated fish in Lake Ontario B.A. Knuth 29 New York Sea Grant Institute	9,523	15,474
Evaluation of Plasmid Profiles as a Method to Determine the Source of Fecal Pollution in an Estuary R.K. Sizemore 08 University of North Carolina Sea Grant College Program	11,515	5,252
SUBTOTAL:	$104,251	$98,481
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
2. Toxic Plankton		
Hydrographic Localization of Toxic Dinoflagellate Blooms in Coastal Waters D.M. Anderson 07 Woods Hole Oceanographic Institution Sea Grant Program	60,000	19,525
2550R/B-91 Immunological Detection of the Brown Tide D.M. Anderson 07 Woods Hole Oceanographic Institution Sea Grant Program	26,500	0
Uptake and Depuration of Red Tide Paralytic Shellfish Poisoning Toxins in East Coast Bivalve Molluscs V.M. Bricelj 06 New York Sea Grant Institute	74,177	31,188
Siderophore Production in the Red Tide Dinoflagellate Protogonyaulax tamarensis G.L. Boyer 07 New York Sea Grant Institute	23,028	23,160
Third International Conference on Ciguatera Fish Poisoning T.R. Tosteson 74 University of Puerto Rico Sea Grant Program	5,000	0
SUBTOTAL:	$188,705	$73,873
PASSTHROUGH:	4,000	
F. ENVIRONMENTAL MANAGEMENT		

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. Environmental Quality Assessment		
Deterring Oil Spills: Optimal Policies R. Carson 14 University of California Sea Grant College Program	11,454	26,428
The Attitude Basis of Marine/Coastal Litter: Assessing Louisiana Coastal Users' Attitudes Toward the Environment S.B. Laska 20 Louisiana Sea Grant College Program	13,678	30,005
Socio-Economic Assessment of Compliance with Estuarine Governance Programs J. Sutinen 20 Rhode Island Sea Grant College Program	32,564	43,615
Coastal Resources Center V. Lee 39 Rhode Island Sea Grant College Program	57,487	89,110
Continuing a Long-Term Experimental Study of Water Quality and Productivity in Replicate Coastal Lagoon Ecosystems Receiving S. Granger 40 Rhode Island Sea Grant College Program	84,035	95,912
The Governance of Estuaries: A Comparative Analysis of Institutions, Public Policy Formulation and Implementation in Six U.S. T. Hennessey 40 Rhode Island Sea Grant College Program	36,356	51,148
Comparison of Trends in Conditions and use of U.S. Estuaries V. Lee 40 Rhode Island Sea Grant College Program	97,053	48,338
Models of Water Quality Governance and the Puget Sound Experience T.M. Leschine 20 Washington Sea Grant College Program	29,400	14,800
SUBTOTAL:	$362,027	$399,356
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS

2. Coastal/Wetlands Management

Long Island Sound Study Public Education and Participation C. Arnold 75 University of Connecticut Sea Grant Program		0	0
A Computer-Directed Geographic Coastal Use Classification System for Ecologic Planning: The Case of the Florida Keys G.A. Antonini 38 Florida Sea Grant College Program		43,100	47,800
Estuarine Planning Handbook D.D. Barile 70 Florida Sea Grant College Program		16,000	13,300
Growth Management in Coastal Communities: Laws, Policies, and Intergovernmental Arrangements to Ensure Balanced Development A. Reiser 38 Maine/New Hampshire Joint Sea Grant College Program		15,000	4,691
A Prototype for Integrated Costal Ocean Research and Management D.J. Grimes 79 Maine/New Hampshire Joint Sea Grant College Program		0	58,000
An Analysis of Normative & Conceptual Issues in the Regulation of Biotechnology in the Nation's Bays and Estuaries M. Sagoff 20 Maryland Sea Grant College Program		24,800	11,700
A Long Island Sound Public Participation Coordinator Based in New York M.P. Voiland 75 New York Sea Grant Institute		0	0
Consumptive Use of Great Lakes Water E.F. Joeres 20 Wisconsin Sea Grant Institute		70,819	17,421
	SUBTOTAL:	$169,719	$152,912
	PASSTHROUGH:	300,000	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS

3. Waste Disposal

Scales of Variability of Sewage-Influenced Water Column Properties in S CA J.A. McGowan 45 University of California Sea Grant College Program		12,277	19,490
Management Models of Wetland Wastewater Treatment B. Finney 46 University of California Sea Grant College Program		12,479	23,680
Small-Scale Mixing Processes-Dispersion- Sewage B. Jones 45 University of Southern California Sea Grant Program		30,161	35,393
China-USA Cooperative Research Project on the Tracking of Wastes Dumped at Sea J.C. Cato 44 Florida Sea Grant College Program		0	0
Marine Disposal of Solidified/Stabilized Incinerator Ash: Field Studies N.E. Kinner 45 Maine/New Hampshire Joint Sea Grant College Program		43,000	9,128
Extraction of PCBs and PAHs from Coastal Waters Using Block Copolymer Micelles T.A. Hatton 13 Massachusetts Institute of Technology Sea Grant College Program		50,000	22,215
Oceanographic Investigations, Johnston Atoll, for Assessing the Impacts of Deep Ocean Disposal of Liquid Brine from the Jacad P.S. Lobel 45 Woods Hole Oceanographic Institution Sea Grant Program		0	0
Siting of Marine Diffusers R.T. Hudspeth 25 Oregon Sea Grant College Program		45,600	22,500
	SUBTOTAL:	$193,517	$132,406
	PASSTHROUGH:	131,005	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS

4. Instrumental/Environmental Observation Techniques

Advanced Development of 3-D Ultrasonic Imaging System J. Jaffe 28 University of California Sea Grant College Program	25,316	6,000
Determining State Variables of Estuaries by Remote Sensing to Estimate Susceptibility to Environmental Change V. Klemas 39 Delaware Sea Grant College Program	20,280	29,178
Utility of Thematic Mapper Data for Chlorophyll Estimation in New Jersey's Coastal Waters of the New York Bight S. Bagheri 50 New Jersey Marine Sciences Consortium Sea Grant Program	0	24,200
Satellite Analyses for Fishery Oceanography in the Gulf of Mexico A.C. Vastano 50 Texas A&M University Sea Grant College Program	54,472	30,000
SUBTOTAL:	$100,068	$89,378
PASSTHROUGH:	0	

G. SPECIAL PRODUCTS

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Technical Book on Tributylin: Editorial and Preproduction Services J.C. Cato 44 Florida Sea Grant College Program	0	0
Publications Support for NOAA's Chesapeake Bay Study Merril 76 Maryland Sea Grant College Program	0	5,110
Production and Distribution of a Bimonthly Newsletter for the Gulf of Mexico Program A. Broussard 76 Texas A&M University Sea Grant College Program	0	0
SUBTOTAL:	$ 0	$5,110
PASSTHROUGH:	92,000	

Division of Technology and Commercial Development

The most critical challenge facing the American economy today is to rebuild the country's competitive position in the global marketplace. The lesson has never been clearer. For fifteen years we have seen a slowdown of productivity growth which has translated into a stagnating standard of living for Americans. The economic competitiveness of the nation's industry in world markets is directly related to its investment in developing human and capital resources. World scientific leadership alone has not been able to sustain our once dominant production economy. We need to become much more aware of how science gets translated into commercial goods and services. The Division of Technology and Commercial Development is the part of the National Sea Grant Office directly concerned with bringing the results of Sea Grant scientific research to the commercial sphere.

The Sea Grant Marine Extension Service has performed very well in transferring knowledge to highly disaggregated, low-technology marine industries like commercial fisheries, seafood processing, and marine recreation and tourism enterprises. However, the extension model, which relies on the extension-agent model for coupling with industry, is not well suited to delivering scientific results to highly concentrated, high-technology industries such as marine biotechnology, underwater robotics, or satellite oceanographic services. For these industries, the Division is encouraging experimentation with a different type of academic-industry linkage. Two programs have set up networks of firms interested in marine resources to facilitate the rapid diffusion of research results, advise on research agendas, and promote the development of university- industry cooperative research programs. Several other forms of industry advisory groups are in the planning stages.

This report for Fiscal Year 1989 covers four Sea Grant Program areas: Ocean Engineering, Marine Economics, Marine and Coastal Transportation Systems, and Marine Recreation and Tourism.

Authors

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Marine Economics

Summary

Sea Grant economists, both through research and extension, are providing a more complete understanding of the organization, conduct, and performance of the marine sector of the economy. By focusing on the efficient use of America's marine resources, Sea Grant is helping to improve the competitiveness of the nation's marine economy, that part of the economy dependent upon ocean and Great Lakes resources.

The Fiscal Year 1989 marine economics program includes 36 projects, with total funding of $1.7 million, of which federal funding amounted to $826 thousand. Eighteen Sea Grant institutions currently participate in the marine economics research program, and at least 12 institutions have an economics specialist on their Marine Advisory Service staff.

Introduction

Sea Grant, through its economics research program, is providing a more complete understanding of the organization, conduct, and performance of the marine sector of the nation's economy. By focusing on the efficient use of America's marine resources, Sea Grant is helping to improve the competitiveness of the nation's marine economy, that part of the economy dependent upon ocean and Great Lakes resources.

The economic growth of marine resource-based industries is an underlying goal of the National Sea Grant College Program. Economics research contributes to this purpose through analyses of the opportunities and problems marine industries face in producing goods and services for the world marketplace.

The Program

The Fiscal Year 1989 marine economics program includes 36 projects, with total funding of $1.7 million, of which federal funding amounted to $826 thousand. This is an increase of several projects but a decrease of $52 thousand in Federal funding compared with the Fiscal Year 1988 level. Matching funds increased by 34 percent to $828 thousand. Eighteen Sea Grant institutions currently participate in the marine economics research program, and at least 12 institutions have an economics specialist on their Marine Advisory Service staff.

Economists supported by Sea Grant and matching state funds are studying a full range of resource-use issues in fisheries, aquaculture, recreation and tourism, coastal resource development, seabed mining, and marine transportation. Table 1 provides a breakdown of the marine economics projects by subject area, with a detailed listing of each project provided at the end of this report.

Trends

The marine economics program has stayed at about six percent of Sea Grant's research budget the last three years, down from eight percent at the beginning of the 1980's. Part of the decline reflects the availability of alternative funding sources to support marine economics research, such as the fisheries development foundations and the fisheries management councils. In part, it also reflects the reaction of Sea Grant programs to leaner budgets. This has also brought about a shift in priorities. Most of the reduction comes in the living marine resource areas, with more attention given to other marine and coastal resource economic development questions.

Economics Research Program

THE IMPACT OF SEA GRANT ON THE NATIONAL ECONOMY

A recent report, published by the Sea Grant network, showed that by stimulating new business opportunities and implementing cost-saving productivity improvements, Sea Grant generated an $842 million impact on the national

TABLE 1

MARINE ECONOMICS PROJECTS
BY SUBJECT AREA, FISCAL YEAR 1989

SUBJECT AREA	NO. OF PROJECTS	SEA GRANT (thou $)	MATCH (thou $)
1. Fisheries Management and Development	12	233	293
2. Aquaculture	1	66	28
3. Marine Recreation	10	202	246
4. Coastal Resources	8	218	182
5. Marine Minerals	2	55	52
6. Marine Transportation	1	17	6
7. Marine Technology	2	35	22
TOTAL	36	826	828

the federal budget was $39 million. A 1981 analysis of Sea Grant estimated a million annual contribution to the national economy. That the impact more than tripled can seen as a striking achievement in the face of declining program resources throughout the 1980's. But it is also reason for concern. A large number of the economic gains reported had their gestation period in the 1970's. Will a report eight years from now be able to make a similar case for Sea Grants economic achievement?

Source: *The National Sea Grant College Program: Economic Impact: 1987*, University of North Carolina Sea Grant College Program, 1989.

THE CONTRIBUTION OF THE OCEAN SECTOR TO THE UNITED STATES ECONOMY

1980 Ocean Sector Study:

In 1980, a cooperative effort between the National Sea Grant program and the Bureau of Economic Analysis in the U.S. Department of Commerce was initiated to measure the value of the Ocean Sector. Until then, there was no clear understanding of the make-up and size of the ocean economy.

The first estimate of the contribution of an Ocean Sector to the Unites States economy was published in 1980 (Pontecorvo, *Science*, May 30, 1980). A new subdivision, an ocean account, was created within the national income accounting system. The ocean account measures the contribution of the Ocean Sector to the United States Gross National Product (GNP) on a value-added basis, and within it, the relative value of subsectors such as fisheries, ports and ocean transportation, and marine mining.

The 1980 study was carried out using 1972 benchmark data, the most recent year for which economic census data were available. In 1972, the aggregate value of the Ocean Sector was $31 billion. At the time, the total GNP of the United

States was $1.1 trillion. The study identified 66 sectors within the national income accounts that either utilize an ocean resource in a productive process (supply-side criteria) or exist because the demand for the final output is due to some attribute of the ocean (demand-side criteria). The supply-side criteria are either extractive, in which the primary activity involves removal of living or inanimate objects from the ocean (e.g. commercial fishing and oil and gas extraction); or spatial, in which the business uses space upon or below the ocean surface (e.g. marine transportation or communications). The demand-side criteria are either complementary, in which the demand for a significant portion of the output is attributable to the ocean (e.g. ship building); or geographic, in which the sector is located within a region proximate to the ocean (e.g. coastal recreation services or real estate).

1988 Update - $109 Billion Ocean Sector Value:

It was envisioned in 1980 that the Ocean Sector measurements would be carried out periodically to refine the original methodology and update the estimates. Clearly, the best course would be to apply the Ocean Sector-disaggregation methodology to update the ocean account whenever the latest benchmark-year data become available. But given budgetary and other constraints this has not possible. Consequently, Sea Grant funded a small research project to update the value of the Ocean Sector using only broad indicators of the performance of the national economy and the ocean account relationships established in the 1980 study.

In 1988, the value added to the United States economy by the Ocean Sector had risen to $109 Billion. In the 15 years since 1972, the Ocean Sector essentially tripled in value, a growth that approximately matched the performance of the overall economy. As noted in the previous study, the contribution of the Ocean Sector to the GNP, approximately 3 percent, is comparable with other GNP components such as mining, transportation, and communications. Based on statistical tests that showed the distribution of GNP across sectors were proportionally the same over this period, it is thought that the $109 billion projection of value added by the Ocean Sector in 1987 is a reasonable approximation.

Source: Pontecorvo, Giulio, "Contribution of the Ocean Sector to the United States Economy: Estimated Values for 1987 -- A Technical Note", *Marine Technology Society Journal*, Vol. 23(2), (June, 1989).

THE SOCIAL SCIENCES IN MARINE RESOURCE CHANGE

Research by six Sea Grant social scientists will be published in a special issue of the *Journal of Ocean and Shoreline Management*. Entitled, *Responses to Marine Resource Change: Perspectives from the Social Sciences*, the volume focuses on the nexus between changes in a resource base and the human adjustment to those changes. It looks at the societal response, particularly the intervention by governmental institutions and the consequences of resultant public policies. The papers were originally presented as part of a Sea Grant social science research forum at the Second Symposium on Social Science in Resources Management, at the University of Illinois/ Champaign-Urbana in June, 1988.

The volume spans a broad range and highlights the work of Sea Grant's social scientists to understand the human response to marine resource change. The papers, some multidisciplinary, span the fields of economics, anthropology, and political science. Together, they provide a primer on how social science scholarship can illuminate the methods we collectively use when responding to resource change. The articles focus on fish stock depletion and recovery, estuarine pollution, and enhanced access to seabed minerals. Three economics articles are included.

"Managing Unpredictable Resources: Traditional Policies Applied to Chaotic Populations," by Sea Grant economists James A. Wilson and Ralph Townsend and their physicist co-authors argue that the uncertainty of the biological environment raises questions regarding claims for rational fisheries management. Specifically, they challenge the presumption of a predictable link between the size of current populations and future population levels. They introduce the theoretical possibility of a chaotic population dynamic by setting a total biomass constraint on a multiple species system. The biomass constraint reflects the increasing mortality of and predation on young fish when total system energy or food limitations are reached. When the

biomass limit is not met, the model produces stable populations; when total weight does reach the limit, stocks develop unpredictable variations. Allowing for a chaotic population dynamic, Wilson and his colleagues examine the implications of pursuing conventional management policies.

The second paper focuses on fisheries rehabilitation programs. Richard Bishop and co-authors in their paper, "Benefit-Cost Analysis of Fishery Rehabilitation Projects: A Great Lakes Case Study," develop an economic framework to weigh the tradeoff between reducing current catch and producing higher yields in the future. In a successful rehabilitation project, the costs, both in terms of the foregone near-term catch and management expenditures, are expected to be offset by the benefits of increased harvests at a later time. Their case study examines the blueprint to restore the Lake Michigan perch fishery. By the authors' calculations, commercial fishing will break even or just gain slightly while the recreational participants garner the lion's share of $19 million in expected net benefits. From an economic perspective, Bishop and his colleagues conclude that the rehabilitation of the yellow perch fishery looks very promising.

Economists James Broadus and Porter Hoagland focus on the information investment stages of seabed mineral development, namely, prospecting, discovery, and exploration. Their paper, "Marine Nonfuel Minerals in the U.S. Exclusive Economic Zone: Managing Information as a Resource," examines seabed resource information in a social capital framework. Investment in systematic exploration can be a significant proportion of total development costs. But gains made in understanding the geological, technological, and even legal/political attributes could make significant reductions in future production costs. In this context, they analyze policy issues dealing with scientific research expenditures and funding source, exclusivity of property rights, confidential treatment of information, performance requirements, and national security classifications.

Source: Shirley Fiske and Francis Schuler, (Editors), *Marine Resource Change: Perspectives from the Social Sciences, Journal of Ocean and Shoreline Management*, (In press).

COASTAL RESOURCES

Sea Grant's economic research directed at coastal resource focuses on issues of water-dependent land use, water issues, pollution abatement, and environmental improvements. The estimation of benefits derived from marine resources not traded in markets--such as identified with coastal recreation, wetlands, pollution, aesthetics, environmental quality, and fish habitat preservation--is a priority research area. It is important to account for these values and to advance the methodologies employed in valuing non-market goods and services.

Coastal Lands:

Coastal land use restrictions and public sector investments in environmental amenities exert a strong influence over coastal property values. Consequently, it is hypothesized that the social costs and benefits associated with zoning restrictions and environmental improvements are captured in coastal residential housing markets. Sea Grant economists are examining these issues.

Increasing growth in coastal areas results in intensified marine and coastal resource use. Attempts at the community or regional level to manage this growth often results in restricted land use. In the Delaware Sea Grant program, research is focusing on restrictive practices such as the California Coastal Commission's permitting rules and the Maryland Critical Areas restricted land use rules for the Chesapeake Bay. This restricted development has positive welfare gains, but it also carries with it an opportunity cost of commercial and residential displacement. The Sea Grant research is attempting to identify and measure these effects, using housing attributes and property values, as a guide to the economic issues of land use planning.

Shoreline erosion, the gradual disappearance of land, often requires investments to reduce the eventually threatening damages. If the benefits of erosion protection investments are capitalized in the market prices of shoreline property, the potential benefits from mitigation can be measured. Ohio Sea Grant economists, by analyzing Lake Erie real estate markets, have shown that erosion protection is a significant determinant of lakeshore property prices.

Source: Kriesel, Warren. *An Economic Analysis of the Role of Shoreline Erosion in Ohio's Residential Housing Market*, Ohio Sea Grant College Program, 103 pp., 1989.

Waterfront property for public access is rapidly disappearing. Recreational boating, which requires public access to water bodies, is particularly hard hit. Because of escalation in land values, the use of waterfront areas for marinas is becoming less profitable than for alternative uses of the land. One study indicates a less than one percent return on equity for saltwater marinas. Economists in the Florida Sea Grant program are evaluating the economics of "bluebelting" laws which could be used to preserve marina space where escalating waterfront values threaten to limit the public's access to boating. Analogous to greenbelting laws in agriculture, the bluebelting laws could help marinas compete for land using instruments such as tax incentives, zoning, and public purchase of development rights. The research will investigate whether land prices truly impede marina development and limit public access to waterways, and compute the economic benefits and costs associated with bluebelting regulations.

Wetlands:

Saltwater wetlands are productive natural systems that supply critical habitat to fish at various times in their life cycle. For the most part, estuarine wetlands are quasi-common property where actual owners cannot capture their implied rental value. This produces a market failure, and great incentive to convert wetlands to uses consistent with organized markets such as residential development and agriculture. Commercial developers and agricultural producers have readily available measures of the economic value resulting from conversion of wetlands to these purposes, since these activities result in market outputs such as housing and farm products. Environmental management agencies have made efforts to preserve these biologically productive resources, but often find it difficult to challenge the development benefits. Quit simply, we don't understand the economic value of the wetlands whose benefits are often unobserved and whose resulting products and services are not directly traded in markets.

Economics research at the Florida Sea Grant College Program, estimated the economic value of saltwater wetlands based upon the value of "services" to estuarine dependent commercial and recreational fisheries. The author employed marginal productivity theory to estimate the incremental contribution of estuarine wetlands to the marine fishery catch. The capitalized value of an acre of Florida's estuarine wetlands -- in terms of the carrying capacity for fishery stocks, one of but many wetland functions -- ranged between $2,000 for the West Coast to $10,000 for East Coast. These values can then be compared to actual acreage price in alternative uses such as residential and agricultural development.

Source: Bell, Frederick W., *Application of Wetland Valuation Theory to Commercial and Recreational Fisheries in Florida*, Florida Sea Grant Program, 118 pp., June, 1989.

Water Diversion:

Researchers at Wisconsin Sea Grant developed an economic model to assess the monetary impacts of potential large-scale Great Lakes water diversions on the shipping and hydropower industries in the region. The model indicates that a moderate-sized (10 thousand cubic feet per second [tcfs]) diversion would cost the industries $70-90 million annually, depending on the lake used as the source. A large diversion (30 tcfs) would cost them $250 million annually. In each case, the added costs to the Great Lakes hydropower industry are roughly 10 times those to the shipping industry. Although the added costs would be significant to these industries, they probably would be minor to the regional economy as a whole.

Source: David, Martin H., Rosenthal, Stuart S., and Eric D. Loucks. *Diversion of Great Lakes Water -- Part 2: Economic Impacts*, Wisconsin Sea Grant College Program, 1988.

_____, "Effects of Diversions of the North American Great Lakes", *Water Resources Bulletin*, Vol. 24(2), pp. 141-48, February, 1988.

Environmental Quality:

A significant proportion of the benefits of water pollution abatement accrue to marine recreational fishing, yet the techniques for valuing such benefits are not well developed. Researchers at the North Carolina Sea Grant program are

undertaking a comparative appraisal of methodologies being used for estimating benefits. The methods being tested are the varying parameters model, the hedonic travel cost model, and the random utility model. Each will be applied to data from recent North Carolina Sea Grant and National Marine Fisheries Service recreational fishing surveys. Research on advanced techniques for estimating the value of enhancements to marine resources resulting from water quality improvement will provide information on pollution abatement benefits directly and help guide future research.

Economists in the California Sea Grant program are measuring the benefits and costs of managing environmental variability in the California salmon fishery. The research will analyze the sources of variability (environmental, fishery harvest, hatchery, stream flow and diversion) that produce uncertainty and stochastic variation in chinook salmon population levels. Costs and benefits of alternative measures to offset these effects, either by reducing variability or improving information, will be examined. The core of the research is a comparison of the tradeoff between the value of having better information to predict variability vs. the value of structural changes that smooth the system.

While oil spills from tanker accidents, such as the *Amoco Cadiz* and the *Exxon Valdez*, reach the public's attention, it's estimated that 75 percent of the oil spilled in marine transportation occurs from discharges by ships in the course of routine operations. Economists at the California Sea Grant program are addressing the question of the optimal policies for deterring these oil spills and the efficiency of public expenditures spent on marine pollution control. It directly addresses the question of whether technical standards or economic incentives provide more effective pollution control policies. A model of optimal pollution control policy will be used to compare damage caused by pollution with the amount paid in penalties by the originators of the spill.

MARINE RESOURCE DEVELOPMENT

The economic growth and competitiveness of the marine sector – aquaculture, commercial fisheries, seabed mining, water-borne transportation, offshore energy, marine biotechnology, and coastal recreation – is important to the national economy. Study of the economic effects of technological innovation on the productivity of marine industries, and the linkages of national macroeconomic and trade policy to their performance are high priority research areas.

Aquaculture:

Sea Grant has long recognized the value of an interdisciplinary research approach, social scientists working alongside natural scientists to develop marine resources. Typical of this is the economic analysis of hybrid striped bass aquaculture carried out by economists at the North Carolina Sea Grant program.

The report examines the projected costs of raising hybrid striped bass in eastern North Carolina. The information is derived from the first commercial-scale facility for raising hybrids in the state and literature on the economics of catfish farming. Budgets are presented for various scenarios a producer might encounter. Costs ranged between $1.34 per pound for 120 acres of water to $1.44 per pound for 30 acres.

Source: Brown, John W., Easley, James, and Ronald G. Hodson. *Investment and Production Costs for the Hybrid Striped Bass x white bass in North Carolina*, North Carolina Sea Grant College Program, November, 1988.

Seafood Quality:

Sea Grant studies at the Florida and the Rhode Island Sea Grant programs will study the economic issues related to seafood safety and quality. The research, focused on seafood consumers, will examine consumer perceptions of seafood quality and estimate how changes in perceived quality influence the demand for and price of seafood products.

Fisheries Rehabilitation:

Economists at the Maryland Sea Grant program are assessing the reasons for the current decline in the seafood processing industry. Using Maryland as a case study, the investigators will evaluate policy alternatives proposed to rehabilitate and encourage the seafood industry's growth, improve employment opportunities, and provide consumers with low-priced seafood. A statistical analysis of the cost structure inherent in a multi-product seafood processing firm and an

econometric analysis of the national market for oysters will be used to analyze policy alternatives which could rejuvenate the industry.

Recreation:

The burgeoning demand for water-based recreation and tourism drives the investment decisions of governments and the private sector recreation industry. At the University of Minnesota, Sea Grant economists are developing a recreation demand model to study how demand is affected by changes in the quantity and quality of the resource base and by the level of investment in recreation and tourism facilities and infrastructure. Lake Superior data will be used to model individual decisions regarding whether to recreate or not, where to go, and how long to stay based on the attractiveness of alternative sites and the cost of gaining access to them. Substitution among sites will be captured in the model. This research will provide a predictive tool to evaluate resource management decisions which affect recreation and tourism development. The modeling results will enable more accurate measures of the impact of investment decisions on recreation activity and an assessment of their economic benefits, which may then be compared to costs.

In placing an economic value on recreation resources such as a fishery, the primary focus is usually on direct benefits to the users. However, the businesses that supply goods and services used in recreational fishing also generate secondary economic benefits. Expenditures by recreation participants are of particular importance in regional economic development and to communities concerned about the local employment and income effects of natural resource policies. If pertinent, these employment and income effects should be accounted for when resource use priorities are set. In order to consider supply side impacts, methods are needed to measure the secondary effects of policies which modify resource availability and use. Economists at the Ohio Sea Grant program are developing techniques, derived from input-output models, that will permit the incorporation of supply side benefits into fisheries policy calculations. The investigators use the Lake Erie fishery as a case study. The U.S. input-output table will be disaggregated for the Lake Erie region using recent Sea Grant surveys of charter boat firms, marinas, bait dealers, charter anglers, and private-boat anglers.

ALLOCATION OF RESOURCES

The design of efficient mechanisms to allocate fishery resources and minimize industry dislocations is a central focus of the Sea Grant marine economics program. Research goals are to determine how fishermen respond to regulatory constraints; to compare the benefits from management against the regulatory costs, both from public outlays and from inefficiencies imposed on the industry as a result of controls; and to develop empirical techniques that will provide comparable measures of the value of fish stocks in alternative uses.

User Conflicts:

Economists at the University of Rhode Island are analyzing the efficiency of the allocation of stocks in recreational fisheries using the New England Atlantic bluefin tuna fishery as an illustrative case study. The focus is on within-season quota allocations with its attendant policy issues (license fees, creel limits) and political constraints. Recreational harvest allowances for the season are taken as given and the question of how this level is efficiently allocated across user groups is analyzed. Assumptions built into the model incorporate peak load demand, quality aspects in terms of fishing success and congestion, and relative benefits between commercial and recreational fishermen.

Limited Entry:

A case study examining the social and cultural aspects of limited entry fisheries management is helping fisheries managers to understand the social effects of regulatory regimes. Social scientists in the New Jersey Sea Grant program are evaluating the regulation of the surf clam and ocean quahog fisheries. Key questions pertaining to the social impacts of fishery regulation are under study. The investigators are tracing entry and exit patterns in this fishery since limited entry began in 1977 to detect social changes in participation, ownership, and labor supply patterns due to the restrictive entry regulations in the surf clam fishery.

Public Policy and Institutional Barriers:

An economic historian/legal scholar at the California Sea Grant College program is studying

how global economic change and U.S. international economic policy have affected the U.S. tuna industry over the last four decades. The target of the study is the impact that segmented public policies had on a key marine fishery. From the historical perspective of global change in technology, science, and commerce, the effectiveness of the tuna industry's response both to changing market forces and public policies will be examined.

Future Directions

Increasing the competitiveness of marine resource-based industries is an underlying goal of the Sea Grant College program. Economics research contributes to this end through analyses of the opportunities and problems marine sector industries face in delivering goods and services to the marketplace.

Sea Grant economists are encouraged to adopt a longer time-horizon and a more basic research approach. Objectives should be focused on long-term marine industry development issues, and related resource-use questions. Several priority areas are identified below. However, good ideas are always welcome and open to full consideration. Research must offer the promise of making a contribution to the both the industry development goals of the Sea Grant program and to economics scholarship. Interdisciplinary efforts with the natural sciences are strongly encouraged.

Research areas considered to be high priority are the following:

o DEVELOPMENT AND COMPETITIVENESS OF MARINE INDUSTRIES -- The long-term economic development, growth, and competitiveness of marine sector industries -- such as aquaculture, commercial fisheries, seabed mining. offshore energy, water-borne transportation, marine biotechnology, and coastal recreation -- are important areas for investigation. Study of the linkage between technological innovation and productivity, and between national economic policy and industry performance is also a high priority research area.

o PROPERTY RIGHTS IN OCEAN SPACE -- There is need for continued clarification of ocean property rights across the whole spectrum of marine resource development. If ocean property rights are not satisfactorily defined, incentives for technological advancement are lessened. The familiar debates on over-fishing, coastal waterfront development, beach access, estuarine pollution discharge, ocean dumping, aquaculture leasing, sea level rise, and seabed mining claims exemplify property rights issues in the oceans. Sea Grant wants to develop a research program built around the concept of property rights in ocean space. It would be multidisciplinary and include economic, legal, social, historical, and political research on ocean property rights related to resource use.

o SEAFOOD INDUSTRY - QUALITY AND PRODUCTIVITY -- There are several key economic issues bearing upon growth of the seafood industry. Product liability, tied to health considerations, and calls for mandatory Federal seafood inspection are of great concern to domestic producers. We need to take a rigorous look at seafood product-quality issues. World trade in aquaculture commodities is growing and will likely add significantly to global competition in seafood products. How will this development affect the competitive position of the United States industry? Also, resource harvesting and food processing technology are changing rapidly. We should understand how this will alter industry productivity.

o RESOURCES OF THE EXCLUSIVE ECONOMIC ZONE (EEZ) -- The declaration by President Reagan of a 200-mile EEZ for the United States in 1983 presents a compelling opportunity for studying the economic resources of this vast area. Research to understand the economic significance of these resources and to analyze economic development strategies is considered high priority.

o FISHERIES MANAGEMENT -- The design of efficient mechanisms to allocate fishery resources and minimize industry dislocations is the most critical problem in fisheries management. Research is required to determine how fishing behavior responds to regulatory constraints; to measure benefits from management; to weigh these against regulatory costs, both public outlays and industry's compliance costs; and to improve empirical techniques to measure the value of fish stocks in alternative uses. Routine economic baseline studies in support of fisheries management are low priority.

o WATER AND COASTAL LAND MANAGEMENT -- Land use control, water quality, and waste management are severe problems in coastal areas and present important economic research opportunities. The economics of ocean disposal of wastes and hazardous materials and the design of market incentives for pollution abatement and environmental improvements continues to be an important area of study.

o CLIMATE AND GLOBAL CHANGE -- NOAA, as the earth systems agency, has a direct interest in understanding human interactions with the global environment. Sea Grant should endeavor to study the socioeconomic dimensions of global climate change through policy-oriented economics research on the effects of climate/ocean changes on climate-sensitive industries such as fisheries and aquaculture, coastal recreation and tourism, and marine transportation.

o ECONOMIC ASPECTS OF MARINE DEBRIS -- Sea Grant has received additional FY 1990 NOAA funds to support an economics research program on marine debris related problems. Priority study areas would include: the economics of public policies to reduce marine debris such as education, monetary incentives, and direct regulation; issues of regulatory compliance and enforcement; alternative on-land marine debris disposal options; impacts of debris on the value of marine resources such as fish stocks and mammals, and coastal aesthetic quality; costs of marine debris to resource dependent industries such as commercial and sports fishing, shipping, and recreational boating, and coastal tourism.

o NON-MARKET BENEFITS FROM MARINE RESOURCES -- The estimation of benefits derived from the use of marine resources not directly traded in markets -- such as identified with marine recreation, wetlands, and fish habitat preservation, and environmental quality -- is an appropriate research area. However, it should be demonstrated that the research will advance and empirically test new valuation methodologies.

PROJECTS

MARINE ECONOMICS

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
1. Fisheries Management and Development:		
Global Economic Change, U.S./Foreign Tuna Industry H.N. Scheiber 20 California Sea Grant College Program	6,590	13,204
Consumer Preferences and the Economic Consequences of Safety Program for Shellfish Products J.W. Milon 14 Florida Sea Grant College Program	30,800	27,800
Predicting Change and Maintaining Productivity in a Fishery Transformed by Real Estate Development and Tourism S.K. Meltzoff 20 Florida Sea Grant College Program	36,900	18,400

An Economical Analysis of the Decline in Maryland Seafood Processing I. Strand 14 Maryland Sea Grant College Program	0	5,700
Social and Cultural Responses to Regulation in the Surf Clam and Ocean Quahog Fisheries B. McCay 20 New Jersey Sea Grant Program	6,400	7,600
Supply Side Benefits of Fisheries: Estimation of Incremental Economic Impacts Using Input-Output L.J. Hushak 14 Ohio Sea Grant College Program	18,733	12,913
Management of a Mixed-Stock Fishery: Economics Evaluation of Alternatives S.S. Hanna 14 Oregon Sea Grant College Program	23,400	56,500
An Analysis of Market Channels for Pacific Coast Salmon and Groundfish R.S. Johnston 14 Oregon Sea Grant College Program	30,400	29,200
Economic Analysis of the Commercial Troll Salmon Fishery W.S. Jensen 14 Oregon Sea Grant College Program	27,000	31,500
Consumer Perceptions of Seafood Quality J. Anderson 20 Rhode Island Sea Grant College Program	22,762	57,253
Optimal Control of the Alaska King Crab Industry* S.C. Matulich 14 Washington Sea Grant College Program	(10,000)	0
Valuation of Great Lakes Fisheries R.C. Bishop 14 Wisconsin Sea Grant Institute	20,081	33,421
SUBTOTAL:	$ 233,066	$ 293,491
PASSTHROUGH	10,000	

2. Aquaculture:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Hybrid StripedBass Culture: Evaluation and Growth Enhancement for Commercial Production R. Hodson 02 North Carolina Sea Grant College Program	66,032	27,581
SUBTOTAL:	$ 66,032	$ 27,581

3. Marine Recreation:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
The Benefits and Cost of Managing Environmental Variability: The Chinook Salmon Fishery W. Hanemann 48 California Sea Grant College Program	28,073	46,267
Toward a Complete Theory of Recreational Fishery Economics L.G. Anderson 14 Delaware Sea Grant College Program	1,950	24,515
Recreational Fishing Practices J. Auyong 06 Hawaii Sea Grant College Program	16,449	43,912
Risk Management for Recreation R. Pfund 19 Hawaii Sea Grant College Program	13,392	17,946
An Analysis of Great Lakes Salmonid Angler Preferences in Lake Michigan R.B. Peyton 20 Michigan Sea Grant College Program	34,361	18,850
Demand for Resource-Based Tourism in Northern Minnesota T.D. Graham Tomassi 19 Minnesota Sea Grant College Program	12,81	3,220
Risk Perception and Communication Regarding Chemically Contaminated fish in Lake Ontario B.A. Knuth 29 New York Sea Grant Institute	9,523	15,474

A Comparative Appraisal of Demand Methodologies for Estuarine Recreational Benefits V. Smith 14 North Carolina Sea Grant College Program	6,168	22,929
Recreational Fish Harvests: The Link Between Economic Benefits, Efficient, Resource Allocations, and Policy Options S.K. Swallow 18 Rhode Island Sea Grant College Program	28,326	25,961
Recreational Angler Survey Techniques: Application of a Simulation Model to Determine Behavior, Bias, and Confidence Interval C. Jones 18 Virginia Graduate Marine Science Consortium Sea Grant Program	51,042	26,477
SUBTOTAL:	$ 202,094	$ 245,551

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
4. Coastal Resources:		
Deterring Oil Spills: Optimal Policies R. Carson 14 California Sea Grant College Program	11,454	26,428
Toward the Development of Probabilistic Scenarios of Sealevel Vulnerability Along the Connecticut Shoreline G.W. Yohe 38 Connecticut Sea Grant Program	21,337	18,723
An Economic Analysis of Beach Preservation J.R. Parsons 14 Delaware Sea Grant College Program	2,340	13,642
An Analysis of Tourist User Value an Its Impact on the Demand for Selected Marine Coastal Resources in Florida F.W. Bell 19 Florida Sea Grant College Program	13,800	6,900
A Computer-Directed Geographic Coastal Use Classification System for Ecologic Planning: The Case of the Florida Keys G.A. Antonini 38 Florida Sea Grant College Program	43,100	47,800

An Analysis of Great Lakes States; Water Diversion Policies and Their Implication for Development and the Environment K.W. Easter 14 Minnesota Sea Grant College Program	22,510	7,370
Socio-Economic Assessment of Compliance with Estuarine Governance Programs J. Sutinen 20 Rhode Island Sea Grant College Program	32,564	43,615
Consumptive Use of Great Lakes Water E.F. Joeres 20 Wisconsin Sea Grant Institute	70,819	17,421
SUBTOTAL:	$ 217,924	$ 181,899

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS

5. Marine Minerals:

Alternate Economic Deposits J.C. Wiltshire 10 Hawaii Sea Grant College Program	9,280	10,800
Cyclical Behavior in Marine Minerals Exploration and R&D: Signals, Sources, and Implications J.M. Broadus 14 Woods Hole Oceanographic Institution Sea Grant Program	45,400	40,863
SUBTOTAL:	$ 54,680	$ 51,663

6. Marine Transportation:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Cargo Preference and Government Export Promotion: Policy Implications for the Great Lakes Shipping in the Port of Duluth C.F. Runge 14 Minnesota Sea Grant College Program	17,080	5,670
SUBTOTAL:	$ 17,080	$ 5,670

7. Marine Technology:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
International Tech and Information Transfer Program J. Sullivan 77 California Sea Grant College Program	10,000	10,577
An Analysis of Normative & Conceptual Issues in the Regulation of Biotechnology in the Nation's Bays and Estuaries M. Sagoff 20 Maryland Sea Grant College Program	24,800	11,700
SUBTOTAL:	$ 34,800	$ 22,277
GRANDTOTAL	$ 825,676	$ 828,132

Marine Recreation and Tourism

Summary

The National Sea Grant College program in Marine Recreation and Tourism responds to the legislative mandate to promote the efficient use and development of marine resources. Coastal recreation is very important to the economic base of coastal communities and the nation in general. It is also a major catalyst in making recreation and tourism one of the fastest growing industries in the United States.

Sea Grant conducts both a research and extension program in marine and coastal recreation. The research program is interdisciplinary involving economists, legal scholars, social scientists, engineers, and specialists from many of the natural sciences. Technology transfer and education is emphasized through the network of marine advisory and extension programs nationwide.

Sea Grant's program in Recreation and Tourism in Fiscal Year 1989 consisted of 22 research projects. Funding for the Recreation and Tourism research amounted to $489 thousand, with another $527 thousand contributed in matching funds. This is approximately the same funding level as in Fiscal Year 1989. In addition, most Sea Grant universities conduct a recreation advisory effort to provide educational and technical assistance to the industry.

Introduction

Sea Grant's legislative mandate to develop marine resources is the impetus for its investment in a coastal tourism and marine recreation program. Coastal tourism development is clearly linked to marine recreation, and both are very important to the economic base of coastal communities and the nation in general. Sea Grant conducts both a research and an extension program to support sound coastal tourism and marine recreation business development.

The research program is interdisciplinary – involving economists, legal scholars, social scientists, engineers, and specialists from many of the natural sciences. The Marine Extension Service, Sea Grant's technology transfer and education arm, provides a network of coastal specialists nationwide to transfer research results.

Sea Grant's Coastal Tourism and Recreation program is currently addressing issues such as coastal recreation expansion, tourism development, marine recreational fishing, boating, marina management, small craft harbor engineering, severe weather information for coastal visitors, waterfront use, coastal access, recreation safety, shoreline protection, recreation demand and economic impact studies. Several other Sea Grant areas – waterfront revitalization, water quality and pollution control, coastal land use, fisheries management, ocean engineering, coastal processes, navigation, and natural hazards – provide indirect support to the coastal tourism development program.

The Program

Sea Grant's program in Recreation and Tourism in Fiscal Year 1989 consisted of 22 research projects. In addition, most Sea Grant universities conduct a recreation advisory effort to provide educational and technical assistance to the industry.

Sea Grant funding for the Recreation and Tourism program amounted to $489 thousand, with another $527 thousand contributed in matching funds. This is approximately the same funding level as in Fiscal Year 1988. Table 1 gives the breakdown by subject areas for recreational fishing, recreational boating, general recreation and tourism, and technical support studies.

TABLE 1

MARINE RECREATION AND TOURISM
BY SUBJECT AREA, FISCAL YEAR 1989

Subject Area	Number of Projects	Sea Grant (Thou. $)	Match (Thou. $)
1. Recreational Fishing	11	232	276
2. Recreational Boating	1	40	23
3. Coastal Tourism Development	7	112	110
4. Technical Support Studies	3	105	119
TOTAL	22	489	527

Recreational Fishing

Marine recreational fishing ranks high among the nation's favorite leisure activities. Sea Grant research addresses the use of ocean, coastal, and Great Lakes resources in satisfying angler demand for quality fishing opportunities. The sport's development potential and current value to the marine economy drive the research agenda and enable Sea Grant to fulfill its legislative mandate to foster the wise use and development of marine resources.

Recreational Fishing Development:

In placing an economic value on recreation resources such as a fishery, the primary focus is usually on benefits to the users. However, the supplies of goods and services used in recreational fishing also generate secondary economic values. Expenditures on goods and services by resource users are of particular importance in regional economic development and to communities concerned about the local employment and income effects of fisheries policies. If pertinent, these employment and income effects should be appropriately included before resource policy priorities are set. In order to consider supply side impacts, methods are needed to measure the secondary effects of policies which modify resource availability and use. Economists at the Ohio Sea Grant program are evolving techniques which incorporate supply side benefits into fisheries policy using input-output models. The investigators use the Lake Erie fishery as a case study. The national U.S. input-output table will be disaggregated for the Lake Erie area using recent Sea Grant surveys of charter firms, marinas, bait dealers, charter anglers, and private-boat anglers.

At New York Sea Grant, economists estimated the benefits of marine sport fishing on Long Island Sound. Two types of measures of economic benefits were employed. The first, direct expenditures, are the outlays made by recreational fishermen as a result of their fishing activity. They include expenditures for food, bait, fuel, party or charter fares, and boating and fishing equipment. Their estimate of expenditures was $1.1 billion in 1987 and shows how important recreational fishing is to the regional economy. The second measure of benefits, net economic benefit (i.e. consumer surplus), can be viewed as the maximum amount anglers are willing to pay to continue to engage in

recreational fishing. It measures the net value of fishing to the fishermen themselves. This measure was approximately as great as total expenditures. Although the sensitivity of economic benefits to changes in the quality of the fishery needs further study, it is apparent that the deterioration of recreational fishing would have serious economic consequences.

Source: Kahn, James R., "The Economic Value of Long Island Saltwater Recreational Fishing", New York Sea Grant Institute, 17pp., 1989.

Fishing Quality:

Efforts are underway throughout the Great Lakes region to find effective ways to communicate information about the chemical contamination of fish . At the New York Sea Grant program, researchers are investigating how risk perceptions are formed and how information regarding chemically contaminated fish is communicated. Social judgment analysis will be used to identify the role communication plays in the formation of risk perceptions among anglers, consumers, and fishery managers. Since the participant study groups differ according to the extent of their fishery involvement, the research will be able to identify key relationships between risk perceptions and risk information communication. The knowledge gained about differences in risk perception will be used to suggest changes in current communication strategies.

An analysis of Great Lakes salmonid angler preference by economists at Michigan Sea Grant is addressing a controversial issue in fishery policy, namely, rehabilitation to self-sustaining stocks versus the operation of hatchery-based sport fisheries. The research takes as a starting point that recreational resource users are not homogenous. Consequently, there is a need for research on angler specialization and development, and for working out its implications for management. The research will add to our understanding of whether anglers place a higher value on Great Lakes diversity, thus favoring rehabilitation. The research also addresses whether the public's involvement through special interest groups represents a broad or limited scope of salmonid angler interests.

Catch and Effort Survey Methodology:

Management of marine recreational fisheries depends on having an accurate knowledge of the level of fishing pressure and the total harvest. When a fishery is thought to have a significant recreational catch and the magnitude of this catch remains unknown, management of the fishery is handicapped. Recreational catch and effort in diffuse-access fisheries has proven particularly difficult to assess. Researchers at the Virginia Sea Grant program are developing a model to improve upon an important recreational angler survey technique, the roving creel survey. A simulation model, specifically developed for application to the blue crab recreational fishery, will be used to study the behavior of the estimates of catch and effort. The simulation model will provide "ground truth" from which the bias of the estimators can be determined.

Recreational Boating

The growth of boating is dependent upon increasing the public's access to the water. While hard statistics are not available, it is thought that waterfront property is rapidly disappearing from use for boating access because escalating land values make marinas unprofitable. A recent study reported a less than 1 percent return on equity for saltwater marinas in Florida.

Marina Development:

Waterfront property for public access is rapidly disappearing. Recreational boating, which requires public access to water bodies, is particularly hard hit. Because of escalation in land values, the use of waterfront areas for marinas is becoming less profitable than for alternative uses of the land. One study indicates a less than one percent return on equity for saltwater marinas. Economists in the Florida Sea Grant program are evaluating the economics of "bluebelting" laws which could be used to preserve marina space where escalating waterfront values threaten to limit the public's access to boating. Analogous to green-belting laws in agriculture, the bluebelting laws could help marinas compete for land using instruments such as tax incentives, zoning, and public purchase of development rights. The research will investigate whether land prices

truly impede marina development and limit public access to waterways, and compute the economic benefits and costs associated with bluebelting regulations.

Recreation and Tourism Development

Enhanced coastal recreation opportunities depend on the approach coastal communities take to development. Business and government leaders often favor coastal recreation and tourism development because it is a clean industry that builds the local economic base. Coastal residents are often more ambivalent, pointing to "tourist pollution", but also recognizing benefits from new jobs, regional income gains, and community infrastructure improvements. Sea Grant research focuses on helping local municipalities and private enterprises to take into account these tradeoffs. For example, socioeconomic studies of participants allow for a better understanding of the recreation market segment being served and to estimate future demand. Economic valuation and impact analyses provide an estimate of benefits that can be expected from investments made to enhance recreation opportunities. This information has proved to be a valuable input in framing fiscal choices about recreation development activities ranging from planning, to promotion, to public or private construction of new recreation facilities.

Resource Effects on Recreation Demand:

The burgeoning demand for water-based recreation and tourism drives the investment decisions of governments and the private sector recreation industry. At the University of Minnesota, Sea Grant economists are developing a recreation demand model to study how demand is affected by changes in the quantity and quality of the resource base and by the level of investment in recreation and tourism facilities and infrastructure. Lake Superior data will be used to model individual decisions regarding whether to recreate or not, where to go, and how long to stay based on the attractiveness of alternative sites and the cost of gaining access to them. Substitution among sites will be captured in the model. This research will provide a predictive tool to evaluate resource management decisions which affect recreation and tourism development. The modeling results will enable more accurate measures of the impact of investment decisions on recreation activity and assessment of their economic benefits, which may then be compared to their costs.

Technical Support Study

Artificial Reefs:

Despite the widespread building of artificial reefs, little is known about their function. Research to test hypotheses concerning recruitment of fishes to artificial reefs and to understand whether artificial reefs redistribute fishes already present or produce significant new biomass is critical for wise management. At the Florida Sea Grant program, researchers are trying to sort out this complex question through a comparative censuses of the relative importance of recruitment, attraction, and production of reef fishes on natural and modular artificial reefs.

To provide the proper quantity and quality of artificial shelter for fish stocks involves questions of the optimal design of man- made reefs. To test the long-standing assumption that the population sizes of reef fishes are determined by the availability of suitable shelter sites, University of Puerto Rico Sea Grant program researchers are experimenting with different artificial reef design characteristics such as compartment configurations and numbers, property of materials, and the fauna of surrounding habitats. In terms of basic science, this study will provide data on the role shelter characteristics play in structuring reef-fish assemblages.

Ocean Recreation Industry Liability:

The changing composition of the marine recreation and tourism market is toward more action-oriented activities. However, the viability of the commercial ocean recreation industry which supports this market segment is in jeopardy because of the high cost of liability insurance. At the University of Hawaii Sea Grant College program, researchers are attacking this problem by surveying the risk management practices of small, ocean recreation businesses. The long-term goal is to assist these enterprises minimize their liability risk and insurance costs by establishing industry guidelines for risk management, including personnel training and certification and client education.

Technology Transfer

The Sea Grant Marine Advisory Service is the technology transfer and educational arm of the research program. For example, diverse Sea Grant research on small craft harbor design, ice engineering, materials science, and financial management is brought together in workshops for Great Lakes marina operators sponsored by the regional extension programs. Research on barrier island dynamics, nearshore sand transport, and shoreline protective structures is transferred to coastal property owners and local or state governments through the network of Sea Grant's advisory programs up and down the Atlantic seaboard. In conjunction with the National Weather Service, Sea Grant prepared weather guides and issued information on severe weather precautions through the local media to coastal recreationists. Recreation safety information is given nationwide distribution. It ranges in content from the prevention of hypothermia, to avoiding recreationally caught contaminated fish and shellfish, to detailing how to swim out of a rip current.

Program Goals

Some program goals are aimed at broadening a general understanding of recreation and tourism; others are targeted more toward marine recreation and tourism development. They are listed in no particular order. Each one was determined through the input of industry, government officials and planners, and scholars to be among the more important goals of a marine recreation and coastal tourism agenda.

o Develop measures of the benefits and costs associated with allocating marine resources to coastal recreation and tourism, relative to alternative uses.

o Understand the biological and physical limits of the coastal environment, and the impact of recreation and tourism activities upon the coastal ecosystem.

o Determine current conditions of water and habitat quality, and provide a scientific basis for resource enhancement, rehabilitation, and preservation of recreational and aesthetic natural assets.

o Measure the full recreational value derived from coastal resources, including non-market and non-consumptive uses.

o Develop forecasting and simulation techniques to gauge the patterns and project future visitor preferences, choices, and satisfactions.

o Determine the factors affecting the demand for and supply of marine recreation and tourism services, and identify recreation trends and their effect on the growth of the industry and the broadening of recreation opportunities.

o Identify the cultural, social, and historical significance of coastal areas and marine communities that enhance tourism.

MARINE RECREATION AND TOURISM

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
1. Marine Recreational Fishing:		
The Benefits and Cost of Managing environmental variability in the California Central Valley Chinook Salmon Fishery W. Hanemann 48 California Sea Grant College Program	28,073	46,267
Toward a Complete Theory of Recreational Fishery Economics L.G. Anderson 14 Delaware Sea Grant College Program	1,950	24,515
Recreational Fishing Practices J. Auyong 06 Hawaii Sea Grant College Program	16,449	43,912
An Analysis of Great Lakes Salmonid Angler Preferences and Expectancies for Future Fisheries Management Programs in Lake Michigan R.B. Peyton 20 Michigan Sea Grant College Program	34,361	18,850
Risk Perception and Communication Regarding Chemically Contaminated fish in Lake Ontario B.A. Knuth 29 New York Sea Grant Institute	9,523	15,474
A Comparative Appraisal of Demand Methodologies for Estuarine Recreational Benefits V. Smith 14 North Carolina Sea Grant College Program	6,168	22,929
Communication Networks in Marine Recreational Fishing R.R. Perdue 18 North Carolina Sea Grant College Program	16,816	4,810
Supply Side Benefits of Fisheries: Estimation of Incremental Economic Impacts Using Input-Output L.J. Hushak 14 Ohio Sea Grant College Program	18,733	12,913

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Recreational Fish Harvests: The Link Between Economic Benefits, Efficient, Resource Allocations, and Policy Options S.K. Swallow 18 Rhode Island Sea Grant College Program		28,326	25,961
Recreational Angler Survey Techniques: Application of a Simulation Model to Determine Behavior, Bias, and Confidence Interval C. Jones 18 Virginia Graduate Marine Science Consortium Sea Grant Program		51,042	26,477
Valuation of Great Lakes Fisheries R.C. Bishop 14 Wisconsin Sea Grant Institute		20,081	33,421
	SUBTOTAL:	$ 231,522	$ 275,529

2. Boating:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
The Effects of Lightning on Strike Probability and Damage to Boats E.M. Thomson 23 Florida Sea Grant College Program		40,500	22,800
	SUBTOTAL:	$ 40,500	$ 22,800

3. Costal Tourism Development:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
An Economic Analysis of Beach Preservation J.R. Parsons 14 Delaware Sea Grant College Program		2,340	13,642
An Analysis of Tourist User Value and Its Impact on the Demand for Selected Marine Coastal Resources in Florida F.W. Bell 19 Florida Sea Grant College Program		13,800	6,900

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Predicting Change and Maintaining Productivity in a Fishery Transformed by Real Estate Development and Tourism S.K. Meltzoff 20 Florida Sea Grant College Program	36,900	18,400
Risk Management for Recreation R. Pfund 19 Hawaii Sea Grant College Program	13,392	17,946
Advisory Services in Marine Recreation and Tourism M.M. Liffmann 19 Louisiana Sea Grant College Program	19,280	19,529
The Attitude Basis of Marine/Coastal Litter: Assessing Louisiana Coastal Users' Attitudes Toward the Environment S.B. Laska 20 Louisiana Sea Grant College Program	13,678	30,005
Demand for Resource-Based Tourism in Northern Minnesota T.D. Graham Tomasi 19 Minnesota Sea Grant College Program	12,810	3,220
SUBTOTAL:	$ 112,200	$ 109,642

4. Technical Support Studies:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Computer-Aided Harbor Design H. Loomis 23 Hawaii Sea Grant College Program	48,288	82,453
Impact Analysis and Foundation Design for Collision Tolerant Pile Structures K.C. Baldwin 25 Maine/New Hampshire Sea Grant Program	39,001	21,772
Harbor Ice and Marine Advisory Services C.A. Wortley 25 Wisconsin Sea Grant Institute	17,656	15,232
SUBTOTAL:	$ 104,945	$ 119,457
GRANDTOTAL:	$ 489,167	$ 527,428

Ocean Engineering

Summary

Competitiveness is directly linked to improved productivity, which in turn is dependent on improved technology. It is the goal of the ocean engineering program to provide the technology needed by the marine sector of our economy.

In FY 89, 85 projects were supported in ocean engineering at a Federal funding level of $3,884,780 with an additional $2,398,180 in non-Federal match. Projects are grouped in 18 subprogram categories in order to better indicate the problem orientation of the various studies. Several examples of effective focusing of activities are given, including fisheries engineering and underwater work vehicles. Program leadership continues to be shown by the Massachusetts Institute of Technology Sea Grant College Program, which had 18 projects at a Federal funding level of $1,268,870.

Introduction

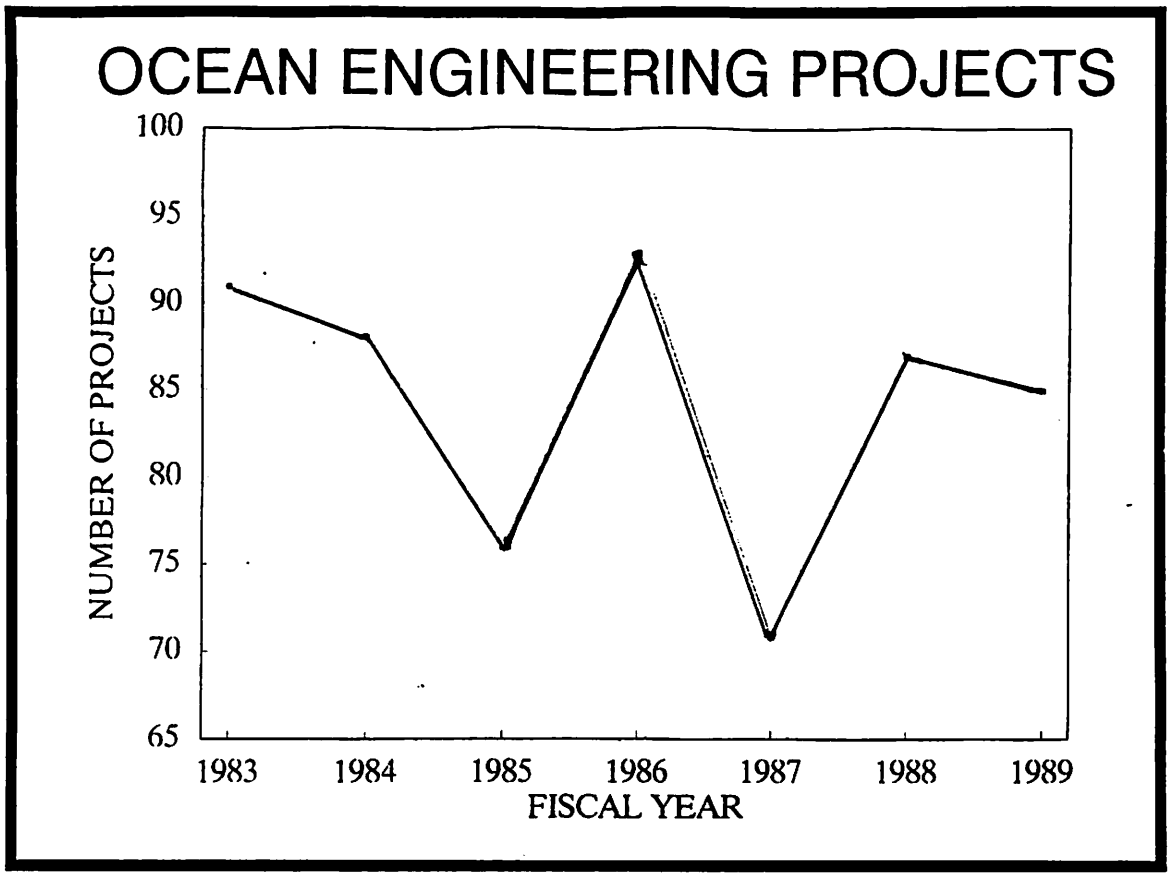
This analysis of the National Sea Grant College Program in Ocean Engineering is based on the listing of current projects as of October 1, 1989. There has been no attempt to avoid multiple listing with other reports being prepared at this time, and the choice of including or excluding projects represents the subjective judgment of the author. A total of 85 projects are listed. The total Federal funding is $3,884,780 and the non-Federal match is $2,398,180. $1,351,515 of the Federal funds were provided by pass-through from other agencies.

Relationship to Other Federal Programs

Support for ocean engineering research and development is provided by many agencies, and in each case the efforts are directed toward the mission interests of the particular agency. The most significant among these programs is undoubtedly Navy. Others include Corps of Engineers, U.S. Coast Guard, Department of Interior, Maritime Administration, and Department of Energy. The National Science Foundation has started a small scale Ocean Engineering Program. Until this past two years, no such program existed in the Foundation, but an investigator might contribute directly or indirectly to ocean engineering problem solution through participation in the other engineering programs which were offered; an example might be a study of structural dynamics analysis methods. The NSF Ocean Engineering Program is affected significantly by the NSF norm of fundamental science. Sea Grant Ocean Engineering studies remain unique in the objective of encouraging the best among academic engineering researchers to turn their attention toward marine problems; and in its full spectrum approach, i.e., an integrated program of research, education, and advisory services.

Interagency program coordination is accomplished by sending proposals to appropriate agency staffs for review, and joint program planning or review meetings when appropriate. Memorandums of understanding affecting ocean engineering research and development have been developed with the Navy Explosive Ordnance Disposal Technology Center and the David Taylor Research Center. These MOU's are considered the basis for pass-through funding of research by other Navy offices also, e.g. the Naval Surface Warfare Center and the Naval Sea Systems Command.

Close cooperation with Navy ocean engineering programs has developed in the past several years, and cooperative research programs are in progress with pass-through funding. The most significant of those current during 1989 included 1) research aimed at the technology necessary to locate submerged objects in harbors (NAVEODTECHCEN); 2) research on the causes of deterioration of synthetic fiber ropes in marine usage (NCEL); 3) research related to propeller and computer-aided hull design (DTRC); and 4) a study of the tensions in towing systems (NAVSEA).



Education

With the restricted budget of the National Sea Grant College Program these past few years has come a curtailment of curriculum development projects in ocean engineering. Support of education projects during FY 1989 was restricted to two institutions. A characteristic of this part of the program is that it is heavily matched (less than $1 Federal to $3 Institution).

Two of these projects (Massachusetts Institute of Technology and New Hampshire) are designed to give undergraduates an engineering research experience. In addition to their educational value (this is an excellent aid to producing promising young engineers and engineering researchers), these projects provide an opportunity for a preliminary study of a "high-risk" nature, and have occasionally been the seed for later research thrusts by the institution. As an example, a student project at the University of New Hampshire several years ago attempted a preliminary design of a collision tolerant pile for marking navigation channels. On the basis of the promise shown, it was continued by an interdisciplinary faculty research team, and the result is a design which is expected to save millions of dollars annually over the old marker piles which had to be replaced regularly because of collisions by barges.

Another peripheral benefit of undergraduate research projects is that they help keep the attention of Engineering College faculty, administrators, and students on marine problems and the Sea Grant Program. The Sea Grant Programs at the Massachusetts Institute of Technology, New Hampshire, and Florida Atlantic University (which similarly includes students in problem oriented interdisciplinary studies) have some of the strongest ocean engineering contributions.

Fisheries and Seafood Processing

This past year seven projects have been supported in this category, four of them in fisheries engineering and three in seafood processing engineering.

A number of the Sea Grant Colleges give regular attention to fishing vessel engineering requirements through advisory service specialist support. The type of problems which are addressed are gear development, refrigeration, vessel stability and other safety problems, and fuel economy. (New York, Rhode Island, MIT, Florida, Mississippi–Alabama, Oregon). Most of this effort does not show up in the project listing.

The advancement of fisheries biology, as is true also of other disciplines, is dependent on advanced technology (more sophisticated instrumentation) and improved techniques. The cooperation of engineering and applied physics researchers with fishery biologists is strongly supported by this office.

Among the significant accomplishments in the recent past are the development of a research agenda for the application of Artificial Intelligence and Knowledge–Based Systems techniques to fisheries and aquaculture (Virginia), a computer program for determining the economic benefits of various fishing vessel modifications aimed at energy savings (New York), and the development of the David Taylor Research Center into one of the best fishing gear research facilities (through a memorandum of agreement between the MIT Sea Grant and Navy).

Aquaculture

While only two projects in this area were supported during the past year, the capability is being developed in several Sea Grant institutions, and significant efforts are expected in the near future. The Artificial Intelligence research agenda mentioned above is expected to spark future work in the application of computer science technology to aquaculture.

Erosion and Control Structures

Large scale support for research on the technological solutions to erosion is expensive and has historically been handled by the Corps of Engineers. Breakthroughs in new engineering designs of low cost erosion control structures are not likely in the next few years. The best direction for Sea Grant help in this area seems to be through the advisory services, since the sociological and political impediments to utilizing present knowledge are considerable. Although not insignificant (nine projects), Sea Grant support in this area during the past year has focused on performance evaluation of various erosion control structures, and better understanding of the erosion phenomenon.

Remote Sensing

Four projects in this category show modest, but continued interest in the development of new measurement techniques.

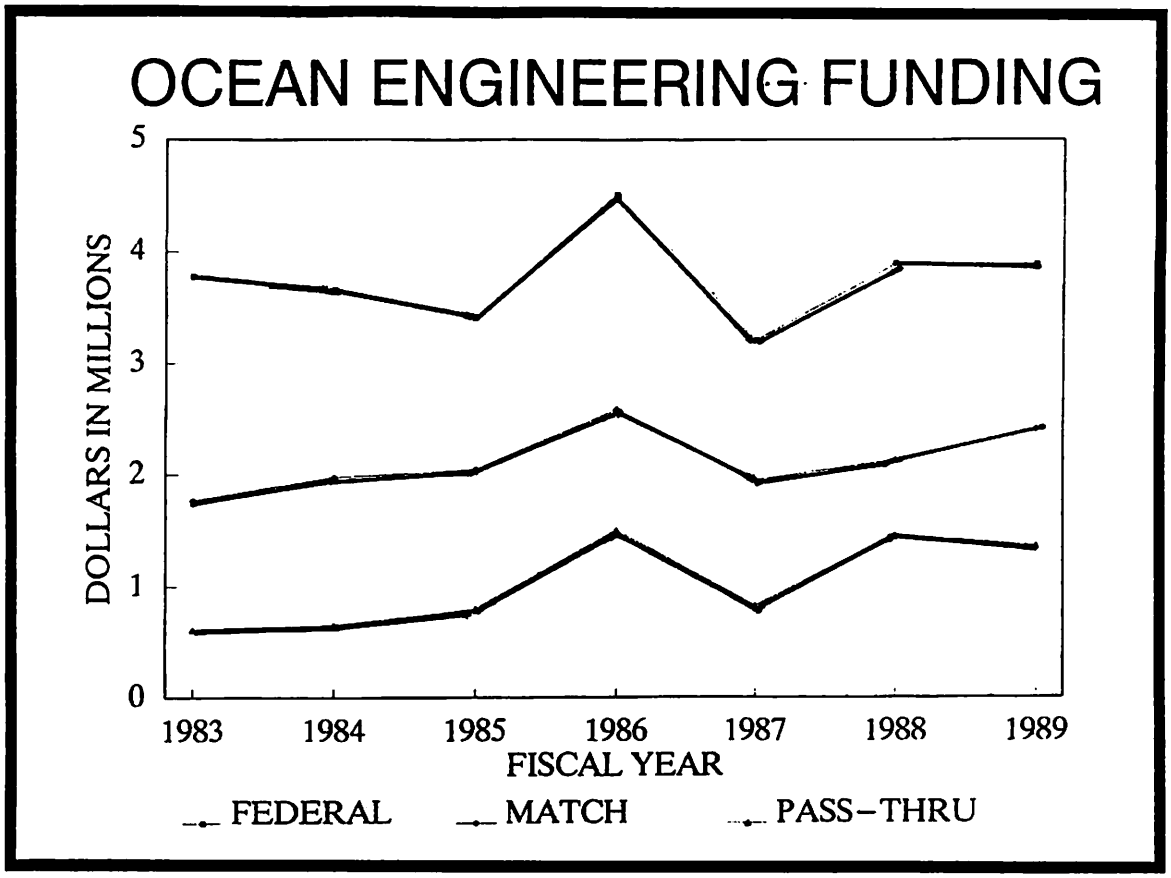
Coastal Construction

The special problems of design and construction of coastal structures relate not only to the actual wind, wave, current, corrosive and fouling problems, but also to the fact that much of the work is handled by smaller consulting firms and contractors who may have only modest knowledge of the peculiar nature of the marine environment. Integration of advisory service and research activities is, therefore, important and maintenance problems need to be addressed, presenting the solutions in a format useful to the average educated lay person. As in the case of fisheries engineering, although a number of programs give regular attention to this problem area, the continuity is in the advisory services, and many years, such as this one, the research project activity is moderate (four projects). It does, however, show an interest in a wide spectrum of important construction activities.

The collision tolerant pile design of the Maine–New Hampshire Sea Grant and the development of welding design procedures to compensate for the inherent difficulties of underwater welding (Ohio Sea Grant) have been particularly significant.

Ship Design, Construction, and Safety

This category of support has grown to be large and significant (twelve projects). Of these,



the fields of 1) Remotely Operated and Autonomous Work Vehicles, 2) Computer-Aided Design, and 3) High-speed Planing Craft represent the newer Sea Grant thrusts. Seven of the projects were supported by pass- through funding, indicating the close working relationship with Navy programs.

Water and Waste Treatment -- Waste Disposal

This category has regularly been one of the largest. Fifteen projects were supported during the past year, with nine focussing on the domestic sewage problem. More activity might be expected related to treatment and disposal of wastes from seafood processing, based on the historical pattern of interest shown by the Sea Grant institutions, but year to year fluctuations of this nature are not unusual.

Offshore Structure Design and Analysis

The thrust here is related to the safety of working in the marine environment. It is important to understand the special hazards related to the large forces and relative unpredictability of extreme sea states, and these four projects relate to design under such adverse conditions.

Both MIT and Michigan have Offshore Advisory Committees now, which advise researchers on urgent research directions and provide partial financial support of projects, mostly in the area of Offshore Structure Design and Analysis. California is attempting to form a similar Industry Advisory group.

Biofouling and Metal Corrosion

(Eight projects). Support in this category has dropped from the level in FY 1983 and earlier, when the "National Program in Corrosion",

involving eight investigators at various institutions on the east coast, was still active. However, significant progress is being made in several directions, particularly the role of bacterial films in the corrosion process.

Materials in the Marine Environment – Other

Only two projects are included in this category for FY 89. The most noteworthy research area is the deterioration of synthetic fiber rope. This work has been conducted with Navy support, and useful outputs are expected in the near future.

Acoustics

These three projects represent three different areas of study, viz., mapping systems, imaging systems, and fish stock assessment.

Oil Spill

The single project in this category is a study of policies for deterring oil spills.

Ice Engineering

This program area has developed well in recent years, with the focus being Great Lakes ice problems. This year, only one projects is listed, but this may be a temporary lull in activity. The Wisconsin Sea Grant has produced excellent design information for marinas.

Ocean Mining

This work is covered more thoroughly in the Marine Geological Resources section of this report, but is shown here to give a better perspective on ocean engineering research. Only one project is listed.

Instrumentation Development

The utilization of modern technology to develop new methods of measurement for the various sciences is important, as has already been noted. This activity (two projects) is considered high priority.

Industry Relations -- Industry Advisory Service

The MIT Marine Industry Advisory Service (MIDAS) is a very useful vehicle for bringing industrial professionals and marine engineering investigators together to discuss research priorities and the possible commercial utilization of the research. The usefulness extends beyond MIT since Sea Grant investigators from other programs are regularly invited to participate, and the priorities which are outlined are made available to the Sea Grant network. Technology transfer to the fishing and marina industries is handled well by the traditional Marine Advisory Service. MIDAS, however, is the most significant Sea Grant effort at technology transfer to U.S. industry as a whole. This is vital, and more attention to this problem is strongly encouraged.

The other initiative is the development of university– industry cooperation in research through "Offshore Advisory Committees" at MIT, Michigan, and California.

Summary Note

As the charts show, the total number of engineering projects has fluctuated considerably from year to year, but the total dollar support has held fairly constant. What has happened, however, is that the Sea Grant support has dropped, as institutional budgets have been squeezed in recent years, and this has been compensated for by an increase in pass–through funding. Pass–through funding now represents more than one–third of the total Federal funding in Ocean Engineering.

PROJECTS

OCEAN ENGINEERING

A. Education

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Opportunities for Undergraduate Research and Development in Marine Science and Engineering A.D. Drake 61 Maine/New Hampshire Sea Grant College Program	37,000	60,055
Ocean Engineering Curricula T.F. Oglivie 61 Massachusetts Institute of Technology Sea Grant College Program	0	140,320
MIT Sea Grant/Undergraduate Research Opportunities Program N. Doelling 70 Massachusetts Institute of Technology Sea Grant College Program	25,000	14,209
The MITSG/MMA Joint Program in Marine Education and Training G. Motte 66 Massachusetts Institute of Technology Sea Grant College Program	70,000	227,590
Development of a Monograph on Computer-Aided Fabrication of Marine Systems K. Masubuchi 70 Massachusetts Institute of Technology Sea Grant College Program	20,000	20,015
SUBTOTAL:	$ 152,000	$ 462,189
PASSTHROUGH:	0	

B. Fisheries & Seafood Processing

Good Manufacturing Practices for Alaska Seafood Processing Industry J.B. Lee 35 Alaska Sea Grant College Program	44,400	21,800
Design & Development of a Sea Urchin Processing System R. Paul 30 California Sea Grant College Program	19,535	24,144

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
Engineering Design of Shrimp Harvesting Gear D.R. Amos 30 Georgia Sea Grant College Program		67,100	123,000
MIT Sea Grant Center for Fisheries Engineering C.A. Goudey 71 Massachusetts Institute of Technology Sea Grant College Program		66,800	88,000
Modeling Quality Changes Which Occur During Frozen Storage of Seafoods T.C. Kolbe 56 Oregon Sea Grant College Program		47,800	41,800
The Selectivity of Cod-ends on Demersal Fishes in New England Waters and the Survivability of Cod-end Escapees J.DeAlteris 30 Rhode Island Sea Grant College Program		24,676	6,471
The Application of Knowledge-Based Systems to Marine Sciences: Fisheries Sciences Management and Aquaculture J.D. Palmer 74 Virgina Graduate Marine Science Consortium Sea Grant Program		20,000	0
	SUBTOTAL	$ 290,311	$ 305,215
	PASSTHROUGH	0	

C. Aquaculture

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Development of Sand Filtration Technologies to Support Intensive Finfish Culture Systems R.F. Malone 02 Louisiana Sea Grant College Program		20,153	13,964
The Application of Knowledge-Based Systems to Marine Sciences: Fisheries Sciences Management and Aquaculture J.D. Palmer 74 Virgina Graduate Marine Science Consortium Sea Grant Program		20,000	0
	SUBTOTAL:	$ 40,153	$ 13,964
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
D. Erosion & Control Structures		
Offshore Breakwaters: Waves and Currents R.A. Dalrymple 25 Delaware Sea Grant College Program	11,995	33,271
Florida's Erosion Problem: Toward an Improved Understanding of Rates and Causes R.G. Dean 25 Florida Sea Grant College Program	40,500	20,600
Enhancing the Underlying Physics of Beach Erosion Modeling W.R. Dally 25 Florida Sea Grant College Program	33,100	32,700
Field Experiment Evaluation of the Effects of Beach Restoration on Stony Corals of Southeast Florida W. Goldberg 28 Florida Sea Grant College Program	0	18,200
Geology and Stratigraphy of the Lake Michigan Shore and Its Influence on Erosion and Bluff Stability G.J. Larson 39 Michigan Sea Grant College Program	34,935	18,916
Predicting Lake Superior Shorline Erosion from Coast Characteristics and Historical Trends C.A. Johnson 39 Minnesota Sea Grant College Program	24,540	4,660
Simulation Modeling of Dune Erosion J. Fisher 25 North Carolina Sea Grant College Program	37,432	13,633
Problems and Processes of Sea Cliff Erosion on the Oregon Coast P.D. Komar 39 Oregon Sea Grant College Program	74,900	30,900
Coastal Engineering Advisory Service P. Keillor 25 Wisconsin Sea Grant Institute	24,584	9,688
SUBTOTAL:	$ 281,986	$ 182,568
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
E. Remote Sensing		
Utility of Thematic Mapper Data for Chlorophyll Estimation in New Jersey's Coastal Waters of the New York Bight S. Bagheri 50 New Jersey Marine Sciences Consortium Sea Grant Program	0	24,200
Fuel Savings on Ocean Routes from Remote Sensing of Ocean Currents M.R. McCord 37 Ohio Sea Grant College Program	26,455	23,452
Satellite Analyses for Fishery Oceanography in the Gulf of Mexico A.C. Vastano 50 Texas Sea Grant College Program	54,472	30,000
SUBTOTAL:	$ 80,927	$ 77,652
PASSTHROUGH:	0	

F. Coastal Construction

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Seismic Effects on Sheet-Pile Walls in Waterfront Structures T. Nogami 36 California Sea Grant College Program	20,222	15,000
Computer-Aided Harbor Design H. Loomis 23 Hawaii Sea Grant College Program	48,288	82,453
Development of In-Process Nondestructive Evaluation Technique for Underwater Welding S.I. Rokhlin 28 Ohio Sea Grant College Program	25,520	10,515
A Rational Analysis and Design Procedure for Rubble Mound Coastal Structures W.G. McDougal 25 Oregon Sea Grant College Program	93,700	80,200
SUBTOTAL:	$ 187,730	$ 188,168
PASSTHROUGH:	0	

G. Ship Design, Construction & Safety

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Autonomous Underwater Systems S.E. Dunn 23 Florida Sea Grant College Program	34,800	150,000
Habor and Inshore Submerged Object Search System: An Intelligent Systems Technology Develop Program D.R. Blidberg* 12 Maine/New Hampshire Sea Grant College Program	0 (473,740)	0
Propellant Embedded Anchors in Sea Floor Rock H.H. Einstein* 22 Massachusetts Institute of Technology Sea Grant College Program	0 (125,570)	0
Theory, Application and Testing of Non-Linear Motions and Tensions in Towing Systems J. Milgram* 23 Massachusetts Institute of Technology Sea Grant College Program	0 (150,000)	0
Geometry Data Representation and Exchange C. Chryssostomidis* 23 Massachusetts Institute of Technology Sea Grant College Program	0 (170,000)	0
Hydrodynamics of Marine Propulsors J. Kerwin* 23 Massachusetts Institute of Technology Sea Grant College Program	0 (50,000)	0
An Autonomous Underwater Vehicle to Study Large Vortical Patterns in the Ocean M.S. Triantafyllou 23 Massachusetts Institute of Technology Sea Grant College Program	50,000	47,351
Geometric Modeling in Computer-Aided Engineering of Marine Systems (Phase II) N.M Patrikalakis 24 Massachusetts Institute of Technology Sea Grant College Program	50,000	35,439
Geometry Data Representation and Exchange (Phase III) C. Chryssostomidis* 24 Massachusetts Institute of Technology Sea Grant College Program	0 (84,000)	0

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
Predicting Complicated Dynamics Leading to Vessel Capsizing		0	12,585
A. Troesch*	23	(56,900)	
Michigan Sea Grant College Program			
Development of an Improved Method for Predicting the Resistance of Planing Boats		31,398	13,591
W.S. Vorus	23		
Michigan Sea Grant College Program			
Seakeeping and Dynamic Analysis of High-Speed Planing Craft		22,080	6,489
A.W. Troesch	23		
Michigan Sea Grant College Program			
	SUBTOTAL:	$ 188,278	$ 265,455
	PASSTHROUGH:	$ 111,021	0
H. Water & Waste Treatment-Waste Disposal			
Wastewater Wetlands: Pulsed Discharges to Protect		27,265	20,092
J. Zedler	39		
California Sea Grant College Program			
Scales of Variability of Sewage-Influenced Water Column Properties in S CA		12,277	19,490
J.A. McGowan	45		
California Sea Grant College Program			
Management Models of Wetland Wastewater Treatment		12,479	23,680
B. Finney	46		
California Sea Grant College Program			
Small-Scale Mixing Processes- Dispersion- Sewage		30,161	35,393
B. Jones	45		
University of Southern California Sea Grant Program			
Detection and Survivability of Some Pathogenic Enterobacteria		43,639	40,642
I. Radolfo	45		
University of Southern California Sea Grant Program			

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
China-USA Cooperative Research Project on the Tracking of Wastes Dumped at Sea J.C. Cato* 44 Florida Sea Grant College Program	0 (112,100)	0
Second International Conference on Marine Debris J.R. Davidson* 74 Hawaii Sea Grant College Program	0 (50,000)	0
The Attitude Basis of Marine/Coastal Litter: Assessing Louisiana Coastal Users' Attitudes Toward the Environment S.B. Laska 20 Louisiana Sea Grant College Program	13,678	30,005
Marine Disposal of Solidified/Stabilized Incinerator Ash: Field Studies N.E. Kinner 45 Maine/New Hampshire Sea Grant College Program	43,000	9,128
Extraction of PCBs and PAHs from Coastal Waters Using Block Copolymer Micelles T.A. Hatton 13 Massachusetts Institute of Technology Sea Grant College Program	50,000	22,215
Characterization of Coastal Colloids F.M. Morel 39 Massachusetts Institute of Technology Sea Grant College Program	47,500	0
Seasonal Changes in Particle Residence Times and Scavenging Rates in Massachusetts Bay G.T. Wallace 44 Massachusetts Institute of Technology Sea Grant College Program	50,000	35,430
Oceanographic Investigations, Johnston Atoll, for Assessing the Impacts of Deep Ocean Disposal of Liquid Brine P.S. Lobel* 45 Woods Hole Oceanographic Institution Sea Grant Program	0 (18,905)	0
Evaluation of Plasmid Profiles as a Method to Determine the Source of Fecal Pollution in an Estuary R.K. Sizemore 08 North Carolina Sea Grant College Program	11,515	5,252

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
Siting of Marine Diffusers R.T. Hudspeth 25 Oregon Sea Grant College Program		45,600	22,500
	SUBTOTAL:	$ 387,114	$ 263,827
	PASSTHROUGH:	$ 181,005	

I. Offshore Structure Design & Analysis

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Methodology for Assess by Regulatory Bodies B. Gerwick 23 California Sea Grant College Program		13,386	11,076
Extreme Loadings of Marine Structures: Wave-Induced J. Paulling 23 California Sea Grant College Program		15,414	18,726
Extreme Loadings of Marine Structures: Slow Drift W. Webster 23 California Sea Grant College Program		14,413	10,867
The Dynamics of Large-Scale Vortices in the Ocean and Their Impact on Offshore Structures and Coastal Processes G.S. Triantafyllou 24 Massachusetts Institute of Technology Sea Grant College Program		50,000	12,001
	SUBTOTAL:	$ 93,213	$ 52,670
	PASSTHROUGH:	0	

J. Biofouling & Metal Corrosion

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Crack Growth in Cathodically Protected Steel Structures J. Todd 24 University of Southern California Sea Grant Program	22,418	23,592

Role of Adsorbed Proteins in Bacterial Colonization and Growth on Surfaces D.L. Kirchman 01 Delaware Sea Grant College Program	16,536	34,542

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Anticorrosive Properties of Adhesive Proteins Isolated from the Mussel Mytilus Edulis Delaware Sea Grant College Program S.C. Dexter 13	16,380	18,689
Influence of Marine Bacterial Films on Cathodic Reaction and on Corrosion Prevention S.C. Dexter 38 Delaware Sea Grant College Program	9,360	17,609
Development of New Biofouling Inhibitor Delivery Systems D.C. Sundberg 45 Maine/New Hampshire Sea Grant College Program	40,999	24,648
The Role of Iron- and Manganese-Oxidizing Bacteria in Marine Corrosion Processes R. Mitchell 13 Harvard University	60,000	40,000
Polypeptide Inhibitors of Corrosion from Marine Organisms S. Sikes 13 Mississippi/Alabama Sea Grant Consortium	27,346	20,181
Advances in Anti-Scaling & Anti-Fouling Technology Based on the Properties of Natural Inhibitors of Mineralization A.P. Wheeler 13 South Carolina Sea Grant Consortium	55,600	31,800
SUBTOTAL:	$ 248,639	$ 211,061
PASSTHROUGH:	0	

K. Materials in the Marine Environment-Other

TITLE/INVEST./INST.	FEDERAL FUNDS	MATCHING FUNDS
Improved Fatigue Life for Moorings R. Seymour 24 California Sea Grant College Program	21,690	16,031

Fiber and Yarn Properties as Related to Rope Deployment in Deep Sea Mooring S. Backer* 24 Massachusetts Institute of Technology Sea Grant College Program	0 (60,300)	0
SUBTOTAL:	$ 21,690	$ 16,031
PASSTHROUGH:	$ 60,300	
TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
L. Acoustics		
Acoustic Studies of Forage Stocks in the Gulf of Alaska R.T. Cooney 07 Alaska Sea Grant College Program	26,100	0
Advanced Development of 3-D Ultrasonic Imaging System J. Jaffe 28 California Sea Grant College Program	25,316	6,000
Shallow Water Swath-Mapping Systems J.S. Jaffe 39 Woods Hole Oceanographic Institution Sea Grant Program	53,000	7,779
SUBTOTAL:	104,416	13,779
PASSTHROUGH:	0	
M. Oil Spill		
Deterring Oil Spills: Optimal Policies R. Carson 14 California Sea Grant College Program	11,454	26,428
SUBTOTAL:	$ 11,454	$ 26,428
PASSTHROUGH:	0	
N. Ice Engineering		
TITLE/INVEST./INST.	FEDERAL FUNDS	MATCHING FUNDS
Harbor Ice and Marine Advisory Services C.A. Wortley 25 Wisconsin Sea Grant Institute	17,656	15,232
SUBTOTAL:	$ 17,656	$ 15,232
PASSTHROUGH:	0	

O. Ocean Mining

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Investigation of Sources, Geometries and Compositions of Potential Titanium- and Zirconium-bearing Placer Deposits C.D. Peterson 09 Oregon Sea Grant College Program	35,100	39,900
SUBTOTAL:	$ 35,100	$ 39,900
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS

P. Instrumentation Development

New Techniques in Seafloor Magnetometry A. Schultz 09 Washington Sea Grant College Program	36,500	21,200
A Proposal to Develop a Deep Ocean Rock Coring Drill H.P. Johnson 09 Washington Sea Grant College Program	50,400	23,300
SUBTOTAL:	$ 86,900	$ 44,500
PASSTHROUGH:	0	

Q. Industry Relations-Industry Advisory Service

MIT Sea Grant/Marine Industry Collegium J. Moore 77 Massachusetts Institute of Technology Sea Grant College Program	149,700	94,247
The University of Michigan/Sea Grant/Industry Consortium in Offshore Engineering M. Bernitsas 23 Michigan Sea Grant College Program	22,060	55,685
SUBTOTAL:	$ 171,760	$ 149,932
PASSTHROUGH:	0	

R. Miscellaneous

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Energy Use Assessment in Alaskan Seafood Processing Plants J.C. Nash 35 Alaska Sea Grant College Program	26,900	8,900

Black Smoker: Vents for Ocean Thermal Power V. Anderson 22 California Sea Grant College Program	65,537	16,137
The Effects of Lightning on Strike Probability and Damage to Boats E.M. Thomson 23 Florida Sea Grant College Program	40,500	22,800

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Impact Analysis and Foundation Design for Collision Tolerant Pile Structures K.C. Baldwin 25 Maine/New Hampshire Sea Grant College Program	39,001	21,772
SUBTOTAL:	$ 171,938	$ 69,609
PASSTHROUGH:	$ 0	

Marine and Coastal Transportation Systems

Summary

This analysis of the National Sea Grant College Program in Marine and Coastal Transportation Systems is based on the listing of current projects as of October 1, 1989. There has been no attempt to avoid multiple listing with other reports being prepared at this time, and the choice of including or excluding projects represents the subjective judgment of the author. A total of three projects is listed, representing the efforts of three institutions. The total Federal funding level is $68,784 and the non-Federal match is $32,196.

Discussion

This program area continues to shrink, and now shows as a very low level of effort. With continuing restricted budgets during the past decade, Sea Grant Institutions have been forced to reduce the number of research thrusts. In the past, strong leadership has been shown by the University of Southern California, Washington Sea Grant, Oregon Sea Grant, and Louisiana Sea Grant Programs. Significant activity continues in the Marine Advisory Services, and is not adequately reflected in the project listing.

Good cooperation has been achieved with the Office of Port and Intermodal Development of the Maritime Administration (MARAD). During FY 1989, MARAD and Sea Grant co-chaired a session at the "Coastal Zone '89" Conference, giving the results of their respective research on the use of computers in port management.

OCEAN ENGINEERING PROJECTS SUMMARY BY INSTITUTION

INSTITUTION	PROJECTS	$ FEDERAL	$ MATCH
ALASKA	3	97,400	30,700
CALIFORNIA	12	258,988	207,666
DELAWARE	4	54,271	104,111
FLORIDA	6	260,900	244,300
GEORGIA	1	67,100	123,000
HAWAII	2	98,286	82,453
HARVARD	1	60,000	40,000
LOUISIANA	2	33,831	43,969
MAINE-NEW HAMPSHIRE	5	633,740	115,603
MICHIGAN	5	167,373	107,266
MIT	18	1,268,870	736,817
MINNESOTA	1	24,540	4,660
MISSISSIPPI-ALABAMA	1	27,346	20,181
NEW JERSEY	1	0	24,200
NORTH CAROLINA	2	48,947	18,885
OHIO	2	51,975	33,967
OREGON	5	297,100	215,300
RHODE ISLAND	1	24,676	6,471
TEXAS	1	54,472	30,000
SOUTHERN CALIFORNIA	3	96,218	99,627
SOUTH CAROLINA	1	55,600	31,800
VIRGINIA	1	20,000	0
WASHINGTON	2	86,900	44,500
WISCONSIN	2	42,240	24,920
WOODS HOLE	2	71,905	7,779

MARINE AND COASTAL TRANSPORTATION SYSTEMS

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Ports and Waterways Advisory Service C. Beacham 77 Louisiana Sea Grant College Program	25,249	3,074
Fuel Savings on Ocean Routes from Remote Sensing of Ocean Currents M.R. McCord 37 Ohio Sea Grant College Program	26,455	23,452
Cargo Preference and Government Export Promotion: Policy Implications for the Great Lakes Shipping in the Port of Duluth C.F. Runge 14 Minnesota Sea Grant College Program	17,080	5,670
SUBTOTAL:	$ 68,784	$ 32,196
PASSTHROUGH:	$ 0	

Division of Living Resources

Research on living resources is a major emphasis of the National Sea Grant College Program. In fiscal year 1989 more than 25 percent of the program's federal funds, more than $10 million, supported this research in nearly 300 projects. In general, these projects, which an additional $7 million in non-federal matching funds also supported, do not include environmental and ecological research.

The four reports in this section cover research in fisheries science, aquaculture, seafood science, and marine biotechnology. Biotechnology is broadly defined to include biochemistry, molecular biology, biochemical engineering, microbiology, phycology, and fundamental studies in chemistry of marine natural products and associated pharmacology. In this report biotechnology does not include most of the research topics traditionally categorized under aquaculture.

The reports discuss fundamental and generic applied research and its relevance to commercial development and resource management. They cover status, trends, priorities, and accomplishment. Each provides a list of funded projects with principal investigators and their institutional affiliations. A few of the projects are listed in more than one report because the bounds between the subjects are not precise. The reports provide examples or lists of recent publications.

The report on aquaculture discusses research in the following categories: (1) aquaculture systems; (2) genetics and selective breeding; (3) nutrition; (4) disease and parasites; (5) physiology and endocrinology; (6) policy; (7) economics; and (8) exploratory research. The report on fisheries discusses achievements under the following categories: (1) developing new techniques for assessments; (2) recruitment and fisheries oceanography; (3) habitat fish productivity interactions; (4) integrating biological and economic information into management strategies and plans; and (5) promising areas of research. It also includes a section on future directions and plans with guidance on priorities. The report on seafood and technology focuses on four categories – (1) engineering and waste treatment; 92) product development and by-product recovery; 93) microbial and nutritional quality; and (4) processing and handling.

Authors

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Aquaculture

Summary

The funding level for support of aquaculture projects during FY– 89 declined slightly over preceding years. Sea Grant supported 94 projects at a level of $3,640,000 with $2,861,000 in matching funds for a total of $6,501,000. This represents 9 less projects than last year and $460,000 less in Federal funding. This reduction is probably within the normal variation to be expected in the dynamics of the grant process. No deliberate reductions have been made.

There was a continuing trend to support more projects in the genetics/biotechnology and physiology/endocrinology subject areas. Nutrition and disease/parasites projects remained about the same.

Almost all categories of projects received less funding this year but the ratio of funding remained the same in terms of program emphasis. Species receiving the greatest emphasis were salmon, rainbow trout, hybrid striped bass, red drum, marine shrimp, hard clams, oysters and algae. Marine shrimp projects, however, declined from last years total. The high number of oyster projects centered around the need for disease control in this group. We did see a clearer focus on projects dealing with marine viruses as these are becoming more of a problem for several cultured species.

Hawaii, Texas, Washington, and California had the largest aquaculture programs in terms of dollars and projects. Texas continued it's shift away from more applied research to more basic research in order to stay ahead of the developing shrimp industry. Hawaii continued it's program to assist the Pacific Islands with their aquacultural development plans. California maintained it's emphasis in more basic research and Washington focused on salmon and oyster related projects.

The National Office participated in the Joint Subcommittee on Aquaculture activities and contributed time to several information service project. The UJNR Aquaculture Panel (Japan–U.S. technical exchange) meetings were held in the U.S. this year and the National Office Aquaculture Director served as Program Chairman for the meeting. The National Office also participated in two workshops on rejuvenating the oyster industry on the East Coast, and one workshop on the use of Artificial Intelligence in Aquaculture. The Aquaculture Program Director also attended meetings for the creation of the Pacific Aquaculture Association and Pacific Island Network. A new project funded by the Dept. of Interior, through the University of Puerto Rico, was developed to create an underwater park in the Virgin Islands with an aquaculture, fishery enhancement theme.

Recent significant research advances include the further refinement of recombinant DNA vaccines for the prevention of virus diseases in fish; continued development of techniques for inserting fish growth hormone genes into bacteria and then extracting the hormone for administering to fish to increase growth; successful insertion of genes for growth into the genome of a commercially important fish; successful cryopreservation of shrimp gametes (sperm only) and demonstration of increased commercial production for marine fish, shrimp and mollusks in ponds provided with increased aeration; demonstrated improvements of growth rate in hard clams due to selective breeding procedures; demonstration of resistance to MSX disease in oysters from a selective breeding program, and improved diagnostic procedures for determining the presence of several shrimp viruses. An improved water filter (fluidized bed) was introduced to soft shell crab and crayfish recirculating systems that allows

a forty-fold increase in holding capacity. Many other results were documented in publications published in peer reviewed journals and were submitted to the Sea Grant Depository in Rhode Island. The next two decades will see a dramatic change in the way we obtain our seafood products. An increasing proportion of our seafood supply will come from aquacultural production, especially for those products of high market value. Today many underdeveloped countries in tropical areas are gearing up for aquaculture production, primarily through shrimp culture. In 1988 approximately 22% of the shrimp placed on world markets was produced on shrimp farms. This production was valued at $2.5 billion at wholesale prices. In 1988 the total hectares devoted to shrimp aquaculture was estimated at 765,500 and the United States only had 500 hectares in production (World Shrimp Farming, 1988).

The United States imported $1.7 billion worth of shrimp, primarily from those countries that are developing shrimp culture, in 1987 (NMFS, Fisheries of the United States, 1987). Other imports of high cost salmon, lobster, mollusks and other seafoods brought the total seafood imports to $8.8 billion. With exports of $1.7 billion this left us with a trade deficit of $7.1 billion.

How can we increase United States fisheries production to offset the large trade deficit in this area? An increase in traditional fisheries production can not be expected unless major habitat improvement and restoration projects are initiated. Immediate increases in domestic seafood availability could occur with the use of less desirable, underutilized, species and/or the development of U.S. aquaculture for high demand species (shrimp, lobster, salmon, etc.). This latter approach is the most likely because Americans demand high quality seafoods that they can recognize. In 1987, United States aquaculture production was about 700 million pounds according to National Marine Fisheries Service figures. This was up 165 million pounds over the 1985 estimate. Aquaculture production has increased at an annual rate of approximately 20% over the past decade and we can expect this rate to continue providing a doubling of production over the next decade. These increases are expected primarily in catfish and crawfish production but significant increases are also foreseen for marine shrimp, finfish and mollusks.

Past research by the National Sea Grant Program and other agencies has led to a situation where we can expect increased investments and increased production in aquaculture over the next decade. Pond production research in South Carolina has shown that the use of aerators can provide yields of 20,000 kg./ha/yr of shrimp and improve the yields for marine finfish such as redfish and hybrid striped bass. This preliminary work needs to be expanded and brought to the point of commercial production.

Further development of aquaculture in the United States can lead to the following benefits:

Reduction of the foreign trade deficit.

Increase in supply of domestically produced, top quality seafoods.

Provision of a stable seafood supply to the United States seafood industry, particularly processors.

Creation of new jobs and spin-off industries.

Improvement of the recreational and commercial potential of our marine waters.

Better understanding of the life cycles of commercially important species.

Development of protein production technology for export to third world countries.

Even though aquaculture production is increasing steadily in the United States there are many technical and socio-economic problems that need to be overcome to reach the full potential of aquaculture and to overcome the foreign trade deficit in fishery products.

For over 20 years the National Sea Grant College Program has taken a strong role in developing aquaculture technology for marine, estuarine and Great Lakes species. This was

TABLE I
ANALYSIS OF FY 89 AQUACULTURE PROJECTS AND FUNDING

YEAR	NO. OF PROJ.	FEDERAL DOLLARS (K)	MATCH (K)	TOTAL
1979	98	$3,707	$3,293	$7,000
1980	111	$4,277	$2,994	$7,271
1981	115	$3,735	$2,744	$6,479
1982	106	$3,050	$2,047	$5,097
1983	109	$3,914	$2,778	$6,692
1984	97	$3,739	$2,994	$6,733
1985	121	$4,414	$3,721	$8,069
1986	110	$4,550	$3,263	$7,813
1987	121	$4,544	$3,111	$7,655
1988	103	$4,102	$3,088	$7,190
1989	94	$3,640	$2,861	$6,501

reinforced in the National Aquaculture Act of 1980 and the National Aquaculture Development Plan of 1983. The National Sea Grant Program has prepared its own Aquaculture Plan through a cooperative effort of involved institutions and has set priorities in line with the National Aquaculture Plan. Yearly guidelines are provided to Sea Grant institutions to focus research proposals on the identified priority areas. Sea Grant also supports workshops and symposia for key aquacultural species groups to establish the status of the industry and to focus on the research that needs to be done to support the developing industry.

This report attempts to describe the projects funded for FY 89 in relation to the areas and species designated in the yearly guidance document and the Sea Grant Aquaculture Plan and to look at future directions for Sea Grant funded aquaculture research.

In 1989 the Sea Grant College Program devoted $3,640,000 to aquaculture projects which was matched by $2,861,000 of state funds for a total of $6,501,000. All of this money was distributed through a competitive grants process that was based on peer review.

The sustained level of funding over the past 2 decades reflects the continued strong interest in aquaculture research by the individual Sea Grant institutions. This interest can also be seen in the relatively high level of matching funds for the aquaculture projects compared to the minimum that is required by law.

Aquaculture related projects account for approximately 9.33% of the total Sea Grant budget for FY-89 not counting MAS efforts in that area that would add another 2.5%. The MAS program estimates that aquaculture support within the MAS has increased from a level of 10% to a level of 12% over the past 5 years because of the high level of public interest in this subject.

Analysis of Program Emphasis

The Sea Grant Aquaculture Plan and retreat reports have identified several areas of particular emphasis for Sea Grant support. Table II compares the number of projects and the funding levels for FY 86 through FY 89 for these areas.

Pass-through funds are becoming more important for all programs because of the level funding for the overall Sea Grant Program during the past few years. These funds are included in the total budget allocated for aquaculture research in all the tables.

In 1989 the relative mix of projects remained about the same as in previous years even though many of the investigators and institutions have changed. Projects related to genetics and selective breeding and physiology/endocrinology continue to receive emphasis and reflect the need

TABLE II
A COMPARISON OF FUNDING FOR SUBJECT AREAS IN FY 86 THROUGH FY 89.

# OF PROJECTS					AMOUNT OF FEDERAL $ (K)			
SUBJECT AREA	1986	1987	1988	1989	1986	1987	1988	1989
1. AQUACULTURE SYSTEMS	20	15	15	14	786	530	589	366
2. GENETICS & SELECTIVE BREEDING	29	38	30	27	1,266	1,478	1,392	1,304
3. PHYSIOLOGY/ ENDOCRINOLOGY	16	22	21	20	1,025	839	750	922
4. NUTRITION	13	16	11	8	435	496	318	272
5. DISEASE/ PARASITES	20	20	17	17	633	661	564	596
6. POLICY/ ECONOMICS	3	3	1	0	70	310	4	0
8. OTHER	9	7	7	8	335	229	483	155
TOTAL	110	121	103	94	4,414	4,551	4,544	3,640

to gain better control of organisms that are being grown in intensive culture conditions considerably different from what is found in nature. We are finding it more important to understand the underlying physiological and endocrine systems of aquacultural species as we attempt to optimize reproduction and growth. The continued interest in the physiology/endocrinology category is also consistent with the trend for more basic or generic research by the grantees.

This year the policy and economics categories do not have any projects. In view of the significant problems in these areas additional effort should be made to recruit social scientists and economists to conduct projects in these areas. This is becoming increasingly clear as discussions with the private sector reveals that these are the principal areas that they have difficulty with in their activities.

Species Funding Analysis

Table III provides information on the species that have received research attention from FY 86-89. An analysis of the FY 89 funding by species relative to the Sea Grant Aquaculture Plan shows good agreement with the plan. More than 75% of the species mentioned in the plan have one or more projects assigned to them. For the most part species not covered by FY 89 projects are minor ones that may be developed at a later time after the higher priority species are addressed.

This year we dropped the categories of white perch, fathead minnow, snook, red snapper, silver carp and mussel as we have not funded these species in the last 4 years. We did add crawfish and the larger category of Virus to our list for FY-88. More work is being done on virus because of their impact on the culture of finfish and shrimp.

No major viral diseases have been observed with mollusks.

Hybrid striped bass projects have completely replaced the striped bass projects because of the perceived superiority of hybrid striped bass as an aquaculture candidate. We are seeing more interest by the private sector in hybrid striped bass culture. We need more projects dealing with the legal policies that are presently restricting development of hybrid striped bass in states other than N.C.

The projects dedicated to work on mollusks remained relatively the same. Work is continuing on the genetic manipulation of mollusk species. New strains and gene combinations are being tested and evaluated. Mollusks lend themselves to genetic studies and we can expect to see more work in this area.

The interest in marine algae is continuing as seen by the eight projects worth $362.2 K included in this years list of projects. Industry is particularly interested in the many products that can be derived from marine algae. This could be a growing area of research opportunity in view of the way algae lend themselves to biotechnology applications.

Aquaculture research on Great Lakes species remained relatively low but consistent with past years. Most Great Lakes species can be cultured in the technical sense but more work needs to be done to develop technology that will allow growout to marketable size in an economic way. There is continued interest in enhancement programs for these species and there are opportunities for work on stock improvement and development of broodstock strains.

The above analyses shows the dynamic character of .Sea Grant funding with different species receiving more or less attention from year to year. Marine shrimp, algae, oysters, salmon, lake trout and hybrid striped bass are well represented this year. We lost some projects on marine finfish and freshwater prawns remain a low interest area with only one project being supported.

An analysis of individual projects by discipline and species suggests that there are opportunities for interaction and coordination between researchers at the various Sea Grant institutions. There are distinct project groups in the following areas:

Aquaculture engineering
Marine Shrimp
Striped Bass
Bivalve Culture
Genetics/Selective Breeding
Disease/Parasites
Crustacean Reproduction
Pond Dynamics

Researchers in these areas are encouraged to exchange information through correspondence or, when possible, in meetings and workshops.

Analysis of Grantee Efforts in Aquaculture

Table IV provides a summary of research activity by the various Sea Grant Institutions.

Hawaii and Texas have the greatest number of projects and are ranked one and two, respectively, in order of funds devoted to aquaculture. Washington is equal to Texas in terms of funds devoted to aquaculture and concentrates it's efforts on genetics and endocrine control in salmon and trout. Hawaii is concentrating it's efforts on marine shrimp and dolphin fish and has ceased to fund work on freshwater prawns. Texas is also concentrating on marine shrimp as well as some work on marine finfish. Texas has shifted it's emphasis to more basic research using biotechnology and endocrinology to obtain greater control and understanding of shrimp reproduction.

California is fourth in ranking for funding aquaculture and they too are concerned more with basic research on reproduction, nutrition and genetics of aquatic species.

Oregon has moved up to fifth place this year and continues its strong program on disease control and vaccine development in salmonid fish. Wisconsi is sixth in terms of funding this year and is our strongest program working with cool water fishes and those appropriate for culture in the mid-west.

Maryland has moved from fourth to seventh place this year in projects related to aquaculture. Their program includes projects on striped bass nutrition, gene transfer in fish, oyster

TABLE III

A COMPARISON OF FUNDING FOR SPECIES IN FY 86/FY 89

SPECIES	NO. OF PROJECTS				AMOUNT OF FEDERAL FUNDING			
	86	'87	'88	'89	'86	'87	'88	'89
FISH								
General	12	16	13	7	358.3	771.5	554.0	219.4
Salmon	23	16	13	13	980.6	546.9	527.3	582.4
Rainbow Trout	0	2	2	2	0.0	67.9	61.9	131.0
Striped bass	1	2	1	0	26.8	88.9	16.6	0
Hybrid Striped Bass	4	4	5	3	128.0	154.8	185.1	118.5
Red Drum	1	2	2	3	15.4	98.5	89.5	138.4
Sturgeon	2	2	2	1	28.2	24.9	35.1	24.1
Yellow Perch	0	*	*	1	0.0	0.0	*	86.1
Walleye	1	2	2	1	16.7	59.9	63.5	15.8
Lake Trout	2	3	6	2	28.0	116.2	243.3	91.1
Sauger	0	*	*	*	0.0	*	*	*
Dolphin Fish (Coryphaena)	2	2	2	3	44.5	51.6	46.7	90.3
Sebastes	0	0	1	0	0.0	0.0	8.5	0.0
CRUSTACEAN								
General	4	4	2	2	108.8	180.5	95.8	101.1
Prawn	2	0	1	1	105.2	0.0	15.6	49.8
Blue Crab	2	3	1	0	54.2	10.3	28.2	0.0
Marine Shrimp	11	18	16	9	461.1	671.9	645.8	381.7
Crawfish	0	0	0	1	0	0	0	51.4
MOLLUSK								
General	9	5	2	4	222.5	135.1	26.2	168.5
Hard Clam	9	8	5	6	287.4	259.5	297.9	285.3
Scallop	3	2	3	1	143.5	126.9	82.3	18.9
Oysters	12	14	13	12	14.7	441.4	354.3	398.3
Abalone	0	1	1	0	0.0	25.3	40.4	0
BACTERIA/ VIRUS	0	0	0	3	0.0	0.0	0.0	116.1
PLANTS								
Higher Plants	1	1	1	1	42.1	40.5	26.6	34.7
Algae	5	7	7	8	259.0	345.4	314.1	362.2
OTHER	3	5	2	8	74.5	393.7	294.2	79.9

* Contained in Other "General" Projects

physiology and disease studies and aquacultural engineering.

South Carolina is eighth with projects on hybrid striped bass, and several projects on genetics in hard clams.

Both Connecticut and New York have dropped out of the top nine in terms of funding aquaculture and Virginia has moved to ninth place because of its new initiative on restoring the oyster industry in the Chesapeake Bay.

The data contained in Figure IV clearly shows that state programs constantly adjust to the research needs of the year in order to take advantage of new developments and opportunities. The relative ranking of States changes from year to year depending on the different projects that are identified for funding.

Special Sea Grant Aquaculture Activities During FY 89

Sea Grant Research has led to the first commercial hybrid striped bass aquaculture farm in North Carolina. The North Carolina Sea Grant Program is providing technical assistance to a private company that received a grant from National Coastal Resources Institute. Technology developed through Sea Grant research is being utilized on the 27 acre farm in coastal N.C. This project is now in its second year and the private farmer is economically successful and expanding the number of production ponds. Last year the farmer harvested over 60,000 pounds of fish with a market value near $3.00 per pound. The market appears to be holding but will depend upon the amount of production and demand over the next few years.

The National Sea Grant Office worked with the Dept. of Interior again this year to continue the aquaculture development on Pacific Islands. The Dept. of Interior has provided funds to the University of Hawaii Sea Grant Program to support giant clam research in Palau. There is now a Regional Aquaculture Association, called the Pacific Aquaculture Association, and a plan has been developed to focus on the species with the best potential for the islands. The Dept. of Interior has already funded some elements of this plan to encourage economic development throughout the region. The University of Guam also received funds from the Dept. of Interior for the support of a freshwater and marine shrimp hatchery and Sea Grant affiliated researchers there will participate in setting up the various regional activities.

The National Sea Grant Office was also instrumental in developing a system (called Pacific Island Network or PIN) of NOAA representatives for the Pacific islands. The PIN is being funded by the Dept. of Commerce, and Dept. of Interior with in kind support from the Corps of Engineers and the Island governments. A full time extension person was added to the island of Ponape and other positions were created on Kosrae and Saipan. The National Marine Fisheries Service has one representative on American Samoa and Hawaii Sea Grant has included their Guam extension agent in the system. Other extension agents are planned for Palau and the Marshall Islands. The network will support aquaculture and other marine resource development projects in the Pacific.

The National Sea Grant Office helped develop a new project in coordination with the Dept. of Interior, for the creation of a Sea Farm Park on St. Croix, Virgin Islands. The project, administered by the University of Puerto Rico, and coordinated with the University of the Virgin Islands, seeks to determine the feasibility of using grouper and conch seedlings, produced in a hatchery, to enhance natural populations of these species. In addition, tourists would be able to observe the hatchery and target reef areas and fishermen would eventually be able to harvest the enriched reef areas.

The National Sea Grant Office helped coordinate the meeting of the U.S.-Japan Cooperative Program in Natural Resources (Aquaculture Panel) that was held in Washington State. A good exchange between U.S. and Japanese aquaculture scientists took place.

The National Sea Grant Office Aquaculture Specialist participated in a meeting with representatives from the Peoples Republic of China and will help coordinate future technical exchanges with China.

The National Sea Grant Office helped sponsor two workshops pertaining to the

TABLE IV
GRANTEE EFFORT IN AQUACULTURE

GRANTEE	NO. OF PROJECTS			FUNDING (K)		
	1987	1988	1989	1987	1988	1989
1 Alaska	2	3	4	67	114	134
2 California	17	9	6	485(2)	400(3)	291(4)
3 S. California	1	0	1	25	0	40
4 Connecticut	4	3	3	161	118(9)	120
5 Delaware	2	3	1	67	47	10
6 Florida	3	2	6	100	45	185
7 Georgia	1	2	3	45	97	133
8 Hawaii	11	10	9	563(1)	529(1)	420(1)
9 Illinois	1	1	2	38	16	66
10 Louisiana	6	3	4	94	87	132
11 ME-NH	5	3	3	170	114	123
12 Maryland	5	8	5	205(9)	300(4)	208(7)
13 MA Woods Hole	0	2	0	0	80	0
14 MA-MIT	0	0	1	0	0	43
14 Michigan	3	3	1	78	106	16
15 Minnesota	3	4	2	84	102	34
16 Miss./Alabama	1	1	3	46	50	119
17 New Jersey	4	3	2	51	0	49
18 New York	7	4	3	314(5)	149(8)	143
19 North Carolina	5	4	4	169	116	85
20 Oregon	4	4	5	223(7)	209(7)	261(5)
21 Puerto Rico	2	0	0	71	0	0
22 Rhode Island	1	1	2	29	20	75
23 South Carolina	5	4	3	215(8)	221(6)	194(8)
24 Texas	10	10	8	441(4)	427(2)	389(2)
25 Virginia	4	2	3	103	30	186(9)
26 Washington	8	7	6	472(3)	427(2)	387(3)
27 Wisconsin	5	6	4	307(6)	260(5)	210(6)

(#) Rank in Terms of Funding

technology and socio-political considerations for the rejuvenation of the oyster industry on the East Coast of the U.S. A plan for research and industry rejuvenation is being prepared for future funding considerations.

Another workshop will be sponsored in FY-1990 to provide National focus on the development of closed, recirculating aquaculture systems. A proposal has been prepared and funded to bring the top people together to determine the status of closed system aquaculture and set national goals for the future.

Another workshop on Artificial Intelligence, as it might be applied to aquaculture and fisheries, was held last year at George Mason Univerisity in Virginia. This has led to a new initiative for Sea Grant to put together several proposals in this new area of research. Leading

aquaculturists and aquacultural engineers in the Sea Grant system are working together on identifying the use of Artificial Intelligence in aquaculture.

These are just some of the highlights of research and activities of the Sea Grant Aquaculture Program. The National Office will continue to coordinate and support activities leading to the development of the U.S. aquaculture industry.

Future Research Priorities

The research priorities established by the National Aquaculture Development Plan and the Sea Grant Aquaculture Plan (1983–1987) and adopted by the Office of Sea Grant remain essentially the same for the near future, these are:

GENERAL. High priority is assigned to research directed toward the enhancement of commercial aquaculture operations involving marine or Great Lakes species (salmonids and percids) that are economically viable or nearly so. This includes: salmon, hybrid striped bass, marine shrimp, hard clams, mussels and oysters. Research on new species and exploratory projects in promising categories are expected to constitute roughly one–tenth of the Sea Grant aquaculture research and may represent much of the aquaculture work in some institutions. Aquaculture research on organisms that do not occur naturally in the Great Lakes, ocean, or brackish water during any part of their life cycle is low priority, especially those for which the Departments of Agriculture and Interior have assumed responsibility.

Projects to fund the general operations of aquaculture facilities or programs at various institutions should be discouraged in favor of projects identifying specific goals related to priority and species subject areas. Most facility expenses should be born by the supporting institutions.

NUTRITION AND FEED DEVELOPMENT. Improved understanding of the nutritional requirements for specific life stages for hard clams, oyster, marine shrimp, prawns, marine finfish, and salmon is high priority. Studies leading to more cost–effective artificial diets for crustaceans and finfish are high priority as are improvement in natural diets, their culture and feeding procedures for mollusks and finfish. The development of commercial rations is considered to be the province of private industry.

PATHOLOGY AND DISEASE CONTROL. Determination of the causes of major disease related mortalities in culture systems and the development and testing of procedures and substances to prevent or control these mortalities is assigned a high priority for oysters, salmon, marine finfish, and shrimp. Disease poses no constraint at this time on mussels and freshwater prawns, thus work of this type on those animals is low priority.

ENVIRONMENTAL REQUIREMENTS. An inadequate understanding of this aspect of aquaculture continues to be manifested by problems of production variability in prawn and shrimp ponds, and stress and related problems of finfish in ponds and net pens. Research directed toward these problems is high priority as is work on determining the carrying capacity of the natural environment for growth of cultured organisms, including mussels, salmon, marine finfish, clams and oysters.

GENETICS AND SELECTIVE BREEDING. High priority is assigned to research to understand the basic genetic make–up of the organisms in culture sufficient to determine the potential for improvement of the species, and to identify the most promising methods for making these improvements. Work to bring about strain improvements for clams, oysters, salmon, marine finfish, and marine shrimp is also high priority, as is improved control of maturation and reproduction of crustaceans and marine finfish. Researchers are encouraged to make use of genetic engineering principles if appropriate to develop industry objectives. There is a high priority need to develop procedures for conserving wild gene pools for all organisms in which cultured individuals are mixed with those in the natural environment.

In addition to the above established priorities there are some
specific areas that need special attention:

In pond dynamics we are just starting to understand the role of bacteria and other micro–organisms in providing nutrition to pond cultured species. The interaction of microbes and pond cultured species becomes more complex as polyculture practices are adopted. Further work

needs to be done on the complex interactions that occur in pond culture.

There still needs to be more work on the development of technology for the production of marine finfish. Evaluations of live planktonic foods as well as artificial diets should be continued. Environmental manipulation as well as hormonal manipulation of spawning should be compared and improved upon.

It is becoming apparent that we need more control over the hormonal systems operating in all groups of animals being cultured. Endocrinology studies should receive high priority.

As the aquaculture industry is coming on line it is clear that Sea Grant needs to become involved with clarifying and simplifying the multitude of regulations and laws that presently inhibit the industry. More work is also needed on setting the economic guidelines for the industry. These areas have not received much attention in the past but time after time the private sector identifies these areas as top priority.

Aquaculture and biotechnology are closely associated in the Sea Grant Program. We are seeing more application of biotechnology to aquaculture than to most other subject areas. Aquaculture projects using biotechnology principles are of high priority.

The Japanese have integrated their artificial reef program with their aquaculture program to assure recruitment of target species to the new substrates and habitat provided by the artificial reef. Marine finfish of a more sedentary nature such as grouper, snappers, sea bass, etc., might be tested on artificial reef substrates as part of the rapidly expanding artificial reef system in the United States to enhance recruitment and recreational fishing opportunities.

PROJECTS

1. AQUACULTURE SYSTEMS

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Development of a Greenhouse Bivalve Hatchery System. Phase I: Evaluation of the Growth Rates and Nutritional Value of Algae Sp P.B. Heffernan 03 Georgia Sea Grant College Program	46,400	0
Seaweed Agronomics P. Helfrich 01 University of Hawaii Sea Grant College Program	33,648	45,300
Pond Water Quality Management P. Helfrich 01 University of Hawaii Sea Grant College Program	8,631	7,500
Sublethal Stress in Mahimahi J. Szyper 02 University of Hawaii Sea Grant College Program	28,115	50,885
R/UG-12 Biology of SeaCucumbers R. Richmond 03 University of Hawaii Sea Grant College Program	20,889	35,109

Development of Techniques for Increasing the Efficiency of Soft Shell Crawfish Production by Removal/Neutralization of the Ey R.F. Malone 01 Louisiana Sea Grant College Program	51,400	41,811
Development of Sand Filtration Technologies to Support Intensive Finfish Culture Systems R.F. Malone 02 Louisiana Sea Grant College Program	20,153	13,964
Preparation of Technology Transfer Documents Based Upon the Corps of Engineers Containment Area Aquaculture Program C.D. Veal 77 Mississippi/Alabama Sea Grant Consortium	0	0
Uptake and Retention of Contaminated by Fish Maintained on Artificial Diets in Lake Ontario J.K. Buttner 02 New York Sea Grant Institute	32,344	20,208
Hybrid Striped Bass Culture: Evaluation and Growth Enhancement for Commercial Production R. Hodson 02 University of North Carolina Sea Grant College Program	66,032	27,581
Maximizing Shellfish by Manipulating Their Environment C.H. Peterson 06 University of North Carolina Sea Grant College Program	4,669	16,484
Clutchless Oyster Culture in Texas L. DiMichele 02 Texas A&M University Sea Grant College Program	54,311	51,703
Rejuvenation of the Chesapeake Oyster Industry R. Mann 03 Virgina Graduate Marine Science Consortium Sea Grant Program	25,000	0
The Application of Knowledge-Based Systems to Marine Sciences: Fisheries Sciences Management and Aquaculture J.D. Palmer 74 Virgina Graduate Marine Science Consortium Sea Grant Program	0	0
SUBTOTAL:	$411,592	$310,545
PASSTHROUGH:	157,200	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
2. Genetics and Selective Breeding		
Broodstock Improvement in a Pink Salmon Hatchery W.W. Smoker 02 University of Alaska Sea Grant College Program	30,100	0
Artificial Selection for Run Timing in Salmon Culture W.W. Smoker 02 University of Alaska Sea Grant College Program	24,700	6,100
Capacitation and Cryopreservation of Shrimp Sperm W. Clark 01 University of California Sea Grant College Program	110,192	62,578
Population Genetics of Commercial Oyster Stocks D. Hedgecock 03 University of California Sea Grant College Program	8,829	33,980
Genetics of Morphology and Growth in Laminaria from the North Atlantic Ocean C. Yarish 05 University of Connecticut Sea Grant Program	35,015	19,038
Plant Tissue Culture Technology for Marine Angiosperms Used in Habitat Restoration K.T. Bird 05 Florida Sea Grant College Program	34,700	46,800
Identification of Fish and Fishery Techniques II Products By Monoclonal Antibody C. Wei 35 Florida Sea Grant College Program	39,600	24,200
Genetic Selection for Increased Growth Rate in the Hard Clam, Mercenaria mercenaria, and the Bay Scallop, Argopecten irradian J.W. Crenshaw, Jr. 06 Georgia Sea Grant College Program	69,700	29,400
Genetic Tagging Mahimahi-MtDNA R.L. Cann 02 University of Hawaii Sea Grant College Program	11,999	19,491
Production of Transgenic Fish: Influence of Bovine Growth Hormone Gene. C.G. Kohler 02 Illinios/Indiana Sea Grant Program	16,323	29,918

Functional Analysis of Isemination in Penaeoid Shrimps: Development of Models for Controlled Natural Artificial Insemination R.T. Bauer 01 Louisiana Sea Grant College Program	30,770	36,775
Genetic Enginerring of Fish and the Use of GH Hormone to Enhance Fish Growth D.A. Powers 02 Maryland Sea Grant College Program	78,000	43,400
Distinguishing Between Naturally Produced and Stocked Walleyes in Saginaw Bay D. Jude 18 Michigan Sea Grant College Program	15,826	30,440
Evaluation of Fish for Aquaculture A.R. Kapuscinski 02 Minnesota Sea Grant College Program	25,480	5,920
Development of Transcriptional Promoters for Gene Transfer into Fish P.B. Hackett 02 Minnesota Sea Grant College Program	8,520	2,980
Vectors for Genetic Engineering in Marine Algae: the Ti Plasmid K.B. Taylor 05 Mississippi/Alabama Sea Grant Consortium	54,793	43,078
Production of Sterile and Unisexual Populations of Salmonids for Aquaculture C. Schreck 02 Oregon Sea Grant College Program	23,200	9,300
Isolation and Characterization of the Interferon Genes of Rainbow Trout J.C. Leong 08 Oregon Sea Grant College Program	82,500	22,600
Applied Breeding of the Hard Clam, Mercenaria: Breeding Phase & the Effects of Allozyme Variation on Growth J.J. Manzi 03 South Carolina Sea Grant Consortium	117,900	77,500
Applied Breeding of the Hard Clam, Mercenaria: Gametogenesis A.G. Eversole 03 South Carolina Sea Grant Consortium	21,300	14,200

Genetic Potential for Improved Productivity in the Hard Clam Mercenaria T.J. Hilbish 03 South Carolina Sea Grant Consortium	54,800	26,900
Mitochondrial DNA Variation in Red Drum & Evaluation of Red Drum Stocking Success in Texas Bays J. Gold 02 Texas A&M University Sea Grant College Program	57,214	34,426
Assessment of MSX Resistance in Hatchery-Reared Oysters from Brood E. Burreson 03 Virgina Graduate Marine Science Consortium Sea Grant Program	15,834	7,542
Biotechnical Approaches To Improve Triploidy and Growth In Pacific Oysters K.K. Chew 03 Washington Sea Grant College Program	79,900	69,900
Porphyra Strain Improvement and Protoplast Development J.R. Waaland 05 Washington Sea Grant College Program	78,100	45,300
Gene Analysis and Transformation in Marine Algae R.A. Cattolico 05 Washington Sea Grant College Program	93,300	69,900
Control of Growth, Sex and Reproduction in Great Lakes Coolwater Fishes by Genetic and Endocrine Manipulation T.B. Kayes 02 Wisconsin Sea Grant Institute	86,145	55,940
SUBTOTAL:	$1,304,740	$867,606
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
3. Physiology/Endocrinology		
Effects of Throid Hormone Smoltification in Salmon S.O. Ebbesson 08 University of Alaska Sea Grant College Program	59,900	13,800
Endocrine Control of Molting and Reproduction in Decapod Crustacea E. Chang 01 University of California Sea Grant College Program	49,489	38,792

Endocrine Stimulation and Regulation of Sturgeon Female G. Moberg 02 University of California Sea Grant College Program	24,082	41,314
Salmonid Development and Seawater H. Bern 06 University of California Sea Grant College Program	92,131	59,818
Control of Reproduction and Growth Regulation in Crustacean Resources H. Laufer 01 University of Connecticut Sea Grant Program	51,602	48,514
Peptide Hormone Control of Reproduction in a Marine Shrimp, Penaeus Yannamei L.S. Quackanbush 01 Florida Sea Grant College Program	39,300	26,200
Promoters of Shrimp Maturation J.B. Brock 01 University of Hawaii Sea Grant College Program	11,235	15,160
Regulation of growth and morphotype in freshwater crustaceans D.W. Borst 01 Illinios/Indiana Sea Grant Program	49,777	35,355
Reproduction in Marine Shrimp: Egg Activation and Early Development J.W. Lynn 01 Louisiana Sea Grant College Program	29,974	14,574
The Identification of Steroids in Fish and the Role of Steroids on Juvenile Development in Atlantic Salmon. S.A. Sower 02 Maine/New Hampshire Joint Sea Grant College Program	33,000	27,737
Hormonal Regulation of Gametogenesis in Striped Bass Morone Saxatilis R.C. Cochra 02 Maryland Sea Grant College Program	42,000	5,200
A Novel Technology for the Manipulation of Fish Reproductive Cycles: Controlled Release of Gonadotropin Releasing Hormones R.S. Langer 06 Massachusetts Institute of Technology Sea Grant College Program	43,000	34,937

Smoltification of Atlantic Salmon (Salmo salar): detection and biochemical and molecular investigations T. Bradley 03 Rhode Island Sea Grant College Program		26,457	53,700
Atlantic Salmon Smoltification: Hormone Physiology of Growth at Sea J. Specker 03 Rhode Island Sea Grant College Program		47,879	38,725
Hormonal Regulation of Reproduction in Penaid Shrimp R. Rankin 01 Texas A&M University Sea Grant College Program		61,354	18,919
Biochemical Genetic Analysis of Osmotic Response in Penaeid Shrimp R.S. Burton 01 Texas A&M University Sea Grant College Program		31,897	16,108
Physiology of Gonadotropins in Atlantic Croaker & Red Drum P. Thomas 02 Texas A&M University Sea Grant College Program		46,242	23,121
Seawater Tolerance and Performance of Triploid Hybrid Salmon G.H. Thorgaard 02 Washington Sea Grant College Program		55,700	45,000
Endocrine Control in Salmonids W.W. Dickhoff 02 Washington Sea Grant College Program		61,600	30,000
Assessment of Low-Level Gas Supersaturation as Stressors in Lake Trout and Rainbow Trout T.B. Kayes 02 Wisconsin Sea Grant Institute		65,641	42,713
	SUBTOTAL:	$922,260	$629,687
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
4. Nutrition		
Effects of Marine Micralgal Metabolites on Feeding Behavior and Growth of Bivalves N.M. Targett 06 Delaware Sea Grant College Program	10,140	11,778

Importance of Lipids and Lopoproteins in the Reproduction Success of the Hard Clam (Mercenaria mercenaria) R.F. Lee 03 Georgia Sea Grant College Program		169,040	0
Feeds Nutrition E.G. Grau 02 University of Hawaii Sea Grant College Program		29,636	80,602
Mahimahi Nutrition and Genetics B. Carlson 02 University of Hawaii Sea Grant College Program		50,176	100,000
The Role of Picophytoplankton in the Nutrition of Larval & Adult Oysters R. Newell 06 Maryland Sea Grant College Program		33,100	12,300
Feeding Regimes and Nutritional Requirements of Hybrid Striped Bass Fingerlings and Larvae M.L. Gallagher 02 University of North Carolina Sea Grant College Program		10,289	10,493
Microencapsulated Diets for Intensive Production of Molluscan Shellfish C. Langdon 03 Oregon Sea Grant College Program		64,200	37,300
Fatty Acid and Lipid Nutrition of Red Drum: Effects on Cold Adaptation, Immunocompetency and Product Quality D.M. Gatlin 02 Texas A&M University Sea Grant College Program		35,049	19,938
	SUBTOTAL:	$249,490	$272,411
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
5. Disease/Parasites		
Development and Evaluation of Gene Probes for Use in the Diagnosis of Baculovirus Infections in Penaeid Shrimp (Thurman) Thurman 13 University of Arizona, Tucson	34,900	21,600

Fatal Inflammatory Bacteremia in Pacific Oysters R. Hedrick 03 University of California Sea Grant College Program	6,750	13,902
Develop of DNA Probes - Pathogenic Marine Bac H. Shizura 45 University of Southern California Sea Grant Program	39,574	37,113
Studies Concerning the Uptake, Elimination, Retention and Depuration of Virulent, Avirulent and VBNC Forms of Vibrio vulnific G.E. Rodrick 08 Florida Sea Grant College Program	22,300	57,000
Ozone-Assisted Depuration of Red Tide Contaminated Shellfish and Seawater G.E. Rodrick 35 Florida Sea Grant College Program	20,000	30,000
Anti-Idiotype Antibodies as Novel Immunogens and Diagnostic Reagents for Aquatic Birnaviruses B.L. Nicholson 08 Maine/New Hampshire Joint Sea Grant College Program	54,160	81,764
Immune Status and Susceptibility to Disease in the Oyster, Crassostrea Virgina R.S. Anderson 08 Maryland Sea Grant College Program	35,000	22,600
Metabolism of Antimicrobial Agents by Penaeid Shrimp K.D. McMurtrey 05 Mississippi/Alabama Sea Grant Consortium	31,840	31,418
Nucleic Acid Probes for the Oyster Parasite Haplosporidium Nelsoni S. Ford 08 New Jersey Marine Sciences Consortium Sea Grant Program	30,500	38,400
Uptake and Depuration of Red Tide Paralytic Shellfish Poisoning Toxins in East Coast Bivalve Molluscs V.M. Bricelj 06 New York Sea Grant Institute	74,177	31,188
Improved Diagnostic Methodology for Diseases of Salmonids P.A. Bowser 08 New York Sea Grant Institute	36,454	33,783

Environmental Regulation of Protozoan Ectoparasites of Fishes: a Model E.G. Noga 08 University of North Carolina Sea Grant College Program	4,410	22,560
Development of Therapeutics for Stress-Related Immune Dysfunction S.L. Kaattari 02 Oregon Sea Grant College Program	29,600	69,600
Virulence Factors Important to the Pathogenesis of Fish Diseases J.S. Rohovec 08 Oregon Sea Grant College Program	61,800	112,400
Interactions of the Environment & the Pathogen, Perkinsus marinus, with Internal Defenses of Oysters W. Fisher 06 Texas A&M University Sea Grant College Program	48,596	29,056
Fungal Pathogens of Nori H.C. Whisler 05 Washington Sea Grant College Program	18,000	10,700
Identification and Production of Trout Stocks Genetically Resistant to Disease C.V. Sommer 02 Wisconsin Sea Grant Institute	48,460	31,310
SUBTOTAL:	$596,521	$674,394
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
6. Policy/Economics		
SUBTOTAL:	$0	$0
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
7. Other		
Larval Biology of the Weathervane Scallop T.C. Shirley 02 University of Alaska Sea Grant College Program	18,900	0

The Importance of Competing Sessile Species to the Survivorship of Juvenile Oysters R.B. Whitlatch 06 University of Connecticut Sea Grant Program		41,771	22,572
Macrobenthic Production in Natural and Restored Seagrass Beds S.S. Bell 40 Florida Sea Grant College Program		29,500	21,100
Strengthening Aquaculture Development in Ijsular Pacific Communities J.R. Davidson 04 University of Hawaii Sea Grant College Program		0	0
Population Dynamics of Hatchery-Reared Juveniles of the Soft-Shell Clam (Mya arenaria L.) in Maine: A Series of Manipulative B.F. Beal 03 Maine/New Hampshire Joint Sea Grant College Program		36,000	9,175
Human Influences on the Dispersal of Living Organisms and Genetic Material into Aquatic Ecosystems A. Rosenfield 74 Maryland Sea Grant College Program		0	0
Studies in Support of the Oyster Fishery of Delaware Bay: Use of Numerical Circulation Modelling to Define Oyter Larval and S T. Jacobsen 07 New Jersey Marine Sciences Consortium Sea Grant Program		18,800	45,000
Aquaculture Advisory Services for Great Lakes Fishes F.P. Binkowski 77 Wisconsin Sea Grant Institute		10,332	8,916
	SUBTOTAL:	$155,303	$106,763
	PASSTHROUGH:	246,000	

Fisheries

Summary

The Fisheries Research Program focuses on a large number of topics falling within the major categories of fisheries biology and management, and fishing and sampling gear technology. This year the program consists of 142 project funded at $4.97M in Federal funds, $3.84M in state matching funds, and $0.64M in pass through funds. All programs support at least one project in fisheries research, and all support advisory activities associated with fisheries. Only 21% of the projects funded comply with the National Sea Grant Office Annual Guidance, thus resulting in an evaluation of the guidance and its revision. Research associated with recruitment fisheries oceanography continues to receive substantial attention from the research community. This topic was funded at $1.05M this year.

Research planning on the topic of recruitment fisheries oceanography continued this year with the completion of the NOAA program development plan and the drafting of a technical development plan for a South Atlantic Bight recruitment study. A number of opportunities in related research sponsored by NOAA and other agencies are identified. Additional research opportunities are identified.

Following practice begun three years ago the report includes abstracts of a number of publications submitted to the Sea Grant Depository. These address the research priorities Developing New Techniques for Assessment, Recruitment and Fisheries Oceanography, Habitat Fish Productivity Interactions, Integrating Biological and Economic Information into Management Strategies and Plans, an Promising Areas of Research.

Introduction

The Marine Division of the National Association of State Universities and Land Grant Colleges (NASULGC) commissioned a review of three Sea Grant research programs. One of these was the Fisheries Program. In its analysis of that program, the reviewers reported that "Sea Grant is of vital national importance in funding near shore fisheries research that would not be conducted otherwise." The review goes on to state that Sea Grant's Fisheries Program is the primary source of support for scientific research on coastal fisheries, and that Sea Grant is the only Federal agency attempting to bring some semblance of priority to the existing chaos in coastal fisheries science and management.

Although there are many who would disagree with some of the findings in the NASULGC report, Sea Grant has long recognized that it is a unique and important component of the fisheries science community. The role of Sea Grant fisheries scientists is one of fostering and emphasizing the development of theory and technological innovation. State and Federal fishery scientists tend to focus on long-term, large scale monitoring programs associated with management responsibilities. The housing in NOAA of Sea Grant and the National Marine Fisheries Service (NMFS), the federal agency charged with the responsibility for the management of the living marine resources in the Exclusive Economic Zone, represents an intellectual base capable of addressing any and all of the complex problems confronting the Nation's recreational and commercial fisheries industries.

Program Statistics and Trends

Program Statistics

The program supports 142 projects at a level of $4.97M in federal funds, $3.84M in state matching funds, and $0.65M in pass through funds. Sixty-seven new and continuing projects were reviewed and evaluated this year. These were funded at or close to the level requested. The

TABLE 1

PROGRAM	NUMBER OF PROJECTS						
	FY83	FY84	FY85	FY86	FY87	FY88	FY89
AK	13	7	8	7	5	10	7
CA	14	11	21	18	22	8	11
CN	2	3	2	2	2	2	3
DL	1	1	5	3	0	0	2
FL	10	9	8	6	8	9	7
GA	6	3	4	3	2	4	3
HI	11	7	6	6	7	7	8
IL/IN	0	3	3	3	2	3	4
LA	5	2	2	2	10	5	4
ME/NH	8	6	9	8	5	3	6
MD	10	7	7	7	6	12	6
MIT	2	2	1	1	2	2	4
WHOI	5	4	5	2	3	2	1
MI	15	7	7	6	5	6	7
MN	2	3	5	3	3	4	4
MS/AL	2	2	2	2	2	2	2
NC	7	6	5	4	6	6	7
NJ	6	2	3	7	9	8	5
NY	8	8	11	8	4	5	8
OH	2	3	2	4	3	2	1
OR	10	6	5	3	4	3	4
PR	2	1	3	4	3	2	1
RI	4	2	4	3	3	6	4
SC	4	3	3	2	4	0	1
USC	1	0	0	0	0	1	1
TX	8	8	6	5	5	9	9
VA	7	5	7	6	6	5	6
WA	14	12	7	8	10	9	12
WI	12	15	9	9	12	9	4
TOTAL	191	146	158	144	153	144	142

Level Of Effort In Fisheries For Each Institutional Program For The Fiscal Years 1983-1989

remaining 75 projects are those reviewed and approved last year as portions of 2-year institutional grants or were more appropriately reviewed within other subject area programs.

All programs support at least one research project in fisheries science (Table 1). The Marine Advisory Programs of all programs also support major education efforts associated with various aspects of fisheries.

Trends

The number of projects supported this year decreased slightly from last year;however the level of funding has remained within the norm (Fig. 1).

This year only 30 projects or 21 % conformed to the Annual Program Guidance provided by the National Sea Grant Office (Table 2). The low level of conformity is in keeping with the trend that began in Fiscal Year 1986 (Table 2). Once again maximum compliance occurs within those areas associated with larval and juvenile fish and shellfish investigations. This is a clear reflection of Sea Grant's emphasis on recruitment fisheries oceanography. This year $1.04M of the Fisheries Program funds are going to support this research topic.

Following up on the decision made last year to evaluate the guidance, it was determined that the degree of specificity of each priority was to confining to an academic audience. As constructed, the guidance is more of a management document than one identifying potentially profitable avenues of research. Accordingly, the guidance was substantially modified this year (Table 3). The research priorities may be revised substantially within the next two years during which period the Fisheries Strategy of 1985 will be evaluated and updated.

Progress and Significant Achievements

Recruitment fisheries oceanography continues to attract a great deal of interest within NOAA and the oceanographic community at large. The Program Development Plan for Recruitment Fisheries Oceanography was completed and distributed throughout NOAA and the Sea Grant network. Following up on the plan a number of research planning meetings and workshops were held at various locales, particularly in the southeast portion of the country. The purpose of these activities was to consider the potential for initiating major oceanographic experiments in fisheries oceanography and recruitment.

Two major products were developed as a result of these planning sessions. One of these is a workshop proceedings describing potential areas of investigation for the state of Fla. The conclusions reached are, however, applicable to most areas of the southeast and Gulf coast states. The other product is a draft Technical Development Plan (TDP) for a major investigation of the South Atlantic Bight. This effort focuses on the so called estuarine dependent species which are associated with oceanic frontal systems. A similar draft plan was produced for the Great Lakes and their forage fishes. Sea Grant investigators have been intimately involved in all these efforts.

There are a number of forces driving these planning activities. Chief among these within NOAA is the new Coastal Ocean Program (COP). One of the major components of that program is Coastal Ecosystems, which focuses primarily on the fisheries oceanography and recruitment processes taking place in near shore waters. Although no funding was provided for this component in Fiscal Year 1990, there is a good chance that funding will be forthcoming in FY 91. Even if funds from the COP become available they will be insufficient, by themselves, to pursue all activities associated with the Recruitment Fisheries Oceanography Program. Some of the additional funds might be obtained from the National Science Foundation's developing Global Ecosystem Dynamics (GLOBEC) program. This year the NSF set up a GLOBEC steering committee to define the direction of that program. Based on personal observations, there are many areas in which the fisheries oceanography program can be integrated into GLOBEC and vice versa.

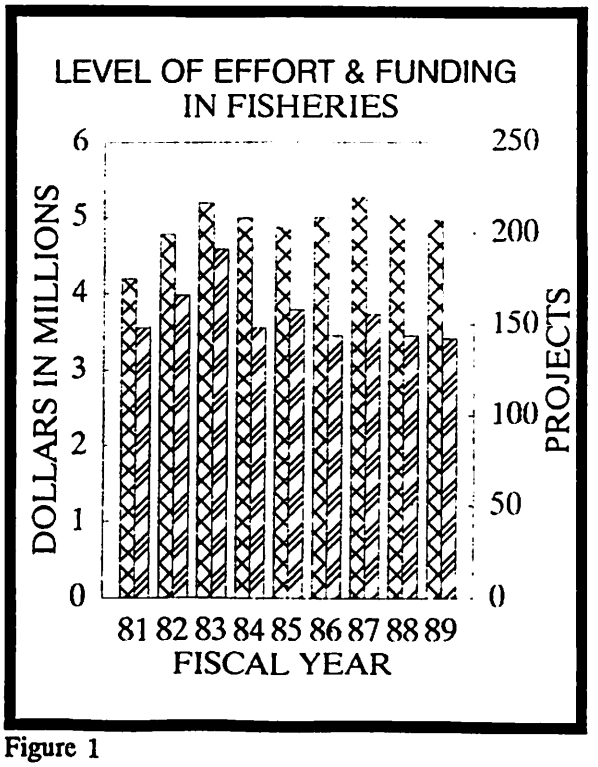

Figure 1

Additional opportunities may become available in the next few years from the Office of Naval Research. During one meeting with a few ONR program managers it was learned that Navy is also considering new initiatives focusing on the linkage of physical oceanographic factors and biological productivity. Navy also expressed interest in physical oceanography of near shore areas, a vital component in all fisheries oceanography studies. Agreement was reached to exchange planning documents as they are developed.

Achievements

In the past this report identified technical papers and reports that exemplified the quality research supported by Sea Grant. The selection was based upon submissions to the National Sea Grant Office and items gleaned from the published literature. Following up on the problem identified last year; the failure of many researchers to submit publications to their Sea Grant directors, only those papers appearing in *Sea Grant Abstracts* were considered of inclusion in this report. *Sea Grant* Abstracts is a publication in which all papers, articles, and reports produced with Sea Grant funds are listed and abstracted. A paper not appearing in *Sea Grant Abstracts* is not considered a Sea Grant publication. Accordingly, failure to publish will be viewed negatively during the project review process. As in the past, papers are listed under research priorities.

Developing New Techniques for Assessments

Bortone, Stephen A., Hastings Robert W., Oglesby, Jerry L. 1986. Quantification of reef fish assemblages: a comparison of several in-situ methods. "Northeast Gulf Science," 8(1):1-22.

Data on reef fish communities have served to evaluate community responses to natural and artificial changes in the biotope. However, accurate and precise evaluation of species composition and abundance has been extremely difficult. Moreover, spatially irregular biotopes and high physical relief preclude the use of conventional surface-tended collection methods. Through the use of saturation diving in conjunction with the underwater diving facility Hydrolab, in-situ methods of reef fish quantification were tested in a single reef environment at two different reef biotopes, both diurnally and nocturnally. Six methods (species-time, random count; transects; quadrats; linear cinetransects; circular cinetransects or cineturret; and still photography) are compared and assessed here.

Recruitment and Fisheries Oceanography

Rice, James A., Crowder, Larry B., Holey Mark E. 1987. Exploration of mechanisms regulating larval survival in Lake Michigan bloater: a recruitment analysis based on characteristics of individual larvae. Trans. Am. Fish. Soc. 116:703-718.

Events occurring between spawning and the first 1-2 months after hatching play a major role in determining recruitment success of bloater *Coregonus hoyi* in Lake Michigan. Mechanisms governing survival of larval bloaters were investigated by comparing characteristics of individual 'survivors' through the first 1-2 months of life with those of larvae at earlier life history stages. Eggs spawned early experienced higher mortality during the incubation period. Studies also suggested that early hatching larvae experienced higher initial mortality than late-hatching larvae. Lower growth rates and higher frequency of stress marks for larvae during the period of higher relative mortality suggest that size or growth-rate-dependent mortality (e.g., predation) during the first few weeks of life may be an important mechanism affecting bloater recruitment.

Monteleone Doreen M., Duguay Linda E. 1988. Laboratory studies of predation by the ctenophore *Mnemiopsis leidyi* on the early stages in the life history of the bay anchovy, *Anchoa mitchilli*. "Journal of Plankton Research," 10(3):359-372.

Along the East Coast of the U.S., *Mnemiopsis leidyi* (a lobate ctenophore) co-occurs with spawning bay anchovy, *Anchoa mitchilli*. Major decreases in zooplankton abundances have been correlated with increases in local *M. leidyi* populations. It is possible that in addition to copepods *M. leidyi* could be consuming early life stages of fish. This study was designed to *mitchilli*. Variations in predation due to prey density, experimental container size, alternate prey, prey condition and size were measured under controlled laboratory conditions. Results suggest that *M. leidyi* has the potential to inflict substantial predation

pressure on early stages in the life history of bay anchovy.

Nyman, Robert M., Conover, David O. 1988. The relation between spawning season and the recruitment of young-of-the-year bluefish *Pomatomus saltatrix*, to New York. "Fishery Bulletin," 86(2):237-250.

Bluefish are found over different portions of the continental shelf from Florida to Nova Scotia at various times of the year. Based on descriptions of the temporal and spatial abundance of larvae, Kendall and Walford (1979) suggested that there are primarily two distinct spawning periods and regions: a spring spawning in the South Atlantic Bight at the edge of the Florida Current, and a summer spawning in the Middle Atlantic Bight. They further proposed that the spring-spawned larvae are transported northward in the slope waters and then move inshore, spending their first summer in the bays and estuaries of the Middle Atlantic Bight; summer-spawned larvae spend their first summer at sea or enter the estuaries only briefly before migrating southward with the onset of winter. The purpose of this study is to evaluate Kendall and Walford's hypothesis by back-calculating the spawn dates of young-of-the-year (YOY) bluefish that have recruited to inshore waters from the number of growth increments in their otoliths.

Morse Aileen N. C. 1988. The role of algal metabolites in the recruitment process. Marine Biodeterioration: Advanced Techniques Applicable to the Indian Ocean," M.-F. Thompson, R. Sarojini, and R. Nagabhushanam (eds.), pp. 463-473.

TABLE 2

ANNUAL GUIDANCE	PROJECT IN AGREEMENT			
	FY 86	FY 87	FY 88	FY 89
Larval Fish Ecology				
a) transport or predation	8	8	9	10
b) evaluate "critical period" hypothesis using existing data	2	3	5	3
Juvenile Fish Survival Rates	4	2	5	7
Restoring and Enhancing Exploited Stocks Through Hybridization and Genetic Engineering				
a) risk analysis of accidental and intentional releases	0	0	0	0
b) production methodology	4	5	6	5
Fisheries Development Research (Multidisciplined)	0	0	0	3
Gear Studies				
a) increased selectivity	1	1	2	2
b) behavior modifications	2	1	0	0
c) improved biological sampling	0	0	0	0

COMPARISON OF PROJECTS FUNDED WITH THE FY 85 ANNUAL GUIDANCE DOCUMENT

Crustose red algae are widely and extensively distributed in the marine environment. Larval recruitment of many marine invertebrates associated with these algae seems to depend on the presence of algal surface molecules responsible for induction of the processes of settlement, adhesion and metamorphosis. Biochemical characterization of these inducer molecules reveals that they are algal metabolites associated with secondary light-harvesting components, which are transported to algal surfaces and made available to larvae by the unique sloughing mechanism of these algae. The represent a new class of low molecular weight compounds with neurotransmitter-mimetic properties.

Habitat Fish Productivity Interactions

Kitchell, James F., Evans Marlene, Scavia, Donald, Crowder, Larry B. 1988. Regulation of water quality in Lake Michigan: report of the food web workshop. "Journal of Great Lakes Research," 14(1):109-114.

During the past 20 years, Lake Michigan has experienced substantial reduction in nutrient inputs, major changes in the biological community, and re-configuration of the pelagic food web. Alewife, the previously dominant zooplanktivore, has decreased to 10-20% of its former abundance, a new assemblage of zooplankton has become dominant, and summer water clarity has increased nearly three-fold in that time. This report summarizes an International Joint Commission-sponsored workshop on food web interactions. In general, physical-chemical conditions are the major regulators of water quality during spring and fall periods. Food web effects are most manifest in offshore waters during the period of summer stratification. Discussion during the workshop led to insights regarding the causes of recent changes, their association with nutrient controls and/or food web interactions, and the likely dimensions for future effects.

Smith, R. L., Paul, A. J. Paul, J. M. 1988. Aspects of energetics of adult walleye pollock, *Theragra chalcogramma* (Pallas), from Alaska. "Journal of Fish Biology," 33:445-454.

This paper examines several aspects of energy metabolism in adult walleye pollock within its normal environmental temperature range. Information is presented on resting (standard) metabolic rate as determined by oxygen consumption, energy intake and its effect on growth, energy partitioning in the body, and the energetic cost of spawning. Using the information presented here,one could calculate the energy or prey biomass requirement for adult pollock based on the equation relating energy consumption to growth. Results would also allow preliminary estimates of the prey stocks necessary to provide that energy for extant populations of walleye pollock.

McIvor, Carole C., Odum, William E. 1988. Food, predation risk, and microhabitat selection in a marsh fish assemblage. "Ecology, "69(5):1341-1351.

Fishes moving onto the surface of a tidal freshwater marsh from an adjacent stream were sampled with flume nets for 2 yr. Higher numbers were found at sites close to shallow-sloped depositional banks than at sites close to deeper, steeper erosional stream
banks. To determine whether the relative abundance of benthic invertebrate prey differed in the two environments, litter bags were placed in the subtidal for 4 wk.To test whether predation pressure differs with subtidal geomorphology, mummichogs (*Fundulus heteroclitus*) were tethered on the first half of the rising tide in both depositional and erosional environments in three creeks. Results suggested that two mechanisms operate in the stream subtidal to give rise to the difference in fish abundance. At low tide, when small fishes are confined to creek channels, they select shallow depositional habitats where (1) the availability of benthic invertebrate prey is greatest and (2) predator pressure is less. As the tide rises and inundates the marsh surface, these small fishes seek shelter on the marsh surface adjacent to their preferred low-tide refuge.

Integrating Biological and Economic Information into Management Strategies and Plans

Pikitch, Ellen K. 1988. Objectives for biologically and technically interrelated fisheries. In "Fisheries science management: objectives and limitation," W.S. Wooster (ed.), pp. 107-136,Springer-Verlag.

As the focus of management shifts from a single to a multispecies perspective, the range of potential objectives increases, and different objectives are

more likely to result in disparate system states and yields. Moreover, whereas preservation of yield capacity and maximization of yield are largely compatible for single species management, adopting a multispecies perspective increases the chance that such objectives will conflict. There are significant constraints on the ability to achieve objectives for multispecies fisheries, not least the fact that a common objective for multispecies fisheries (maximized yield of each species) is unattainable for systems containing interactions among species. The adoption of firm objectives for fisheries that contain biological or technological interactions presumes levels of knowledge or control that are unlikely to be obtainable or desirable; therefore, it is suggested that a more feasible approach to defining objectives is to seek satisfactory and progressively improved management solutions.

Daniel, Peter C., Bayer, Robert C., Waltz, Cheryl. 1989. Egg production of V-notched American lobsters (*Homarus americanus*) along coastal Maine. "Journal of Crustacean Biology," 9(1):77-82.

Current Maine law allows fishermen to place a V-shaped notch in the right uropod of ovigerous lobsters before returning them to the sea. The landing of a lobster in Maine with a mutilated or notched right uropod with or without eggs is illegal. The Maine Department of Marine Resources buys some ovigerous and nonovigerous female lobsters to V-notch and release in addition to the voluntary V-notching by lobstermen. The rationale for this management tool is to protect lobsters with proven reproductive capability, thus enhancing egg production and ultimately recruitment, but no attempts have been made to evaluate its impact on the fishery until this study. Preliminary results indicate the need to include V-notched lobsters in Maine fishery surveys and assessments and to investigate the possibility of V-notching as a management tool for the entire Gulf of Maine
fishery region.

Promising Areas of Research

Pikitch, Ellen K. Demory, Robert L. 1988. Assessment of scales as a means of aging Dover sole. "Transactions of the American Fisheries Society," 117:345-349.

Analysis of scales taken from 74 tagged Dover soles collected off Oregon demonstrated that scales were inadequate aging structures for this species. This contradicted earlier work that used marginal growth of scales and age-length observations as indirect validation methods. Errors in scale-age determinations were found for fish assigned scale ages of 5 years and greater.
Relationships between expected scale age and actual age indicated that maximum longevity for Dover sole off Oregon may be in the
range of 48-52 years, in contrast to the maximum scale age (28) observed for this species.

Hill, Kevin T., Radtke, Richard L. 1988. Gerontological studies of the damselfish, *Dascyllus albisella*. Bulletin of Marine Science," 42(3):424-434.

This study was conducted to examine the occurrence and accumulation of lipofuscin pigments in the brain tissues of the damselfish, *Dascyllus albisella*, and to determine the relationship between brain lipofuscin levels and chronological age as determined by examination of otoliths. Chronological ages were estimated using observed patterns of daily and annual growth in the sagittae. Brain lipofuscin content was determined using previously developed extraction and assay techniques. The study of lipofuscin as an indicator of physiological age in fishes holds many exciting possibilities for answering questions regarding their biology and ecology, and will add another dimension to aspects of age elucidation.

Martin, Linda K., Cailliet, Gregor M. 1988. Age and growth determination of the bat ray, *Myliobatis californica* Gill, in central California. "Copeia," (3):762-773.

The bat ray has been the target of an annual sport fishery since at least 1950, and occasionally appears as a commercially fished species. To adequately assess the impact of continued or
increased exploitation of the bat ray, it is necessary to know growth rates and age-specific fecundities. Cartilaginous fishes, including the bat ray, cannot be aged using traditional fish ageing methods, since they lack the necessary calcified
structures. The objectives of this study were to test and use two techniques for age determination of bat rays to produce reasonable growth curves.

Borst, David W., Laufer, Hans, Landau, Matthew, et al. 1987. Methyl farnesoate and its role in crustacean reproduction and development. "Insect Biochemistry," 17(7): 1123-1127.

The juvenile hormones (JH) play important roles in the regulation of insect development and reproduction. Until recently there had been no successful chemical identification of a JH in any non-insect arthropod. The authors have isolated a JH-like compound, methyl farnesoate (MF), in the hemolymph of the spider crab *Libinia emarginata*, and identified the mandibular organ as the site of synthesis of this compound. In this paper they describe the detection of MF in other decapods, and present data demonstrating its relationship to reproduction and larval development.

White, A. W., Fukuhara O., Anraku M. 1989. Mortality of fish larvae from eating toxic dinoflagellates or zooplankton containing dinoflagellate toxins. Red Tides: Biology, Environmental Science, and Toxicology, " Okaichi, Anderson and Nemoto (eds.), pp. 395-398.

Blooms and red tides of the toxic dinoflagellate *Gonyaulax excavata (tamarensis)* have caused mass kills of adult fish in nature, resulting in losses to traditional fisheries and mariculture. Investigated here are the effects of *G. excavata* on first-feeding larvae of two commercially important fishes in Japan, red sea bream (*Pagrus major*) and Japanese anchovy (*Engraulis japonica*), and the effects of zooplankton containing *G. excavata* toxins on older larvae. Despite low toxin content of the dinoflagellates relative to field conditions, effects of the toxins were apparent. Results suggest that blooms and red tides of *G. excavata* and its toxic relatives cause kills of larval, as well as, adult fish.

Future Directions and Plans

The next few years hold a great deal of promise for Sea Grant and the Fisheries Program. In order to get ready a symposium is being planned for the 120th Annual Meeting of the American Fisheries Society to be held in August in Pittsburgh, Pennsylvania. As envisioned the one day symposium will include a session focusing on the results of Sea Grant supported research and another on discussing the topic: what are the directions for fisheries research in the next 20 years? It is anticipated that this discussion will serves to initiate the revision of the Sea Grant Fisheries Strategy. Hopefully, most of the researchers receiving support from Sea Grant will attend.

During this past year it has become increasing apparent that Sea Grant is failing to meet the short-term needs of the fisheries management constituency. Often Sea Grant is requested to provide information that is important to managers (e.g., growth rates of important species, life history data, fecundity estimates, simple population estimates). The acquisition of such information often does not constitute innovative research and has been discouraged. Noting the need for such information the program directors for Marine Advisory Service and Fisheries have begun to develop policy which will facilitate the provision of this type of information to this important constituency. If this policy is effective it may facilitate the transfer of Sea Grant's more innovative research to management agencies. A problem that has been persistent and most difficult to resolve.

Opportunities

As mentioned above the developing NOAA Coastal Ocean Program and the NSF GLOBEC program are potential sources for additional funding for fisheries oceanography and recruitment research. The COP also offers opportunities for research on the relationship of habitat to fish productivity. In developing projects that can meet the objectives of these major programs it is important to coordinate, or better still, link the research with appropriate NOAA activities.

The analysis of the projects supported by the Fisheries Program indicates that there is substantial potential for the development of a number of new subprograms or multi-institutional studies. A few of the most obvious include: fisheries oceanography and recruitment of redfish in the Gulf of Mexico (LSU, MS/AL, TAMU); the ecology and environmental consequences of the exotic species, zebra mussel and *Bythotrephes cederstroemi* in the Great Lakes (OSU, MI, WI); and a similar investigation on the ruffe in the St Louis Estuary of Lake Superior (MINN, WI, MI). Current research on these subjects is being pursued

Table 3

1990 ANNUAL GUIDANCE PRIORITIES*

Population and Community Modeling

a) New Models
b) Evaluating Assumtions of Commonly Used Models
c) Incorporating Results of Recruitment Studies
d) Individual Based Modeling
e) Integrating Time Series with Long-Term Climate data

Recruitment Fisheries Oceanography

a) Comprehensive Studies of the South Atlantic Bight, Mississippi River Plume, and the Northwestern Gulf; Estuarine Species
b) Studies of the Middle Atlantic Bight Coastal Pelagic Species
c) Studies in Association with or complementary to NOAA's FOCI and CalCOFI Activities

Restoring and Enhancing Exploited Stocks Through Hibridization and Genetic Engineering

a) Risk analysis of accidental and intentional releases

Fisheries Development Research (Multidisciplined)

Gear Studies

a) Increased selectivity
b) Behavior modifications
c) Improved biological sampling

LIST OF PRIORITIES IDENTIFIED IN THE **NOAA'S NATIONAL SEA GRANT COLLEGE PROGRAM ANNUAL PROGRAM GUIDANCE FOR FISCAL YEAR 1990.** * INDICATES THAT RESEARCH PRIORITIES IDENTIFIED IN THE FISHERIES STRATEGY DOCUMENT (1985) ARE STILL VALID.

could be integrated to produce a significantly more comprehensive set of investigations.

Last year the NSGO supported a workshop on the application of Artificial Intelligence (AI) to Aquaculture and Fisheries. The workshop was held at George Mason University, Fairfax, Virginia in June, 1989. The product of the workshop is a report describing the disciplines involved and the problems that AI could be used to address. At present the report is in a final draft stage. When it is published it will be distributed throughout the Sea Grant network in an attempt introduce researchers to these potentially useful techniques. The NSGO will be very interested in supporting fisheries research that incorporates some the ideas presented in the proceedings of the AI workshop.

PROJECTS

FISHERIES

A. Improving the Capability for Predicting Yields, Age-Class Strength & Long-Term Population Status.

1. Improve Predictive Capability of Single Species & Multi-Species Models:

TITLE/INVEST./INST.	FEDERAL FUNDS	MATCHING FUNDS
Stock Assessment and Population Dynamic Models for Management Guidance of the Florida Stone Crab Fishery N.M. Ehrhardt 07 Florida Sea Grant College Program	31,100	15,500
Comparative Analysis of Year Class Strength and Population of Pink Salmon in the Upper Great Lakes W. Taylor 18 Michigan Sea Grant College Program	29,919	20,842
Field Verification & Application of a Host-Parasite Model for Fisheries Management of Significantly Impacted Oyster Population E. Powell 08 Texas A&M University Sea Grant College Program	69,163	56,147
Predatory-Prey Linkages in Great Lakes Food Webs J.F. Kitchell 47 Wisconsin Sea Grant Institute	76,005	19,032
SUBTOTAL:	$ 293,087	$ 140,721
PASSTHROUGH:	0	

B. Determine the Developmental Stage of Fish & Shellfish at Which Year Class Strength is Established:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Larval Biology of the Weathervane Scallop T.C. Shirley 02 University of Alaska Sea Grant College Program	18,900	0

Larval Mortality-Haw Anchovy T. Clark 47 University of Hawaii Sea Grant College Program		19,926	53,271
	SUBTOTAL:	$ 38,826	$ 53,271
	PASSTHROUGH:	0	

C. Determine the Physical, Chemical & Biological Factors Most Important to Recruitment:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Immunological Ident Larval Fish Prey M. Ohman 06 University of California Sea Grant College Program	18,409	33,936
The Importance of Competing Sessile Species to the Survivorship of Juvenile R.B. Whitlatch 06 University of Connecticut Sea Grant Program	41,771	22,572
Feeding, Growth and Survival of Juvenile Summer Flounder T.E. Targett 06 Delaware Sea Grant College Program	8,020	18,544
Toward Forecasting Stone Crab Recruitment and Environmentally Induced Year-Class Strength W.J. Lindberg 06 Florida Sea Grant College Program	63,200	47,000
Florida Spiny Lobster Recruitment: Project Extension W.F. Herrnkind 07 Florida Sea Grant College Program	38,900	19,500
Red Drum Ichtypoplankton Dynamics and Recruitment Implications R.F. Shaw 06 Louisiana Sea Grant College Program	14,058	24,548
Seasonal Abundance and Transport of Blue Crab Larvae in the Mississippi Bight and At a Tidal Pass J.H. Power 06	31,117	30,202
Enhancement of Coastal Productivity Associated with Processes in the Atchafalaya Bay Ecosystem: VIII. Ichthyoplankton Flux Al R.F. Shaw 39 Louisiana Sea Grant College Program	50,996	29,686

Trophic Coupling Between Juvenile Demersal Fishes and the Benthos in Sheepscot Bay L. Watling 06 Maine/New Hampshire Joint Sea Grant College Program	31,000	11,804
Planktonic Delivery of Larvel Lobsters, Homarus americanus, to Selected Benthic Habitats L. Incze 06 Maine/New Hampshire Joint Sea Grant College Program	38,000	0
Causes and Consequences of Cladoceran Dynamics in Lake Michigan: Implications for Recruitment Success of Forage Fish Species J.T. Lehman 40 Michigan Sea Grant College Program	23,871	58,512
Year Class Strength of Rainbow Smelt and Lake Whitefish as Influenced by Interspecific Interactions and Climate W.W. Taylor 40 Michigan Sea Grant College Program	51,230	28,861
Spawning, Early Life History and Larval Transport of Bluefish, Pomatomus saltatrix, in the R.K. Cowen 06 New York Bight New York Sea Grant Institute	75,431	38,539
Spawning and Development Temperatures of the Atlantic Menhaden: Inference from Ion Microanalysis D.M. Checkley 07 University of North Carolina Sea Grant College Program	5,332	24,508
Physical Processes and Inlets and Effect on the Transport of Immature Fishes J. Miller 46 University of North Carolina Sea Grant College Program	48,247	8,358
Size-Dependent Recruitment Mechanisms for Larval and Juvenile Fishes: An Integrated Model and Experimental Approach J.A. Rice 47 University of North Carolina Sea Grant College Program	28,437	5,900
Larval Red Drum (Sciaenops ocellatus) Transport in Non-Stratified Estuaries S.A. Holt 06 Texas A&M University Sea Grant College Program	40,124	21,641

Satellite Analyses for Fishery Oceanography in the Gulf of Mexico A.C. Vastano 50 Texas A&M University Sea Grant College Program		54,472	30,000
Biological Factors as Determinants of Blue Crab Recruitment J.R. McConaugha 06 Virgina Graduate Marine Science Consortium Sea Grant Program		50,162	29,267
Recruitment Dynamics of the Blue Crab: Patterns, Processes, and Fisheries Applications R. Orth 06 Virgina Graduate Marine Science Consortium Sea Grant Program		55,370	87,580
Recruitment Fisheries Oceanography of Walleye Pollock in the Eastern Bering Sea R.C. Francis 06 Washington Sea Grant College Program		30,000	9,700
Long-term Variation in Growth and Abundance of Bristol Bay Sockeye Salmon D.G. Rogers 06 Washington Sea Grant College Program		65,500	39,000
Dungeness Crab and English Sole Population Dynamics and Recruitment D.A. Armstrong 06 Washington Sea Grant College Program		67,900	35,200
Recruitment Fisheries Oceanography of* Walleye Pollack in the Eastern Bering Sea R.C. Francis 6 Washington Sea Grant College Program		(1,600)	0
Integrating Factors Controlling Recruitment Dynamics of Fishes: A Synthesis Based on Larval Size F.P. Binkowski 40 Wisconsin Sea Grant Institute		75,005	17,669
	SUBTOTAL:	$1,006,552	$ 672,527
	PASSTHROUGH:	$ 1,600	

D. Develop Cost Effective Techniques for Assessing Stock Size & Distribution:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Acoustic Studies of Forage Stocks in the Gulf of Alaska R.T. Cooney University of Alaska Sea Grant College Program	07	26,100	0
	SUBTOTAL:	$ 26,100	$ 0
	PASSTHROUGH:	0	

E. Develop Means for Adapting Multi-Species Socio-Economic Models to Short Term Operational Models:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Management of Mixed Stock Fisheries: A Turning Point E.K. Pikitch Washington Sea Grant College Program	06	109,600	69,300
Management of Mixed Stock Fisheries: A* Turning Point E.K. Pikitch Washington Sea Grant College Program	06	(183,000)	0
	SUBTOTAL:	$ 109,600	$ 69,300
	PASSTHROUGH:	183,000	

B. Determine the relationships of habitat to fisheries production and the means of managing habitats for multiple users.

1. To determine the environmental characteristics of primary and secondary nursery areas and explain why some areas are more productive than other similar areas:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Use of the Vegetated Intertidal Marsh by the Young of Estuarine-dependent Fishes and Crustaceans R.T. Kneib Georgia Sea Grant College Program	40	51,700	11,200
Habitat Specific Recruitment Patterns in Estuarine Dependent K. Able New Jersey Marine Sciences Consortium Sea Grant Program	07	49,900	60,600
Influence of Nursery Habitat on Production of Kelp Bass S.J. Holbrook University of Southern California Sea	40	24,453	36,995

Grant Program Estuarine Dependence of Juvenile Chinook Salmon W.J. McNeil 06 Oregon Sea Grant College Program		28,500	42,000
	SUBTOTALS:	$ 154,553	$ 150,795
	PASSTHROUGH:	0	

2. The environmental factors that affect fisheries and quantify their relationships to fisheries productivity in major habitats inshore and offshore:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
The Role of Picophytoplankton in the Nutrition of Larval & Adult Oysters R. Newell 06 Maryland Sea Grant College Program	33,100	12,300
In Situ Studies on the American Lobster: Its Ecology and Susceptibility to Dragging R.S. Steneck 06 Maine/New Hampshire Joint Sea Grant College Program	78,067	33,293
Fishing Impact on Coral Reefs R. Brock 07 University of Hawaii Sea Grant College Program	10,454	23,463
Recruitment Success J. Parrish 06 University of Hawaii Sea Grant College Program	22,373	20,198
Habitat Requirements of Molting and Mating Blue Crabs T.G. Wolcott 06 University of North Carolina Sea Grant College Program	28,547	2,230
Maximizing Shellfish by Manipulating Their Environment C.H. Peterson 06 University of North Carolina Sea Grant College Program	4,669	16,484
Ecological Energetics of Rainbow Smelt in the Laurentian Great Lakes D.J. Stewart 07 New York Sea Grant Institute	28,115	21,098

System Characteristics of the Fisheries in Lake Superior and the Potential for Rehabilitation of the Fishery Community Y. Cohen 06 Minnesota Sea Grant College Program		15,140	4,930
Competition for Food Among the Major Predators in Saginaw Bay J. Diana 40 Michigan Sea Grant College Program		35,949	13,219
Energetics of Halibut, Yellowfin Sole and Flathead Sole R.L. Smith 06 University of Alaska Sea Grant College Program		79,000	0
Columbia River Juvenile Salmonids* R.C. Francis 06 Washington Sea Grant College Program		(12,200)	0
	SUBTOTALS:	$ 335,414	$ 147,215
	PASSTHROUGH:	12,200	

3. To develop models for predicting the consequences of change in environmental parameters on fisheries production:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Field Mortality Rates of Neoplastic vs. Nonneoplastic Soft-Shell Clams (Mya Arenaria) D.J. Brousseau 06 University of Connecticut Sea Grant Program		29,758	21,6700
Interactions of the Environment & the Pathogen, Perkinsus marinus, with Internal Defenses of Oysters W. Fisher 06 Texas A&M University Sea Grant College Program		48,596	29,0560
	SUBTOTALS:	$ 78,354	$ 50,726
	PASSTHROUGH:	0	0

4. Develop means of estimating the consequences of limiting anthropogenic changes in the environment.

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Influence of Complex Biofilms and Absorbed Pollutants on Oyster Set and Survival R. Weiner 30 Maryland Sea Grant College Program	60,000	33,000
Causes and Mitigation of Toxics Contamination of the Fishery in the St. Louis River/Duluth-Superior Harbor, Fishery Nursery A G. Rapp 44 Minnesota Sea Grant College Program	24,000	5,790
Human Influences on the Dispersal of* Living Organisms and Genetic Material into Aquatic Ecosystems A. Rosenfield 74 Maryland Sea Grant College Program	(20,000)	0
Workshop on the Effects of Dredging* Upon Physiological Behavior of Andramous Fishes of the Pacific Coast C.A. Simenstad 06 Washington Sea Grant College Program	(52,500)	0
SUBTOTALS:	$ 84,000	$ 38,790
PASSTHROUGH:	72,500	

C. Restoring and/or enhancing heavy exploited stock.

1. Develop means for evaluating management options in enhancing fisheries and and the consequences of various associated strategies:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Distinguishing Between Naturally Produced and Stocked Walleyes in Saginaw Bay D. Jude 18 Michigan Sea Grant College Program	15,826	30,440
An Analysis of Great Lakes Salmonid Angler Preferences and Expectancies for Future Fisheries Management Programs in Lake Mich R.B. Peyton 20 Michigan Sea Grant College Program	34,361	18,850

Mitochondrial DNA Variation in Red Drum & Evaluation of Red Drum Stocking Success in Texas Bays J. Gold 02 Texas A&M University Sea Grant College Program		57,214	34,426
Managing Adaptively: Early Experience in Western North America K.R. Lee 20 Washington Sea Grant College Program		60,000	40,300
Optimal Control of the Alaska King* Crab Industry S.C. Matulich 14 Washington Sea Grant College Program		(10,000)	0
	SUBTOTALS:	$ 167,401	$ 124,016
	PASSTHROUGH:	10,000	

2. Integrating biological, environmental, social, and economic knowledge into management plans for enhancement or rehabilitation of fisheries:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Immune Status and Susceptibility to Disease in the Oyster, Crassostrea Virgina R.S. Anderson 08 Maryland Sea Grant College Program	35,000	22,600
Population Dynamics of Hatchery-Reared Juveniles of the Soft-Shell Clam (Mya arenaria L.) in Maine: A Series of Manipulative Studies B.F. Beal 03 Maine/New Hampshire Joint Sea Grant College Program	36,000	9,175
Hawaiian Pelagic Fish T. Clark 47 University of Hawaii Sea Grant College Program	20,000	24,953
Predicting Change and Maintaining Productivity in a Fishery Transformed by Real Estate Development and Tourism S.K. Meltzoff 20 Florida Sea Grant College Program	36,900	18,400

Techniques For Dealing with uncertainty in Fisheries Management Information J.M. Hoening 70 Florida Sea Grant College Program	30,500	15,200
Comparison of the Reproductive C.C. Krueger 07 New York Sea Grant Institute	47,835	30,548
Effect of Substrate Size on Spawning Site Selection by Lake Trout and on Overwinter Mortality of Eggs C.C. Krueger 07 New York Sea Grant Institute	38,021	19,006
Natural Production of Migratory Salmonids in Lake Ontario Tributaries N.H. Ringler 07 New York Sea Grant Institute	30,822	31,923
Studies in Support of the Oyster Fishery of Delaware Bay: Use of Numerical Circulation Modelling to Define Oyter Larval Set T. Jacobsen 07 New Jersey Marine Sciences Consortium Sea Grant Program	18,800	45,000
Nucleic Acid Probes for the Oyster Parasite Haplosporidium Nelsoni S. Ford 08 New Jersey Marine Sciences Consortium Sea Grant Program	30,500	38,400
Social and Cultural Responses to Regulation in the Surf Clam and Ocean Quahog Fisheries B. McCay 20 New Jersey Marine Sciences Consortium Sea Grant Program	6,400	7,600
Rejuvenation of the Chesapeake Oyster* Industry R. Mann 03 Virgina Graduate Marine Science Consortium Sea Grant Program	(150,000)	0
The Application of Knowledge-Based* Systems to Marine Sciences: Fisheries Sciences Management and Aquaculture J.D. Palmer 74 Virgina Graduate Marine Science Consortium Sea Grant Program	(20,000)	0

Assessment of MSX Resistance in Hatchery-Reared Oysters from Brood E. Burreson 03 Virgina Graduate Marine Science Consortium Sea Grant Program		15,834	7,542
Management of a Mixed-Stock Fishery: An Economics Evaluation of Alternatives S.S. Hanna 14 Oregon Sea Grant College Program		23,400	56,500
Aboriginal Exploitation of Marine Estuarine Environments: A Thousand-Year Perspective from the Mouth of the Columbia River R. Minor 29 Oregon Sea Grant College Program		14,100	9,500
	SUBTOTALS:	$ 384,112	$ 336,347
	PASSTHROUGH:	170,000	

3. Develop, through hybridization and genetic engineering, better strains of fish and shellfish:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Genetic Enginerring of Fish and the Use of GH Hormone to Enhance Fish Growth D.A. Powers 2 Maryland Sea Grant College Program	78,000	43,400
Production of Transgenic Fish: Influence of Bovine Growth Hormone Gene. C.G. Kohler 02 Illinios/Indiana Sea Grant Program	16,323	29,918
Development of Transcriptional Promoters for Gene Transfer into Fish P.B. Hackett 02 Minnesota Sea Grant College Program	8,520	2,980
Broodstock Improvement in a Pink Salmon Hatchery W.W. Smoker 02 University of Alaska Sea Grant College Program	30,100	0

Genetic Potential for Improved Productivity in the Hard Clam Mercenaria T.J. Hilbish 03 South Carolina Sea Grant Consortium		54,800	26,900
	SUBTOTALS:	$ 187,743	$ 103,198
	PASSTHROUGH:	0	

4. Evaluate the effectivness of fish attraction devices and artificial reefs on local fish populations and fishermen:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Variation of Reef Dispersion to Manage Targeted Fishery Assemblages W.J. Lindberg 18 Florida Sea Grant College Program	44,400	28,700
Role of Area Productivity in Supporting Reef Fish Communities D.G. Lindquist 29 University of North Carolina Sea Grant College Program	9,986	10,447
Artificial Reefs and Virgin Islands Fisheries: Optimizing Design and Predicting Effects M. Hixon 40 University of Puerto Rico Sea Grant Program	27,900	18,200
SUBTOTALS:	$ 82,286	$ 57,347
PASSTHROUGH:	0	

D. Increase commercial uses of underutilized fish and shellfish.

1. Identify and evaluate species with the greatest potential for development:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Biology and Fishery of Hagfish G. Caillet 06 University of California Sea Grant College Program	25,385	16,454
Evaluation/Enhancement Developing Claw & Whole Body Fishery A. Kuris 06 University of California Sea Grant College Program	11,297	14,337

Northern CA Red Sea Urchin J. Shenker 06 University of California Sea Grant College Program		33,724	27,935
	SUBTOTALS:	$ 70,406	$ 58,726
	PASSTHROUGH:	0	

E. Devloping efficient and selective methods to harvest fish and shellfish.

1. Improve the selectivity of harvesting gear:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Engineering Design of Shrimp Harvesting Gear D.R. Amos 30 Georgia Sea Grant College Program	67,100	123,000
The Selectivity of Cod-ends on Demersal Fishes in New England Waters and the Survivability of Cod-end Escapees J. DeAlteris 30 Rhode Island Sea Grant College Program	24,676	6,471
SUBTOTALS:	$ 91,776	$ 129,471
PASSTHROUGH:	0	

2. Develop harvesting gear with reduced friction drag:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Theory, Application and Testing of* Non-Linear Motions and Tensions in Towing Systems J. Milgram 23 Massachusetts Institute of Technology Sea Grant College Program	(150,000)	0
SUBTOTALS:	$ 0	$ 0
PASSTHROUGH:	150,000	

4. Analyze fish behavior as it relates to the development and deployment of fishing gear:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Evaluating the Ecological Effects of Commonly Used Hard Clam (Mercinaria) Harvesting Methods S. Fegley 06 New Jersey Marine Sciences Consortium Sea Grant Program	0	18,900
SUBTOTALS:	$ 0	$ 18,900
PASSTHROUGH	0	

F. Investigating promising areas of research or aquisition of needed information.

1. Hormonal controls:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Endocrine Stimulation and Regulation of Sturgeon Female G. Moberg 02 University of California Sea Grant College Program	24,082	41,314
Salmonid Development and Seawater H. Bern 06 University of California Sea Grant College Program	92,131	59,818
Effects of Throid Hormone Smoltification in Salmon S.O. Ebbesson 08 University of Alaska Sea Grant College Program	59,900	13,800
Biochemical Genetic Analysis of Osmotic Response in Penaeid Shrimp R.S. Burton 01 Texas A&M University Sea Grant College Program	31,897	16,108
Physiology of Gonadotropins in Atlantic Croaker & Red Drum P. Thomas 02 Texas A&M University Sea Grant College Program	46,242	23,121

Smoltification of Atlantic Salmon (Salmo salar): detection and biochemical and molecular investigations T. Bradley 03 Rhode Island Sea Grant College Program		26,457	53,700
Atlantic Salmon Smoltification: Hormone Physiology of Growth at Sea J. Specker 03 Rhode Island Sea Grant College Program		47,879	38,725
Endocrine Control in Salmonids W.W. Dickhoff 02 Washington Sea Grant College Program		61,600	30,000
Control of Growth, Sex and Reproduction in Great Lakes Coolwater Fishes by Genetic and Endocrine Manipulation		86,145	55,940
Hormonal Regulation of Gametogenesis in Striped Bass Morone Saxatilis R.C. Cochra 02 Maryland Sea Grant College Program		42,000	5,200
The Identification of Steroids in Fish and the Role of Steroids on Juvenile Development in Atlantic Salmon. S.A. Sower 02 Maine/New Hampshire Joint Sea Grant College Program		33,000	27,737
Regulation of growth and morphotype in freshwater crustaceans D.W. Borst 01 Illinios/Indiana Sea Grant Program		49,777	35,355
Pond Water Quality Management P. Helfrich 01 University of Hawaii Sea Grant College Program		8,631	7,500
Peptide Hormone Control of Reproduction in a Marine Shrimp, Penaeus Yannamei L.S. Quackanbush 01 Florida Sea Grant College Program		39,300	26,200

A Novel Technology for the Manipulation of Fish Reproductive Cycles: Controlled Release of Gonadotropin Releasing Hormones R.S. Langer 06 Massachusetts Institute of Technology Sea Grant College Program		43,000	34,937
Control of Reproduction and Growth Regulation in Crustacean Resources H. Laufer 01 University of Connecticut Sea Grant Program		51,602	48,514
Endocrine Control of Molting and Reproduction in Decapod Crustacea E. Chang 01 University of California Sea Grant College Program		49,489	38,792
Control of Growth, Sex, and Reproduction in Great Lakes Coolwater Fishes T.B. Kayes 02 Wisconsin Sea Grant Institute		86,145	55,940
	SUBTOTALS:	$ 793,132	$ 556,761
	PASSTHROUGH:	0	

2. Physiology:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Reproduction in Marine Shrimp: Egg Activation and Early Development J.W. Lynn 01 Louisiana Sea Grant College Program	29,974	14,574
Sublethal Stress in Mahimahi J. Szyper 02 University of Hawaii Sea Grant College Program	28,115	50,885
Importance of Lipids and Lopoproteins in the Reproduction Success of the Hard Clam (Mercenaria mercenaria) R.F. Lee 03 Georgia Sea Grant College Program	16,900	0

Effects of Marine Micralgal Metabolites on Feeding Behavior and Growth of Bivalves N.M. Targett 06 Delaware Sea Grant College Program		10,140	11,778
Uptake and Retention of Contaminated by Fish Maintained on Artificial Diets in Lake Ontario J.K. Buttner 02 New York Sea Grant Institute		32,344	20,208
Metabolism of Antimicrobial Agents by Penaeid Shrimp K.D. McMurtrey 05 Mississippi/Alabama Sea Grant Consortium		31,840	31,418
Salinity and Metabolic Adaptations of Taxa of the Genus Menippe in the Gulf of Mexico H. Perry 06 Mississippi/Alabama Sea Grant Consortium		51,098	72,035
of Dietary Thiaminase on Lake Trout Reproduction I.R. Adelman 06 Minnesota Sea Grant College Program		7,130	1,990
Assimilation of Organic Aggregates by Bay Scallops (Argopecten irradians) I. Valiela 03 Woods Hole Oceanographic Institution Sea Grant Program		35,700	19,934
Effect of Low Dissolved Oxygen on Ability to Metamorphose R. Mann 07 Virgina Graduate Marine Science Consortium Sea Grant Program		0	19,186
Recent Growth and Nutrition in Larval Lobsters: Assessment Using RNA:DNA Ratios in Laboratory and Field J.S. Cobb 06 Rhode Island Sea Grant College Program		55,519	16,056
	SUBTOTALS:	$ 298,760	$ 258,064
	PASSTHROUGH:	35,636	

3. Life history:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Biology of Sea Cucumbers R. Richmond 03 University of Hawaii Sea Grant College Program		20,889	35,109
Natural History Analysis of Sea Turtle in the Northwestern Gulf of Mexico A.M. Landry 06 Texas A&M University Sea Grant College Program		48,915	28,264
Biology of the Kemp's Ridley Turtle D.W. Owens 08 Texas A&M University Sea Grant College Program		55,171	60,067
	SUBTOTALS:	$ 124,975	$ 123,440
	PASSTHROUGH:	0	

4. Species interactions:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Yellow perch versus zooplankton in Lake Michigan W.H. Horns 08 Illinios/Indiana Sea Grant Program		35,474	32,737
Dynamics of Zooplankton-Fish Interactions: Impact of the Introduction of Bythotrephes Cederstroemi into Lake Erie D.W. Garton 40 Ohio Sea Grant College Program		25,766	15,554
	SUBTOTALS:	$ 61,240	$ 48,291
	PASSTHROUGH:	0	

5. Stock separation:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Population Structure of Lobster in the Gulf of Maine I. Kornfield 06 Maine/New Hampshire Joint Sea Grant College Program	29,000	15,980

Genetic Tagging Mahimahi-MtDNA R.L. Cann 02 University of Hawaii Sea Grant College Program		11,999	19,491
Population Genetics of Commercial Oyster Stocks D. Hedgecock 03 University of California Sea Grant College Program		8,829	33,980
	SUBTOTALS:	$ 49,828	$ 69,451
	PASSTHROUGH:	0	

6. Information for managing exploited stocks:

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
Growth Line Periodicity in Larval and Postlarval Shells of the Hard Clam: A Tool for Ecological Research and Resource Managment S.E. Siddall 30 New York Sea Grant Institute		24,105	15,739
Temporal and Spatial Variation in Species Compos D. Hankin 06 University of California Sea Grant College Program		17,227	12,282
Size at Maturity for Alaskan Red King Crab A.J. Paul 06 University of Alaska Sea Grant College Program		39,200	0
Handling Mortality of Dungeness Crabs T.C. Shirley 06 University of Alaska Sea Grant College Program		35,900	0
Variation in Species Composition of* the Deep Water Eureka Trawl Fisheries D.G. Hankin 06 University of California Sea Grant College Program		(10.000)	0
	SUBTOTALS:	$ 116,432	$ 28,021
	PASSTHROUGH:	10,000	

7. Parasitology

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Environmental Regulation of Protozoan Ectoparasites of Fishes: a Model E.G. Noga 08 University of North Carolina Sea Grant College Program	4,410	22,560
Fatal Inflammatory Bacteremia in Pacific Oysters R. Hedrick 03 University of California Sea Grant College Program	6,750	13,902
Virulence Factors Important to the Pathogenesis of Fish Diseases J.S. Rohovec 08 Oregon Sea Grant College Program	61,800	112,400
SUBTOTALS:	$ 72,960	$ 148,862
PASSTHROUGH:	0	

8. Toxcity:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCHING FUNDS
Light, water and the photoinduced toxicity of complex mixtures of hydrocarbon pollutants R. Davenport 49 Illinios/Indiana Sea Grant Program	48,686	28,514
Disposition and Metabolisms of Polychlorinated Dibenzofurans in Fish New York Sea Grant Institute H.C. Sikka 45	50,568	26,745
Effects of Maternal Exposure of Rainbow Trout to 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD)on Reproduction J. Giesy 45 Michigan Sea Grant College Program	41,536	26,864
Toxic Halogenated Aromatic Hydrocarbons in Lake Trout Gametes as a Factor in Fry Survival R.E. Peterson 45 Wisconsin Sea Grant Institute	63,151	54,091
SUBTOTALS:	$ 154,553	$ 150,795
PASSTHROUGH:	0	

9. Training

TITLE/INVES./INST.		FEDERAL FUNDS	MATCHING FUNDS
The MITSG/MMA Joint Program in Marine Education and Training G. Motte Massachusetts Institute of Technology Sea Grant College Program	6	70,000	7,590
MIT Sea Grant Center for Fisheries Engineering C.A. Goudey Massachusetts Institute of Technology Sea Grant College Program	71	66,800	8,000
	SUBTOTALS:	$ 136,800	$ 315,590
	PASSTHROUGH:	0	
	GRAND TOTAL:	$4,968,278	$ 836,044
	TOTAL PASSTHROUGH:	644,936	

Marine Biotechnology

Summary

Research in support of marine biotechnology continued to be an important component of the National Sea Grant College Program in fiscal year 1989. The research, which is largely fundamental in nature, is providing the scientific basis for using marine organisms or their components to provide goods and services. During the last year $2,325,000 in federal funds and $1,793,000 in matching funds supported 59 projects in four categories including biochemistry and pharmacology, molecular biology, biochemical engineering, microbiology and phycology. Notable advances were described in more than 90 recent papers. For example, procedures for genetic engineering of fish were demonstrated, recombinant vaccines for viral diseases of fish were successfully tested, a potent mammalian immunohormone was isolated for the first time from a plant, and a novel bioreactor for studying high pressure–high temperature relationships in bacterial growth and productivity was designed, constructed, and used to study biochemical processes of a methanogenic bacterium from a deep–sea vent.

The report describes major new initiatives of Japanese government, industry, and academe to develop marine biotechnology as a basis for economic growth in the twenty–first century. It discusses other issues and suggests opportunities and needs for future research.

Introduction

Marine biotechnology can be defined as the application of scientific and engineering principles to provide goods and services through mediation of marine biological agents. Biotechnology, including marine biotechnology, is not new. For centuries technologists, farmers, and home–makers have used it to produce food and alcoholic beverages. Exclusive of agriculture, use of biotechnology in sewage treatment and water purification now comprises the largest sector in volume. Biotechnical production of many other products such as organic acids and antibiotics also is important in commerce.

Rapid advancements in molecular biology and related sciences over the past few years have focused intense attention on biotechnology because of the techniques they are providing for rapidly changing and exploiting the metabolic and biosynthetic capabilities of plants, animals, and microorganisms. Most of the research and related industrial developments in biotechnology are based on the use of terrestrial organisms. Relatively little research has focused on marine organisms even though their much greater species and phylogenetic diversity and their use of a wide spectrum of environments suggest they should offer unique biological processes and components of potential usefulness.

Sea Grant's small program of research in marine biotechnology has been productive. It has advanced fundamental science, including advances needed for genetic engineering of marine species, showed many facets of unusual secondary metabolism and other biological processes, and provided the basis for new products and processes of commercial significance. For example, in the early 1970's Sea Grant paid for the pilot–scale production of chitosan, which can be derived from crustacean shells, and subsequently supported annually one or a few research projects dealing with the study of chitosan, its chemical and physical manipulation, its mechanisms of biological activity, and its use in a variety of ways. This research has been a significant factor in the development of new uses for chitin that one industrial newsletter, **Inside R&D** (October 4, 1989), says "are poised to propel chitin/chitosan sales to nearly $2 billion/year – and to change the competitive balance of companies in agriculture, cosmetics/toiletries, food/beverages, health care, immobilization and cell culture, product

TABLE 1
Funding for Sea Grant Projects in Marine Biotechnology in Fiscal Years 1988 and 1989 (in thousands of dollars)

	FY 88			FY 89		
Category	No. of Projects	Funding Fed	Match	No. of Projects	Funding Fed	Match
Biochemistry & Pharmacology	22	810	522	22	837	605
Genetic Engineering	15	730	513	14	710	528
Biochemical Engineering and Industrial Chemicals	8	237	287	10	361	299
Microbiology and Phycology	10	349	303	13	397	361
TOTALS	55	2,126	1,625	59	2,325	1,793

separation/recovery, waste/water treatment, and other industries."

Still extant are a broad spectrum of opportunities for academic research to advance fundamental knowledge of biological processes in marine systems and to provide the basis for further biotechnical development on a large scale. Some of these opportunities are discussed in a general way in the third section below which suggests the need for greater reliance on interdisciplinary research and educational programs.

Funding and Examples of Progress

In fiscal year 1989 fifty-nine projects were active. They were supported with $2,325,000 in federal funds and $1,793,000 in matching funds. The projects can be considered in the four broad categories shown in Table 1 which compares funding and number of projects over the last two fiscal years. Investigators in some projects, all of which are listed in Appendix B, may be surprised to find their research classified under biotechnology because a broad definition is used although traditional aquacultural research is excluded.

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In fiscal year 1989 fifty-nine projects were active. They were supported with $2,325,000 in federal funds and $1,793,000 in matching funds. The projects can be considered in the four broad categories shown in Table 1 which compares funding and number of projects over the last two fiscal years. Investigators in some projects, all of which are listed in Appendix B, may be surprised to find their research classified under biotechnology because a broad definition is used although traditional aquacultural research is excluded.

However, all projects included have produced or are expected to yield fundamental knowledge or practical information that will aid in providing goods and services through the use of marine organisms or their components. Table 2 shows the history of federal funding over the past ten years. Funding levels in Appendix B and the Tables do not include support for student research assistants in some of the projects.

The number of projects and level of funding in 1989 were up somewhat over 1988, but still below 1987's high. The biggest increase was in the category encompassing genetic engineering and other types of molecular biology. Research in this category recently has yielded significant achievements as the examples below show. The bibliographic references appear form in Appendix A.

The diagnosis and control of viral and bacterial diseases of fish, especially infectious pancreatic necrosis (IPNV), infectious hematopoietic necrosis (IHNV), and vibriosis, which are economically important in salmon culture, have been goals for several years. In one approach to these problems researchers at Oregon State University prepared subunit vaccines containing portions of genes encoding for the surface proteins of IPNV and IHNV. They cloned and expressed the genes in *Escherichia coli*. Crude extracts of *E. coli* expressing these proteins have proven to be effective vaccines in fish against lethal doses of the viruses (Gilmore et al., 1988). Thus, recombinant DNA technology can be used to meet industrial requirements for safe and effective, yet inexpensive vaccines for aquacultural species.

In related research in another laboratory at Oregon State University researchers developed a fluorescent antibody test (FAT) for the rapid detection of IHNV (LaPatra et al., 1989). All strains of IHNV tested, which included different electropherotypes, those isolated from selected salmonids at different life stages, and those from different geographic regions, reacted with the antisera. The FAT has been used for the detection of IHNV in blood smears and organ imprints from clinically infected juvenile fishes and in IHNV-infected cells in ovarian fluid from adult carriers. The test was equal in sensitivity to the plaque assay method and required less time to obtain a definitive diagnosis.

DNA technology also has been applied to production of transgenic fish which grow up to 50% faster than their parents. As part of their work Chen, Powers and associates (Agellon et al., 1988) showed that the rainbow trout has two genes for growth hormone (GH). They also showed (Chen et al., 1989) that biosynthetic preparations of these hormones in *E. coli* enhances growth of yearling trout through weekly intramuscular injection. Using carp and loach as test animals they have shown that introduction of additional copies of GH gene results in transgenic fish which produce elevated levels of growth hormone and grow faster than controls. A small, but significant, proportion of the first generation of fast-growing fish can pass this trait to their offspring. Thus, it appears that true-breeding fish strains of altered character can be produced.

In their efforts to develop techniques for genetically engineering fish, researchers at the University of Minnesota developed a fast and reliable procedure for generating subclones necessary for sequencing long stretches of DNA (Liu and Hackett, 1989). The procedure involves cloning a fragment of DNA into a single-stranded plasmid or phage vector containing a polycloning region; synthesizing variable lengths of double-stranded DNA using a "Universal Primer"; isolating the double-stranded DNA; and force cloning the double stranded DNA fragments into a complementary vector with the polycloning region in the reverse orientation. The resulting clones can be sequenced, using the same Universal Primer and T7 DNA polymerase, to provide overlapping DNA sequences. The researchers have used the new procedure to sequence thousands of bases without detecting any errors due to improper copying of the single-stranded template.

Research in the category of biochemistry and pharmacology also has been productive and previous reports in this series have provided examples of pharmaceutical developments resulting from this research. In 1989 the research continued to identify interesting and important natural products and to define their biological effects.

At Oregon State University where studies are continuing on seaweeds as sources of new products with potential biomedicinal application, researchers have identified another red alga, *Farlowea mollis*, as a rich source of structurally novel and physiologically active icosanoids whose

TABLE 2
Federal Funding for Sea Grant
Projects in Biotechnology in Fiscal Years 1980 – 1989
(in thousands of dollars)

FISCAL YEAR

Category	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Biochemistry and Pharmacology	440	402	525	440	671	820	865	916	810	837
Molecular Biology	---*	100*	266*	419*	487	537	624	778	730	710
Biochemical Engineering & Industrial Chemicals	349	285	454	515	540	581	384	393	237	361
Microbiology and Phycology	---*	50*	100*	284	248	206	342	593	349	397
TOTALS	789	837	1,345	1,658	1,946	2,144	2,215	2,680	2,126	2,325

*Estimate

complete structures they have solved (Solem et al., 1989). They also reported the first isolation from a plant of the potent mammalian immunohormone, 12–(S)–hydroxy–5,8,10,14–icosatetraenoic acid (Moghaddam et al., 1989).

Research in the same laboratory suggests that novel cytotoxic peptides from the tropical cyanobacterium, *Hormothamnion enteromorphoides*, may function to deter predation by herbivorous animals, including fish, zooplankton and mollusks. The major peptide, hormothamnin A, shows antimicrobial activity against two human pathogenic microorganisms and toxicity to cancer cells in vitro (Gerwick et al., 1989).

Collaborative work between researchers at the University of Oklahoma and the Bigelow Laboratory for Ocean Sciences also points to the ecological significance of marine secondary metabolites. This research on toxic cembranolides in sessile octacorals shows that the tissue fluids of the gorgonians examined are supersaturated with respect to these diterpenoids which are continuously produced and released into the water surrounding the animals (Ciereszko and Guillard, 1989). Thus, they could serve to prevent predation. The cembranolides immobilize marine flagellates. This property may serve the animals by immobilizing flagellates that serve as food and by converting certain dinoflagellates to their vegetative forms that occur as symbionts in many octacorals.

Researchers at the University of California at Santa Cruz have determined the novel structures of amino acids of five structural types that were isolated from sponges of the order Chorista. The researchers have been devoting attention to the nitrogen-containing heterocyclic compounds from this group of animals because these multifarious secondary metabolites are almost always accompanied by exciting biological activity, including powerful antibiosis. The researchers reported the complete amino acid chemistry of a Jaspidae sponge collected in the Fiji Islands and suggested biogenetic pathways for each of the most novel amino acid types (Adamczeski et al., 1989).

In further research to determine the mechanism by which stypoldione, a marine natural product, inhibits cell division researchers at the University of California at Santa Barbara have shown the stypoldione uncouples cytokinesis from mitosis at the lowest effective concentrations. Although it can disrupt microtubules at relatively higher concentrations, it inhibits cell division at the lowest effective concentrations by a selective action on cytokinesis through a mechanism that does not appear to involve disassembly of microtubules (O'Brien et al., 1989).

Researchers at the Scripps Institution of Oceanography and Cornell University have determined the structure of haliclonadiamine, an antimicrobial alkaloid from the sponge *Haliclona* sp. from Palau (Fahy et al., 1988). They selected the bright red sponge for study because it overgrows and kills corals and because initial screening of crude extracts of the sponge indicated significant antimicrobial activity, particularly against the fungus *Candida albicans*. They determined the structure of a crystalline diacetate derivative by single crystal X-ray diffraction.

Research at the University of California at Berkeley shows that certain seaweeds along the U.S. Pacific coast produce a unique plant hormone methyllanosol that stimulates growth in lettuce (Kubo, 1989). Methyllanosol is one of the first such plant growth regulators to be isolated from a marine organism. When it was used on lettuce plants, it boosted growth by 50 per cent. So far, the compound appears to be selective in its benefits by prompting growth in lettuce, but having no effect on some other plants such as rice.

Important results also were reported in the category of biochemical engineering recently. Thermophilic organisms offer many potential advantages for biotechnological processes, but realizing this potential requires appropriate experimental systems for studying organisms at high temperature and pressure. Thus, researchers at Cornell University developed a novel bioreactor for studying pressure-temperature relationships in bacterial growth and productivity at temperature up to 260°C and pressures up to 350 bar (Miller et al., 1988). The apparatus is versatile and corrosion resistant, and enables direct sampling of both liquids and gases from a transparent culture vessel without altering the reaction conditions. Gas recirculation through the culture can be controlled through the action of a magnetically driven pump.

Initial studies in this bioreactor of *Methanococcus jannaschii*, an extremely thermophilic methanogen isolated from a deep-sea hydrothermal vent, revealed that increasing the pressure from 7.8 to 100 bar accelerated the production of methane and cellular protein by this archaebacterium at 90°C, and raised the maximum temperature allowing growth from 90 to 92°C. Further increases in pressure had little effect on the growth rate at 90°C.

Discussion of Recent Developments, Issues, Opportunities and Needs for the Future

MARINE BIOTECHNOLOGY IN JAPAN

Japan is undertaking major initiatives in marine biotechnology as a basis for economic growth in the twenty-first century according to a report by a three-man team that under the auspices of the National Oceanic & Atmospheric Administration and the National Science Foundation visited Japan in September, 1989. The centerpiece of the Japanese initiatives will be the creation of three new institutes dedicated to marine biotechnology.

In a tripartite approach, Japanese government, industry and academe have joined forces to position themselves as world leaders in marine biotechnology. The dominant players at this time are the Japanese Ministry of International Trade and Industry (MITI) and 24 industrial partners who have committed 26.8 billion yen, or $189 million, to two of the three institutes for the next decade. Two other governmental agencies, the Ministry of Agriculture, Forestry and Fisheries (MAFF) and the Science and Technology Agency, are also moving aggressively to build new facilities

and support research. MAFF will operate the third new institute for marine biotechnology.

In 1988, 24 private Japanese companies representing petroleum, steel, liquor, food, chemical, construction, and ship building came together in a consortium for establishing the Marine Biotechnology Institute Co., Ltd. (MBI). MITI has turned to the MBI to build and operate two new research institutes for the industrial utilization of marine organisms.

One institute is being built at Kamaishi to take advantage of organisms of the cold currents on Japan's east coast and the other at Shimizu where the currents are warm. Construction of each center is expected to cost three billion yen. The MBI will also operate a sophisticated research ship with space for a scientific crew of 32.

The research at the institutes is expected to be both long-term and fundamental in nature and will focus on new technologies to use marine organisms and to produce useful substances. A 20-person board of academic and governmental scientists advises the MBI, and some professors already are collaborating with the organization. The two institutes are expected to be sites of ongoing collaboration between university personnel and the permanent employees of the MBI who are sponsored by industry.

MAFF research has traditionally focused on edible species of algae, invertebrates and fishes, with some biotechnology work focused on selective breeding and gene recombination techniques. MAFF has now formulated a plan for the next generation of technology to a degree comparable to that of MITI.

MAFF's five-year strategy for marine biotechnology research, which had a budget of 1,500 million yen in fiscal year 1989, is concentrating on methods to use marine organisms in Japanese waters and on technology to use normally wasted parts of edible species. Being built at Kamaishi, the MAFF institute will be the same size as the separate MBI facility located there, will cost the same amount (three billion yen), and will employ 30 scientists and approximately 20 support staff. The agency will also expend six billion yen to build a new oceanic research vessel, the Kaiyomaru, equipped with advanced facilities.

The establishment of these three new institutes will certainly attract new investigators to marine biotechnology. While the younger field of molecular biology is being applied more often to marine biotechnology, the more traditional disciplines, such as natural products chemistry, chemical engineering, microbiology, and biochemistry, will also be heavily integrated into efforts at the new institutes. What will result, however, is that the experienced scientists and engineers from traditional areas will now pursue new lines of research.

On the academic front, university scientists and administrators as well as 30 commercial firms have formed the new Japanese Society for Marine Biotechnology. With leadership coming from the University of Tokyo and the Tokyo University for Agriculture and Technology, this society provides a forum to promote industrialization, international cooperation, and utilization of support technologies such as electronics and robotics. The society has already held the highly successful First International Marine Biotechnology Conference in Tokyo from September 4-6, 1989, and it is expected to help support the second conference in the United States in 1991.

Conducting this study of Japanese marine biotechnology with me were Professor Akira Mitsui of the University of Miami and Dr. Oskar Zaborsky of the National Research Council. As a result of our study, we suggest that federal agencies and industry in the United States should:

*Recognize the importance of marine biotechnology for its benefits and enhance support for R&D in this field,

*Keep informed about developments in Japan and exchange information more actively.

*Assess the opportunities and needs in marine biotechnology of benefit to both countries,

*Assist developing countries in marine biotechnology, especially in building an infrastructure,

*Participate in the 1991 international conference on marine biotechnology, and

*Develop new initiatives in marine biotechnology.

Copies of the report are available by writing: Division of International Programs, National Science Foundation, 1800 G. Street, N.W., Washington, D.C. 20550 or National Sea Grant College Program, NOAA, 6010 Executive Boulevard, Rockville, MD 20852.

GLOBAL CHANGE

In early December 1989, the National Research Council's Commission on Life Sciences sponsored two workshops to consider the feasibility of reducing [the putative] global warming by enhancing biological processes in the ocean. The primary participants in these workshops were distinguished scientists from governmental and academic institutions. The findings of those workshops appear below; some appear in paraphrased form.

Reducing Global Warming by Enhancing Carbon Dioxide Assimilation in Phytoplankton

> Marine deposition of carbon represents a long-term potential sink for atmospheric carbon dioxide. It is conceptually feasible to inhibit the increase of atmospheric carbon dioxide by enhancing primary production in the ocean. From existing models, the participants estimated that an additional two gigatons of carbon per year can be removed from the atmosphere at a cost of less than $10 billion per year if new primary production is enhanced and most unused nutrients are assimilated.

> One hypothesis suggests that primary producers in the southern oceans, equatorial oceans, and North Pacific Ocean do not use available nutrients because of limitations in metabolically available iron. Because they require iron only in nanomole concentrations, the participants projected the cost of adding sufficient iron over large oceanic areas to be low.

> Knowledge of the effects of variation in pCO_2 on the growth rate and elemental composition (cellular C:N:P) of natural marine phytoplankton communities is very limited. Developing better information of this kind will be required in order to predict reliably the capacity of the ocean to sequester excess atmospheric CO_2.

Reducing Global Warming by Enhancing Carbon Dioxide Assimilation in Macroalgae

> It is conceptually feasible to use marine plants to stabilize and reduce carbon dioxide in the atmosphere by –

* by enhancing transport of photosynthetic carbon to the deep ocean, and

* by using biomass as a replacement for fossil carbon in production of energy and materials.

> The participants recommend that steps be taken to develop and test a system to remove one billion tons of carbon dioxide per year from the atmosphere by production of marine biomass some of which can be processed into products of high value. They made the following (preliminary) recommendations:

"1. that we develop an on-going analysis of mitigation strategies (a systems approach) to determine research priorities.

2. That we study the potential of enhancing carbon dioxide fixation in a Sargasso Sea-type system.

3. That we study macroalgal carbon dioxide refossilization and use for food, fuel and chemicals.

4. We recommend that one or more test farms be in place and under evaluation by 1995, to meet established international goals to reduce carbon dioxide in the atmosphere."

The issue of increasing carbon dioxide in the atmosphere suggests other types of biotechnology for reducing dependence on fossil fuels and chemicals. Some research reported at the First International Marine Biotechnology Conference in Tokyo in September, 1989 bear on this topic. Among the most interesting are efforts to develop the scientific basis for using marine microalgae and photosynthetic bacteria for producing fuel and chemical products. The results of some of these efforts look promising and indicate that Sea Grant should be active in this field. For example, research by A. Mitsui at the

University of Miami on synchronous culture of marine unicellular aerobic nitrogen-fixing cyanobacteria indicates that the production of hydrogen, ammonia, carbohydrate-polymers, and various enzymes are cyclic events and that controls at the cellular and molecular levels can be used to enhance production of these substances.

E. Greenbaum of the Oak Ridge National Laboratory reported on the first measurements of the simultaneous photoproduction of hydrogen and oxygen in a marine green algae. Eight species in three genera were tested in CO_2-free seawater. Four of the five species of *Chlamydomonas* were able to produce hydrogen in the light after a period of three to four hours of dark anaerobic adaptation. One *Chlamydomonas* species had a steady-state rate of hydrogen and oxygen production during irradiation with a stoichiometric ratio near 2:1. This and other data presented suggest that this species makes seawater a potential substrate for solar production of hydrogen and oxygen.

In a recent paper on the R&D challenge presented by global warming, Fulkerson et al. (1989) make the following statements: "Although the R&D effort is broad, none of the nonfossil energy sources are ready to be substituted competitively for fossil fuels at the scale necessary to reduce CO_2 emissions. To correct this inadequacy, a three-pronged R&D strategy is required: improve the efficiency of energy conversion and use, improve nonfossil energy sources, and improve technologies tailored to meet the needs of developing nations." Items two and three of this strategy suggest activities appropriate for Sea Grant.

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Research and Educational Needs and Opportunities

The National Sea Grant College Program's research in support of marine biotechnological over the past ten years has demonstrated the potential for academic research to provide the basis for commercial activity at the level of tens or hundreds of millions of dollars annually. This research has advanced fundamental science by helping to define marine processes and it has trained students for productive careers. These advancements have been the result of only limited investment. They suggest that marine biotechnological research of broader scope and larger scale could play an important role in development of products and technology for the future. What are some of the relevant research opportunities?

For most marine natural products natural function in marine systems and behavior in a wide array of biological and pharmacological assays are unknown. These gaps in knowledge denote opportunities for research. By and large research on marine natural products has focused on lipid extracts of macroalgae and invertebrates. Few scientists have turned their attention to aqueous extracts, enzymes, other bioactive macromolecules, or to marine bacteria, fungi, yeasts, and microalgae as subjects of study. These neglected topics and classes of organism also represent areas of opportunity for research.

Trevan and Mak (1988) make the point that algae are a largely untapped source of potentially useful biotransformations. Their research in the United Kingdom focuses on the use of immobilized algae as biocatalysts performing biotransformations and **de novo** biosyntheses, in energy production, for bioaccumulation of wastes, and for inclusion into biosensors. More of this kind of research in American universities would benefit the United States.

Few marine invertebrates have been subjected to cell or tissue culture. Successful research to this end with organisms that produce useful metabolites could have several benefits. For example, it could help set the stage for using cells to produce pharmaceuticals, enzymes, growth regulators, pigments, and pesticides. It could provide techniques useful in studying the basic

physiology and nutrition of organisms and for determining natural regulation of secondary metabolism. It could enhance the study of biochemical relationships between invertebrates and the symbiotic organisms associated with many of them. It could provide the science for using bioreactors, photobioreactors, and fermentors in exploiting the biosynthetic capabilities of marine organisms.

Application of DNA technology to the study of marine processes and development of DNA technology for genetic engineering of most classes of marine organisms offer opportunities for advancing science and enhancing the scientific basis for new biochemical products and services.

Marine organisms may play an increasing role in biotechnology and medicine as a result of unique functioning of their organelles and associated biochemical pathways. Biosensors promise to meet some important measurement needs for drugs, metabolites, and other biomolecules. Biosensors use an immobilized biological material, even a living material, in contact with a transducer to convert biochemical signals into quantifiable electrical signals. For example, the antennules of the blue crab have been used as a source of chemoreceptive nerve fibers for use in a biosensor (Belli and Rechnitz, 1988). Other chemoreceptors, which are biomolecular assemblies involved in numerous physiologic functions in marine organisms such as olfaction, are candidates for molecular recognition and application in biosensors.

Previously undiscovered marine organisms, even abundant representatives of little known groups such as the prochlorophytes, still come to light through field work in marine science (Chisholm and Olsen, 1988) and they should be investigated for unique bioprocesses and biosynthetic abilities.

These topics and others offer opportunities to study basic issues in biological systems and require or could benefit from interdisciplinary approaches to developing the fundamental science on which new technologies can be based. So far, however, most research in support of marine biotechnology is conducted within traditional disciplinary bounds. In his president's message to the American Chemical Society, Clayton Callis (1989) called for breaking down the artificial barriers that exist in the scientific and technical communities and those that exist between academe and industry. He said, "This is critical if we are to develop new technologies, for example, from discoveries in genetic engineering, new superconductors, new materials, new specialty products, in the most efficient ways possible."

The interdisciplinary requirements of research in support of marine biotechnology will make this field particularly fertile ground for illuminating scientific phenomena and advancing socially responsible technology.

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Appendix B
FISCAL YEAR 1989 PROJECTS

A. MARINE BIOTECHNOLOGY

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. Biochemistry & Pharmacology		
Marine Pharmaceutical Discovery Program: Pharmacology R. Jacobs 12 University of California Sea Grant College Program	76,306	89,260
Marine Pharmaceutical Discovery Program: Chemistry Comp B W. Fenical 12 University of California Sea Grant College Program	45,921	18,725
Marine Pharmaceutical Discovery Program: Chemistry Comp A D. Faulkner 12 University of California Sea Grant College Program	46,853	24,456
Marine Natural Products Develop New Chemotherapeutics P. Crews 12 University of California Sea Grant College Program	23,331	34,513
Halogenation by Naturally Occuring Enzymes in Marine A. Butler 12 University of California Sea Grant College Program	18,312	16,937
Potential Anti-Tumor Drug from Marine Waste By-Products K.P. Wong 12 University of California Sea Grant College Program	39,608	31,756
Effects of Marine Micralgal Metabolites on Feeding Behavior and Growth of Bivalves N.M. Targett 06 Delaware Sea Grant College Program	10,140	11,778
Marine Pharmaceuticals R. Moore 13 University of Hawaii Sea Grant College Program	30,663	44,413
Marine Metabolites for Medicine P. Scheuer 13 University of Hawaii Sea Grant College Program	30,000	22,000

Pharmacological Tropical Seaweeds V. Paul 13 University of Hawaii Sea Grant College Program	28,131	20,852
Siscowet Trout as a Source of Antithrombotic, Hypocholesterolemic Fatty Acids for Human Medicine P.B. Addis 12 Minnesota Sea Grant College Program	4,970	4,020
Isolation and Characterization of Phytotoxic Compounds from Lemna minor F.K. Gleason 13 Minnesota Sea Grant College Program	24,490	4,860
Marine Organisms as Sources of Agrochemically Sgnificant Compounds J.H. Cardellina 13 Montana State University	46,000	30,000
Modified Nucleosides of Marine Organisms G. Sharma 12 New Jersey Marine Sciences Consortium Sea Grant Program	42,000	47,900
The n-3 Polyunsaturated Acids of Marine Lipids: Determination of Biochemical Effects, Optimum Dietary Intake and Oxidative St J.E. Kinsella 12 New York Sea Grant Institute	22,275	63,576
Structural and Synthetic Studies on Marine Natural Products J.C. Clardy 12 New York Sea Grant Institute	71,209	36,318
Bioactive Compounds from Marine Organisms F.J. Schmitz 12 University of Oklahoma, Norman	70,200	35,574
Biomedicinals for Pacific Northwest Marine Algae W.H. Gerwick 12 Oregon Sea Grant College Program	65,300	21,800
Absorption of Ethyl Ester and Triglycerides of Fish Oil Omega-3 Fatty Acids in Man W.E. Connor 12 Oregon Sea Grant College Program	22,900	18,100

Do Dietary Saturated Fatty Acids Reduce Effects of Fish Oils on Lipid Metabolism and hemostasis W.E. Connor 12 Oregon Sea Grant College Program	35,100	28,200
New Compounds for Ice Suppression on Fish Antifreeze Proteins T. Caceci 13 Virgina Graduate Marine Science Consortium Sea Grant Program	59,970	30,673
Crab Shell Chitosan, its Mode of Gene Activation L.A. Hadwiger 13 Washington Sea Grant College Program	65,600	17,600
SUBTOTAL:	$837,279	$605,411
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
2. Molecular Biology		
Development and Evaluation of Gene Probes for Use in the Diagnosis of Baculovirus Infections in Penaeid Shrimp (Thurman) Thurman 13 University of Arizona, Tucson	34,900	21,600
Develop of DNA Probes - Pathogenic Marine Bac H. Shizura 45 University of Southern California Sea Grant Program	39,574	37,113
Production of Transgenic Fish: Influence of Bovine Growth Hormone Gene. C.G. Kohler 02 Illinios/Indiana Sea Grant Program	16,323	29,918
Genetic Enginerring of Fish and the Use of GH Hormone to Enhance Fish Growth D.A. Powers 02 Maryland Sea Grant College Program	78,000	43,400
An Analysis of Normative & Conceptual Issues in the Regulation of Biotechnology in the Nation's Bays and Estuaries M. Sagoff 20 Maryland Sea Grant College Program	24,800	11,700

Immunological Detection of the Brown Tide D.M. Anderson 07 Woods Hole Oceanographic Institution Sea Grant Program	26,500	0
Development of Transcriptional Promoters for Gene Transfer into Fish P.B. Hackett 02 Minnesota Sea Grant College Program	8,520	2,980
Vectors for Genetic Engineering in Marine Algae: the Ti Plasmid K.B. Taylor 05 Mississippi/Alabama Sea Grant Consortium	54,793	43,078
Nucleic Acid Probes for the Oyster Parasite Haplosporidium Nelsoni S. Ford 08 New Jersey Marine Sciences Consortium Sea Grant Program	30,500	38,400
Isolation and Characterization of the Interferon Genes of Rainbow Trout J.C. Leong 08 Oregon Sea Grant College Program	82,500	22,600
Biotechnical Approaches To Improve Triploidy and Growth In Pacific Oysters K.K. Chew 03 Washington Sea Grant College Program	79,900	69,900
Gene Analysis and Transformation in Marine Algae R.A. Cattolico 05 Washington Sea Grant College Program	93,300	69,900
Control of Growth, Sex and Reproduction in Great Lakes Coolwater Fishes by Genetic and Endocrine Manipulation T.B. Kayes 02 Wisconsin Sea Grant Institute	86,145	55,940
Anti-Idiotype Antibodies as Novel Immunogens and Diagnostic Reagents for Aquatic Birnaviruses B.L. Nicholson 08 Maine/New Hampshire Joint Sea Grant College Program	54,160	81,764
SUBTOTAL:	$709,915	$528,293
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
3. Biochemical Engineering		
Biopolymers from Marine Sources P.R. Austin 13 Delaware Sea Grant College Program	14,040	35,100
Use of Chitosan for Plant Biotechnology Processes D.W. Knorr 13 Delaware Sea Grant College Program	9,828	39,813
A Novel Technology for the Manipulation of Fish Reproductive Cycles: Controlled Release of Gonadotropin Releasing Hormones R.S. Langer 06 Massachusetts Institute of Technology Sea Grant College Program	43,000	34,937
Biotechnological Applications of Marine Biopolymers M. Karel 06 Massachusetts Institute of Technology Sea Grant College Program	57,000	29,164
Polypeptide Inhibitors of Corrosion from Marine Organisms S. Sikes 13 Mississippi/Alabama Sea Grant Consortium	27,346	20,181
Development of Coastal Fish Oil Resources for Potential U.S. Health Industry J.G. Turcotte 12 Rhode Island Sea Grant College Program	73,070	27,098
Advances in Anti-Scaling & Anti-Fouling Technology Based on the Properties of Natural Inhibitors of Mineralization A.P. Wheeler 13 South Carolina Sea Grant Consortium	55,600	31,800
Chitosan Delivery Systems for Medicines G.G. Allan 13 Washington Sea Grant College Program	42,600	21,600
A Biotechnological Application of biogenic Ice Nucleator for Energy Saving and Improved Quality in the Freezing of Seafood T.C. Lee 35 New Jersey Marine Sciences Consortium Sea Grant Program	23,000	43,400

Petroleum Seeps Program: Evaluation of Marine Microbial Chemoorganotropha/Chemolithoautotrophs for Contributions to Benthic H R.J. Portier 11 Louisiana Sea Grant College Program	15,001	14,769
SUBTOTAL:	$360,485	$297,862
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
4. Microbiology & Phycology		
Genetics of Morphology and Growth in Laminaria from the North Atlantic Ocean C. Yarish 05 University of Connecticut Sea Grant Program	35,015	19,038
Role of Adsorbed Proteins in Bacterial Colonization and Growth on Surfaces D.L. Kirchman 01 Delaware Sea Grant College Program	16,536	34,542
Improving on Nature: Stress-Tolerant Plants from the Marine Estuarine Environments for Ecosystem Restoration and Agriculture J.L. Gallagher 05 Delaware Sea Grant College Program	21,060	47,996
Anticorrosive Properties of Adhesive Proteins Isolated from the Mussel Mytilus Edulis S.C. Dexter 13 Delaware Sea Grant College Program	16,380	18,689
Influence of Marine Bacterial Films on Cathodic Reaction and on Corrosion Prevention S.C. Dexter 38 Delaware Sea Grant College Program	9,360	17,609
Plant Tissue Culture Technology for Marine Angiosperms Used in Habitat Restoration K.T. Bird 05 Florida Sea Grant College Program	34,700	46,800

Technical Book on Tributylin: Editorial and Preproduction Services J.C. Cato 44 Florida Sea Grant College Program	0	0
Microbiology and Chemistry of Vents D. Karl 32 University of Hawaii Sea Grant College Program	22,000	21,652
Development of New Biofouling Inhibitor Delivery Systems D.C. Sundberg 45 Maine/New Hampshire Joint Sea Grant College Program	40,999	24,648
The Role of Iron- and Manganese-Oxidizing Bacteria in marine Corrosion Processes R. Mitchell 13 Harvard University	60,000	40,000
Studies of Hydrocarbon Seep Communities on the Texas/Louisiana Continental Slope J.M. Brooks 40 Texas A&M University Sea Grant College Program	49,598	26,002
Influence of Complex Biofilms and Absorbed Pollutants on Oyster Set and Survival R. Weiner 30 Maryland Sea Grant College Program	60,000	33,000
Metabolism of Antimicrobial Agents by Penaeid Shrimp K.D. McMurtrey 05 Mississippi/Alabama Sea Grant Consortium	31,840	31,418
SUBTOTAL:	$397,488	$361,394
PASSTHROUGH:	20,000	
GRAND TOTALS	$2,325,167	$1,792,960

Seafood Science and Technology

Summary

The United States has enormous fisheries within its zone of extended jurisdiction along its marine coasts, yet a large proportion of the seafood sold domestically is imported. Fuller development of fisheries by U.S. fishing fleets and processors depends on stronger competition in international markets. Enhancement of their competitive position depends in part on enhancing the quality of seafood, improving the technology and efficiency of processing and handling seafood, including dealing satisfactorily with organic wastes, developing acceptable products from non-traditional species and for non-traditional markets, and assuring safe products of high quality. The 49 Sea Grant projects dealing directly or indirectly with seafood technology in fiscal year 1989 focused on these issues and helped prepare students for careers in industry and academe through advanced training. Federal funding in the amount of $1,662,000 and $1,202,000 in matching funds supported these projects. This report discusses some of the recent issues and Sea Grant advances in this field. For example, the recent rapid growth of the increasingly important soft shell crawfish industry in domestic and foreign markets results from research on intensive culture systems in the early 1980s at Louisiana State University.

Introduction

Research in this program is focused on enhancing the competitiveness of the seafood industry through improvements of processing technology and products and through development of new products and by-products. Another major part of the program is directed to issues of safety and nutrition of seafood.

The ability to capture a larger share of domestic and foreign markets and to develop new ones depends in part on technological advancements. Sea Grant's research represents a significant share of academic contributions to these developments in the United States and is important because most seafood companies are small and without components for research and development. This research also upgrades technology through the students it trains for industrial careers.

Table I shows that $1,662,350 in federal funds and $1,101,745 in matching funds, totaling $2,864,045, supported 49 projects in four broad categories in fiscal year 1989. The number of projects and level of funding were up somewhat from fiscal year 1988, but still below the record funding ($2,902,000) of 1987 and the record number of projects (50) in 1982.

This program complements related research of the National Marine Fisheries Service (NMFS) in its technological laboratories in Gloucester, Massachusetts; Charleston, South Carolina; Pascagoula, Mississippi; and Seattle, Washington. annually on seafood technology. NMFS also supports of extramural projects in seafood technology with Saltonstall-Kennedy funds.

One of the highlights of 1989 was an international workshop on depuration. Working with the National Fisheries Institute, the National Coastal and Development Institute, the Virginia Polytechnic Institute and State University, the Gulf and South Atlantic Fisheries Development Foundation, and the National Marine Fisheries Service, the Florida Sea Grant College Program sponsored the First International Conference on Shellfish Depuration in Orlando, Florida from November 5 to 8. The highly successful conference addressed a range of economic and technological issues concerning shellfish depuration. Approximately 200 shellfish producers and processors attended the meeting and more than 40 domestic and foreign experts reported on the latest technical developments in shellfish

TABLE 1
Federal Funding for Projects in Seafood Science and Technology in Fiscal Years 1981–1989
(in thousands of dollars)

Federal Funding/No. of Projects

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Engineering & Waste Treatment	58/4	56/2	19/1	144/4	76/2	101/6	56/2	84/3	116/3
Product Development & By-Product Recovery	444/13	335/13	406/14	444/14	403/14	324/11	545/14	572/16	330/8
Microbiological & Nutritional Quality	427/16	556/21	610/19	646/17	829/22	923/24	818/22	444/17	745/26
Handling & Processing	371/14	396/14	376/12	411/13	271/9	261/7	308/10	242/8	467/12
TOTALS	1300/47	1343/50	1411/46	1645/48	1579/47	1609/48	1727/48	1342*/44	1662/49

*NON-FEDERAL MATCHING FUNDS WERE $11,101,745 IN FY 1989; TOTAL FUNDING WAS $2,860,095. TOTAL FUNDING IN FY 1988 WAS $2,545,000

depuration in the United States, Canada, England, New Zealand, Spain, France, Denmark, Turkey and Italy.

Depuration has proven effective under a range of conditions, but further research will need to define appropriate conditions for certain target organisms, especially viral agents, and to better define economic feasibility of commercial operations.

The organizers expect to publish the proceedings of the conference by September 1990.

The following four sections provide recent examples of Sea Grant progress in research. Appendix A gives a partial listing of recent publications. Appendix B is a listing of projects funded in fiscal year 1989. The references in the text below are to papers in Appendix A, which is a listing of recent Sea Grant publications in seafood technology.

Engineering and Waste Treatment

The number of projects in this category remains low even though waste management is an important problem in the seafood industry. It is a

problem of increasing urgency. All three projects were in process engineering, but none dealt with waste treatment. The primary approach to problems of waste management is in recovery of by-products and projects of this type fall under the next category of research discussed below.

Researchers at Cornell University published a thorough review of extraction with supercritical carbon dioxide for concentration of omega-3 fatty acids from fish oil (Rizvi et al., 1988). The paper describes the various parameters influencing the purity and yield of eicosapentaenoic and docosahexaenoic acids obtained after various pretreatments of the fish oils. Special health benefits are attributed to these compounds.

Product Development and By-Product Recovery

Development of new products for both domestic and foreign markets is increasingly important for expanding commerce in seafood. Underutilized species and species traditionally used only for industrial products now are considered more seriously as viable food resources, especially for production of surimi, a form of minced fish which is an intermediate in making a wide variety of products of high quality such as simulated scallops and crab legs. The United States has rich resources of fishes that are potentially useful for these kinds of products and several projects, a few each year, have addressed these opportunities. Other projects in this category deal with other types of products and with developing by-products from processing wastes -- such things as fertilizers, animal feeds, and industrial enzymes and pigments.

Researchers at Oregon State University recently reported on some of their research on Pacific whiting as a candidate for surimi. In his thesis (Pacheco-Aguilar, 1989) a student reported on the use of low levels of bromate to effect major improvements in gel cohesiveness and elasticity of gels made from this species. Other work in the same laboratory (Chang-Lee et al., 1989) yielded washing procedures for reducing protease activity in deboned flesh. Without the addition of egg white and potato starch, however, the methods yielded only poor gels.

Like soft shell crabs soft shell crawfish can be consumed almost entirely. Because they taste somewhat like a cross between shrimp and soft shell crab, a rapid market for this product is developing. Development and testing of intensive culture systems for crawfish at Louisiana State University in the early 1980s is the basis of this commercial growth. (Thomasson and Malone, 1989; Malone and Burden, 1988). This research demonstrated that the dominant species in Louisiana, the red swamp crawfish, *Procambarus clarkii*, could be held in tanks at high densities and molted to yield a high priced product. Now, more than 250 producers sell soft shell crawfish in a variety of forms - fresh, frozen, and breaded.

Researchers and advisory personnel in New York in cooperation a private marina and sports store operator executed a demonstration project to help deal with the problem of disposing of processing wastes. (White et al., 1989). Their approach was to use composting with peat moss and wood chips in order to produce horticultural or agricultural fertilizer. Their work demonstrated a workable process. For some small businesses it may be too costly and messy, but for others it is expected to be a viable solution to crucial problems in managing wastes.

Microbial, Chemical and Nutritional Quality

Research in this category deals both with the quality of seafood as it comes out of the water, particularly in regard to contamination by pathogenic microorganisms, and with deterioration of quality and its prevention in transit, processing, and storage. Some projects focused on determining the environmental factors responsible for contamination of shellfish with viruses, bacteria, and toxic algae or on procedures for their accurate measurement or elimination. A large proportion of U.S. coastal waters are closed to shellfishing because of concern about bacterial, viral or algal contamination. Thus, the projects focused on important issues.

In an investigation to determine the levels of viruses associated with solids in a polluted estuary, researchers in the Mississippi-Alabama Sea Grant College Program showed that

distributions of viruses and fecal coliform bacteria are unrelated to each other and appear to be random (Ellender et al., 1989). Virus levels either did not correlate or showed a weak positive correlation with salinity, turbidity, temperature, pH, organic matter, carbonate carbon, smectite, kaolinite, illite, and mean particle size. Viral concentrations correlated with rainfall at only one sampling site. The studies showed the difficulty of identifying the sources of viruses in natural waters. Other research in this program (Cook and Ruple, 1989) showed that increases in the levels of indicator bacteria in post-harvest shellstock oysters generally were accompanied by increases in *Vibrionaceae*, but sometimes the *Vibrionaceae* multiplied in the absence of fecal coliform multiplication. Storage of oysters at 10°C prevented multiplication of vibrios and fecal coliforms, but not *Aeromonas hydrophila*.

The researchers state that increases in both fecal coliforms and *Vibrionaceae* appear to be governed by such factors as harvest and transport temperature, salinity, and possible conditions of transport sacks and humidity. Of these factors, transport temperature is the easiest to control. Therefore, emphasis should be placed on controlling the temperature of oysters from the time they are harvested until they are consumed. This will help to keep the numbers of potential pathogens low and reduce the incidence of illness resulting from consumption of shellfish. They noted that the transport trucks in their study did not always meet the requirement to maintain temperatures at or below 45°F. They noted increases in fecal coliforms and sometimes *Escherichia coli* during transport by truck.

Microbiologists at Louisiana State University have developed rapid methods for the detection of *Vibrio cholerae, Vibrio mimicus, and Vibrio vulnificus* (Adams et al., 1988, Simonson and Siebeling, 1988). The methods, which can be used to test for human and fish pathogens, are based on the use of monoclonal antibodies to flagellar antigens. Several laboratories in the United States and Canada have tested the new reagents and found them effective.

In further reports on evaluating the compounds contributing to the flavors and aromas of fish and fish oils, researchers at the University of Wisconsin showed that vacuum steam-deodorized fish oils oxidized under fluorescent light initially developed green flavors which were caused principally by *t,c*-2,6-nonadienal, but some green-type flavor notes were contributed by *t*-2-hexenal and 1,*c*-5-octadien-3-one (Karahadian and Lindsay, 1989). Diminishment of green flavor notes resulted from the depletion of 2,6-nonadienal and the formation of *c*-4-heptenal (>1 ppm) which contributed oxidized, burnt flavor notes. Concomitant formation of *t,c,c*- and *t,t,c*-2,4,7-decatrienal (>1 ppm) yielded characterizing burnt/fishy or cod liver oil-like flavors in fish oils. Two unidentified compounds exhibiting minnow-bait-bucket and trout-like odor qualities, respectively were encountered in oxidizing fish oils. Hexanal, 2,4-heptadienals and 2,4-decadienals contributed general oxidized, painty flavors to fish oils.

Processing and Handling

Research in this category ranges over a variety of approaches to improving quality of seafood and the efficiency of its production--in some ways the bread and butter issues in Sea Grant because the results are frequently directly useful to agents and specialists in Sea Grant Extension Programs. Recent projects have dealt with a variety of issues in processing and storage of fish.

Researchers at Oregon State University have published a manual for using a mathematical model to evaluate retort operations for the processing of seafood in cylindrical or oval-shaped cans (Simpson et al., 1989A,B). Since several seafood products are processed overseas in oval-shaped containers, there was a need to develop a model to include this type of container. This is particularly important for U.S. companies that purchase or process seafood products overseas.

The authors state that sterilization provides a good example of the benefits that can be gained from modelling. "First, all mathematical equations for the physical laws involved are well known. Moreover, experimentation with computer-supported models offers practical advantages over canning experiments, which are expensive and time consuming."

The mathematical model was based on a finite difference approximation of the differential equation for transient heat conduction in three dimensions. A large number of container locations were considered for average bacterial lethality and

quality retention calculations. The reliability of the numerical method was evaluated by comparing computer predictions with published experimental data for the retention of thiamine, chlorophyll, and betanin in several food products.

The computer program was written in BASIC and can be used with any IBM-PC™ compatible computer. Computing time (IBM PC AT) was approximately 3 minutes per minute of real process time. Current research efforts are aimed at reducing computational time.

Researchers in New York have demonstrated that the trimming techniques that have been suggested to reduce the amount of chlorinated hydrocarbons in the edible flesh of other fishes produced a significant reduction in the level of PCB residues in bluefish (Armbruster et al., 1989). A relatively large proportion of PCBs in bluefish is in the skin. Their work suggests that vaporization of PCBs during cooking may account for a far higher proportion of loss that extraction with fats liquefied and drained away during cooking.

Discussion and Special Issues

Last year Sea Grant's level of effort in seafood science and technology declined sharply. Although it is up considerably this year, some of the research and advisory specialists active in this field are concerned that the level of effort is too low to meet the wide range of problems and opportunities facing the industry and insufficient for training the personnel needed in industry and academe. For example, if inspection of seafood is made mandatory as expected, a range of education to institute procedures in hazard analysis and critical control points (HACCP) will be required. Much of this education would be the logical responsibility of universities.

Increasingly difficult problems with waste disposal in the seafood industry, increasing public concern about quality and safety of seafood, and advancements in molecular biology that could have academically interesting and important applications in research dealing with seafood suggest that the trend should be toward increased efforts in this field. There may be special opportunities for improving efficiency of seafood processing through new and better technology for by-product recovery, for recovery of such things as flavoring components and amino acids.

Over the next few months the National Sea Grant Office is planning to work with the Seafood Technology Group of the Institute of Food Technologists and with the seafood industry to develop a strategy document or white paper that will enunciate the rationale for a coherent national program and for additional effort in research, demonstration, and advisory service.

Appendix A
RECENT PUBLICATIONS

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Appendix B
FISCAL YEAR 1989 PROJECTS

B. SEAFOOD SCIENCE & TECHNOLOGY

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. Engineering & Waste Treatment		
Design & Development of a Sea Urchin Processing System R. Paul 30 University of California Sea Grant College Program	19,535	24,144
A Biotechnological Application of biogenic Ice Nucleator for Energy Saving and Improved Quality in the Freezing of Seafood T.C. Lee 35 New Jersey Marine Sciences Consortium Sea Grant Program	23,000	43,400
Development of Coastal Fish Oil Resources for Potential U.S. Health Industry J.G. Turcotte 12 Rhode Island Sea Grant College Program	73,070	27,098
SUBTOTAL:	$115,605	$94,642
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
2. Product Development & By-Product Recovery		
Control of Surimi Functionality Through Modification of Protein Composition J.S. French 35 University of Alaska Sea Grant College Program	39,100	6,100
Salmon Meal as a Fertilizer S.D. Sparrow 35 University of Alaska Sea Grant College Program	17,500	0
Potential Anti-Tumor Drug from Marine Waste By-Products K.P. Wong 12 University of California Sea Grant College Program	39,608	31,756
Fish Myofibrillar Protein as a Food Ingredient D. Hamann 35 University of North Carolina Sea Grant College Program	5,145	40,211

Functional Characterization of Surimi Waste Stream T. Lanier 35 University of North Carolina Sea Grant College Program		56,163	4,671
Microencapsulated Diets for Intensive Production of Molluscan Shellfish C. Langdon 03 Oregon Sea Grant College Program		64,200	37,300
Crab Shell Chitosan, its Mode of Gene Activation L.A. Hadwiger 13 Washington Sea Grant College Program		65,600	17,600
Chitosan Delivery Systems for Medicines G.G. Allan 13 Washington Sea Grant College Program		42,600	21,600
	SUBTOTAL:	$329,916	$159,238
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
3. Nutritional, Microbial & Chemical Quality		
Extending Prime Quality Market Life of Seafoods N. Haard 35 University of California Sea Grant College Program	10,216	17,965
Collagenolytic Activity in Skeletal Muscle of Fish N. Haard 35 University of California Sea Grant College Program	31,649	30,189
Oxidative Metabolism of Polyunsaturated Fatty Acids in Fish J. Bruce 35 University of California Sea Grant College Program	19,142	21,026
Detection and Survivability of Some Pathogenic Enterobrac I. Radolfo 45 University of Southern California Sea Grant Program	43,639	40,642
Develop of DNA Probes - Pathogenic Marine Bac H. Shizura 45 University of Southern California Sea Grant Program	39,574	37,113

Consumer Preferences and the Economic Consequences of Safety Program for Shellfish Products J.W. Milon 14 Florida Sea Grant College Program	30,800	27,800
Identification of Fish and Fishery Products By Monoclonal Antibody Techniques II C. Wei 35 Florida Sea Grant College Program	39,600	24,200
Detecting of Vibrio cholerae 01 Cells In Shellfish Meat Homogenate Meat Enrichment Broths by Dipstick ELISA R.J. Siebeling 35 Louisiana Sea Grant College Program	42,814	24,543
Hydrographic Localization of Toxic Dinoflagellate Blooms in Coastal Waters D.M. Anderson 07 Woods Hole Oceanographic Institution Sea Grant Program	60,000	19,525
Immune Response in Great Lakes Fisheaters M. Sowers 45 Michigan Sea Grant College Program	63,911	16,563
Siderophore Production in the Red Tide Dinoflagellate Protogonyaulax tamarensis G.L. Boyer 07 New York Sea Grant Institute	23,028	23,160
Siscowet Trout as a Source of Antithrombotic, Hypocholesterolemic Fatty Acids for Human Medicine P.B. Addis 12 Minnesota Sea Grant College Program	4,970	4,020
Causes and Mitigation of Toxics Contamination of the Fishery in the St. Louis River/Duluth-Superior Harbor, Fishery Nursery A G. Rapp 44 Minnesota Sea Grant College Program	24,000	5,790
Uptake and Retention of Contaminated by Fish Maintained on Artificial Diets in Lake Ontario J.K. Buttner 02 New York Sea Grant Institute	32,344	20,208

The n-3 Polyunsaturated Acids of Marine Lipids: Determination of Biochemical Effects, Optimum Dietary Intake and Oxidative St J.E. Kinsella 12 New York Sea Grant Institute	22,275	63,576
Risk Perception and Communication Regarding Chemically Contaminated fish in Lake Ontario B.A. Knuth 29 New York Sea Grant Institute	9,523	15,474
Disposition and Metabolisms of Polychlorinated Dibenzofurans in Fish H.C. Sikka 45 New York Sea Grant Institute	50,568	26,745
Evaluation of Plasmid Profiles as a Method to Determine the Source of Fecal Pollution in an Estuary R.K. Sizemore 08 University of North Carolina Sea Grant College Program	11,515	5,252
Social and Cultural Dimensions of Consumer Knowledge Among Seafood Consumers: Consumer Education Implications D. Griffith 29 University of North Carolina Sea Grant College Program	13,459	8,932
Absorption of Ethyl Ester and Triglycerides of Fish Oil Omega-3 Fatty Acids in Man W.E. Connor 12 Oregon Sea Grant College Program	22,900	18,100
Do Dietary Saturated Fatty Acids Reduce Effects of Fish Oils on Lipid Metabolism and hemostasis W.E. Connor 12 Oregon Sea Grant College Program	35,100	28,200
Processing Crab and Shrimp Meat for Improved Product Quality and Safety D.L. Crawford 35 Oregon Sea Grant College Program	25,000	56,700
Fatty Acid and Lipid Nutrition of Red Drum: Effects on Cold Adaptation, Immunocompetency and Product Quality D.M. Gatlin 02 Texas A&M University Sea Grant College Program	35,049	19,938

Consumer Perceptions of Seafood Quality J. Anderson 20 Rhode Island Sea Grant College Program	22,762	57,253
The Role of Formaldhyde in the Textural Deterioration of Frozen Gadoid Fish Muscle K.L. Parkin 35 Wisconsin Sea Grant Institute	26,728	11,068
Third International Conference on Ciguatera Fish Poisoning T.R. Tosteson 74 University of Puerto Rico Sea Grant Program	5,000	0
SUBTOTAL:	$745,566	$523,982
PASSTHROUGH:	4,000	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
4. Handling & Processing		
Good Manufacturing Practices for Alaska Seafood Processing Industry J.B. Lee 35 University of Alaska Sea Grant College Program	44,400	21,800
Energy Use Assessment in Alaskan Seafood Processing Plants J.C. Nash 35 University of Alaska Sea Grant College Program	26,900	8,900
Studies Concerning the Uptake, Elimination, Retention and Depuration of Virulent, Avirulent and VBNC Forms of Vibrio vulnific G.E. Rodrick 08	22,300	57,000
Florida Sea Grant College Program Ozone-Assisted Depuration of Red Tide Contaminated Shellfish and Seawater G.E. Rodrick 35 Florida Sea Grant College Program	20,000	30,000
Development of Techniques for Increasing the Efficiency of Soft Shell Crawfish Production by Removal/Neutralization of the Ey R.F. Malone 01 Louisiana Sea Grant College Program	51,400	41,811

An Economical Analysis of the Decline in Maryland Seafood Processing I. Strand 14 Maryland Sea Grant College Program		0	5,700
Stability of Fish Oils During Production and Use H. Hultin 13 Massachusetts Institute of Technology Sea Grant College Program		50,000	18,800
Uptake and Depuration of Red Tide Paralytic Shellfish Poisoning Toxins in East Coast Bivalve Molluscs V.M. Bricelj 06 New York Sea Grant Institute		74,177	31,188
Mathematical Models for Mgmt Decisions of Fresh Seafood Quality: Combined Heat Transfer and Microbial Growth Models J.A. Torres 35 Oregon Sea Grant College Program		34,800	13,200
New Compounds for Ice Suppression on Fish Antifreeze Proteins T. Caceci 13 Virgina Graduate Marine Science Consortium Sea Grant Program		59,970	30,673
Determination of Autolytic Decomposition Rates in Selected Mid-Atlantic fish Species Stored Under Iced and Super-Chilling Tem G.J. Flick 35 Virgina Graduate Marine Science Consortium Sea Grant Program		35,135	21,378
Fishery Development D.A. Stuiber 71 Wisconsin Sea Grant Institute		48,181	43,433
	SUBTOTAL:	$467,263	$323,883
	PASSTHROUGH:	0	
	GRAND TOTAL	$1,662,350	$1,101,745

Division of Human Resources

The Human Resources Division again experienced some personnel changes in 1989. Senior secretary, Mrs. Jacqueline Turnage, took a career development position in the NOAA Procurement Office, and long-time Division Head Robert Shephard served as Acting Sea Grant College Program Deputy Director for most of the year. Bernard Griswold then acted as Division Head in his absence while maintaining program directions of MAS.

Responsibilities of the Human Resources Division include:

Marine Advisory Services, Communications, Marine Policy and Social Sciences, Education and Training, and Marine Law.

In addition, staff duties assigned Human Resources Division personnel are: Great Lakes Research Coordination, OAR Long Range Plan, Social Sciences Arctic Research, Sea Grant Federal Fellowship Program, Marine Debris, Special Publications, Vessel Safety, and Global Change Education.

The 1990's promise to be a challenging decade for the Human Resources Division. New technology in information management and dissemination will provide major new tools for the Division. Resource issues, all involving human interactions, are becoming more complex and global in nature. We feel we are ready to respond.

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Communications

Summary

The Sea Grant communications network experienced a period of transition accompanied by a maturation of regional efforts during Fiscal Year 1989. As it continued to fulfill Sea Grant's mandate for the "broad and prompt dissemination of knowledge and techniques," the network for the first time saw one of its own members become an official representative to the Council of Sea Grant Directors and proudly unveiled its first-ever regional magazine Nor'easter, published by the Northeast Sea Grant programs.

For the National Office, the transition to a new Administration presented a chance to introduce Sea Grant to new officials not only through the printed word but also through a visual medium. With the creative assistance of the communications programs in Texas, North Carolina and Georgia, the documents Oceans of Opportunity and The National Sea Grant College Program Economic Impact--1987 as well as a new national insignia were produced, thus helping to bring further visibility to Sea Grant.

So that the results of Sea Grant research, education, and advisory/extension work flow into the hands of users in both the public and private sectors, NOAA Sea Grant supported communications projects at all 29 Sea Grant programs during Fiscal Year 1989. Federal funds of $3,141,481 were matched by $2,012,632 in state funds for a total of $5,154,113. In terms of overall program funding, the amount for communications comprised 7.5 percent of the total.

Introduction

Along with three specialized projects -- the National Sea Grant Depository archive and lending library, the national *Sea Grant Abstracts* quarterly publication, and the regional "Earthwatch" radio program -- there are 27 distinct, institutional communications projects in the Sea Grant network. At the remaining two Sea Grant programs, in Massachusetts (Woods Hole) and in Virginia, support for communications efforts comes under advisory and program management budgets.

NOAA Sea Grant support for communications projects amounted to $3,141,481 during Fiscal Year 1989, with programs providing matching funds of $2,012,63, for a total of $5,154,113. These funds ensure that the results of Sea Grant research, education, and advisory/extension work flows into the hands of users in both the public and private sectors.

In addition, the Environmental Protection Agency, the NOAA Estuarine Program Office, and the NOAA Chief Scientist's Office provided funds to the Texas, Maryland, and Alaska Sea Grant Programs respectively for a variety of communications projects. That Sea Grant's communications expertise is being recognized, tapped, and remunerated by federal sources outside of the National Sea Grant Office is certainly a noteworthy development.

From FY 1986-88, half of the communications coordinator positions in the network experienced a turnover. During FY 1989, new coordinators were named in Florida, Massachusetts (MIT), and Wisconsin, with vacancies occurring in Delaware and Mississippi/ Alabama. This turnover situation appears to have stabilized now, offering the opportunity for even more networking and cooperative communications ventures.

Communications Productivity

Publications production remains the backbone of Sea Grant communications activity, with active writing/editing/designing operations being performed by communicators. Desktop

Table I

NETWORK COMMUNICATIONS PUBLICATIONS PRODUCTIVITY IN MAJOR CATEGORIES

	1984	1985	1986	1987	1988	1989 (to date)
ADVISORY/EXTENSION REPORTS	75	128	87	103	73	37
BOOKS	6	5	5	2	5	-
EDUCATIONAL/ CURRICULAR MATERIALS	23	14	10	16	4	2
HANDBOOKS/ GUIDES	22	24	16	23	17	4
JOURNAL ARTICLE REPRINTS	486	504	493	502	424	121
PROCEEDINGS	24	39	21	30	26	5
TECHNICAL REPORTS	100	115	101	90	69	28

Source: National Sea Grant Depository database; total 26,781 records as of December 18, 1989.

publishing has now been embraced by many communications programs, thus permitting greater speed and flexibility in producing new publications attractively and at less cost.

The preceding table provides one measure of communications productivity. However, it is not exhaustive for communicators also produce program and project directories; biennial reports; and omnibus proposals for funding. In addition, 1989 figures are preliminary with many more publications from this year as well as some from 1988 still expected to arrive at the Sea Grant Depository for processing in 1990.

A Year of Transition

Representation...

The Sea Grant communications network experienced a period of transition accompanied by a maturation of regional efforts during Fiscal Year 1989. As it continued to fulfill Sea Grant's mandate for the "broad and prompt dissemination of knowledge and techniques," the network for the first time saw one of its own members become an official representative to the Council of Sea Grant Directors. While Marine Advisory Services has for several years had a representative to this council, it was not until Sea Grant Week 1989 that a communicator (Millie Flory of Michigan, the current chair of the communications network) was invited to sit formally with the Sea Grant Directors to provide a voice for communicators and to offer suggestions for future activities.

After Sea Grant Week, Ms. Flory represented communications at the Council of Sea Grant Directors meeting and the National Marine Extension/Advisory Symposium, both held in July 1989 in Portland, Oregon. In addition, she attended the Agricultural Communicators in Education meeting, held in the same city that week, to develop links with Cooperative Extension Service (Land Grant) communicators. Such activity and inclusion will enable the Sea Grant network to act more proactively in meeting new communications opportunities in the 1990's. Plans are now being formulated to produce a new national Sea Grant brochure for use alongside individual program materials.

Regionalization...

At the regional level, communications groups actively meet to cooperate on joint projects. Proudly unveiled in the spring of 1989 was the first-ever regional Sea Grant magazine, *Nor'easter*. This attractively produced, 8,000 circulation magazine resulted from the collaborative efforts of Sea Grant directors, communicators, and advisory service leaders from the states of Connecticut, Massachusetts, New York, and Rhode Island. Reader response, as documented in unsolicited letters, has been quite gratifying, and plans call for an increase in circulation to 8,800 for the Fall 1989 issue.

Turning to our inland seas, the Great Lakes Sea Grant network held a workshop in Alexandria Bay, New York, May 1–4, 1989. This regional meeting enabled directors, advisory leaders, and communicators to share information and to develop new initiatives. Among the communications topics discussed were: the role of publicity in conflicts and controversial issues; outdoor writers gatherings; and the use of videotape for hypothermia training. Since that meeting, this regional group, which encompasses the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio and Wisconsin, has issued the *Great Lakes Sea Grant Network* pamphlet which explains Sea Grant's extension and outreach efforts. In addition, this network published a booklet profiling *The Great Lakes Charter Sailing Industry*.

In the Southeast/Gulf Coast, communicators provided material for use in the regionally-distributed newsletter *Gulfwatch* which debuted in January 1989. This newsletter, funded by the Environmental Protection Agency (EPA) with a $50,000 two-year grant to Texas Sea Grant, focuses on resource and management issues in the Gulf of Mexico and provides another vehicle for disseminating Sea Grant information to wider audiences.

On the West Coast, a 1988 meeting of the Pacific Sea Grant College Program, composed of directors, communicators, and advisory leaders from Alaska, California, Hawaii, Oregon, and Washington, focused on a Pacific global climate change initiative with major emphasis on ozone depletion and ultraviolet increase. During FY 1989, the communications network (in fact, the whole world) saw media attention turning to global change and its impacts, and a new proposal (more fully described in this volume's Marine Advisory Services report) is being formulated to address global change education through advisory/extension services. Communicators will certainly have a role to play as this project evolves.

...And A New Administration

For the National Sea Grant Office, the transition to a new Administration presented a chance to introduce Sea Grant to new officials not only through the printed word but also through a visual medium. With the creative assistance of the communications programs in Texas, North Carolina and Georgia, the documents *Oceans of Opportunity* and *The National Sea Grant College Program Economic Impact--1987* as well as a new national insignia respectively were produced, thus helping to bring further visibility to Sea Grant. In addition, a slide show on Sea Grant was revised and a new National Office staff biographies booklet was produced.

But along with this visibility came network concern over national publications, particularly those issued by the National Sea Grant Office. As a result, the National Sea Grant Communicators Steering Committee, on which the National Office communicator serves as an ex-officio member, formed a subcommittee to review publications policy. This group will meet throughout Fiscal Year 1990 to discuss how national publications are developed and how individual programs are represented.

A New Decade

As the world enters the last decade of the 20th century, the rapid growth both in the volume of information being generated and in the methods for delivering information spurred the National Office to begin developing a long-range communications strategy for NOAA's recently formed Office of Oceanic Research Programs (ORP) which encompasses both the National Sea Grant College Program and the National Undersea Research Program. As mentioned in the book *Intermedia: Interpersonal Communication in a Media World*, "In one year, the average American will read or complete 3,000 notices and forms, read 100 newspapers and 36 magazines, watch 2,463 hours of television, listen to 730 hours of radio,

buy 20 records, talk on the telephone almost 61 hours, read 3 books, and spend countless hours exchanging information in conversations." Therefore, most of our waking hours are spent with information, either consuming it or producing it through various communications modes. Given this vast world of information and a renewed sense of commitment to the environment, Sea Grant communications must poise itself to focus even more public attention on important marine science and resource issues.

PROJECTS

Communications:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Public Information Services B.R. Melteff 75 University of Alaska Sea Grant College Program[1]	111,000	272,000
Communications Program J. Sullivan 76 University of California Sea Grant College Program	229,650	34,818
Communications and Pubs P. Grifman 76 University of Southern California Sea Grant Program	102,661	145,608
Communications M. Van Patten 79 University of Connecticut Sea Grant Program	59,775	0
Sea Grant Communications S.H. Fitzgerald 76 Delaware Sea Grant College Program	136,529	50,079
Florida Sea Grant Communications Program J.T. Woeste 76 Florida Sea Grant College Program	79,500	53,300
Communications Program R. Rivers 77 Georgia Sea Grant College Program	75,100	57,000
Communications Program R.T. Pfund 76 University of Hawaii Sea Grant College Program	106,094	21,712
Communications R. Goettel 76 Illinios/Indiana Sea Grant Program	24,141	14,176
Publications and Information Dissemination E.B. Coleman 76 Louisiana Sea Grant College Program	46,575	140,283

Communications and Information Programs S. Adams 79 Maine/New Hampshire Joint Sea Grant College Program		179,000	68,952
Publications Support for NOAA's * Chesapeake Bay Study M. Leffler 76 Maryland Sea Grant College Program		(22,000)	5,110
Sea Grant Communications J.R. Greer 80 Maryland Sea Grant College Program		118,000	179,200
Marine Communications/Information Service Massachusetts Institute of Technology K. Hartley 76 Sea Grant College Program		240,400	7,000
Michigan Sea Grant Communications M. Flory 76 Michigan Sea Grant College Program[1]		145,527	48,319
Communications A. Tibbetts 79 Minnesota Sea Grant College Program[1]		14,550	58,590
Program Management: Communications J.I. Jones 79 Mississippi/Alabama Sea Grant Consortium		70,351	22,336
Communications K. Kosko 73 New Jersey Marine Sciences Consortium Sea Grant Program		51,300	11,100
Communications A.H. Bartkus 79 New York Sea Grant Institute		48,643	73,108
Program Communications K. Hart 76 University of North Carolina Sea Grant College Program		53,200	119,318
Communications of the Ohio Sea Grant Program M. Brainard 79		36,723	67,644
Ohio Sea Grant College Program Sea Grant Communications J. Larison 80 Oregon Sea Grant College Program		144,000	118,100
Communications/Publications E.F. Hernandez 76 University of Puerto Rico Sea Grant Program		55,700	65,600

Marine Information Program C. Jaworski 76 Rhode Island Sea Grant College Program		194,489	6,056
A Proposal for the Support of Continuing and New Activities of the National Sea Grant Depository C. Murray 77 Rhode Island Sea Grant College Program		105,000	0
Communications and Information Services M.R. DeVoe 80 South Carolina Sea Grant Consortium		51,300	45,100
Marine Information Services A. Broussard 76 Texas A&M University Sea Grant College Program		146,677	201,764
Production and Distribution of a Bimonthly Newsletter for the Gulf of Mexico Program A. Broussard 76 Texas A&M University Sea Grant College Program	*	(50,000)	0
Washington Sea Grant Communications P. Peyton 76 Washington Sea Grant College Program[1]		236,000	89,400
Earthwatch Public Service Radio Program S. Wittman 75 Wisconsin Sea Grant Institute		42,615	29,080
Communications S. Wittman 76 Wisconsin Sea Grant Institute		166,981	107,879
Sea Grant Abstracts F. Shephard 76 Woods Hole Data Base, Inc.		70,000	0
	SUBTOTAL: [2]	$3,141,481	$2,012,632
	PASSTHROUGH:*	$ 72,000	

[1]Additional funds for communications personnel are included within the advisory/extension budgets at these programs.

[2]Funding for communications at Virginia and Woods Hole Sea Grant is included in Marine Advisory Services and program management budgets.

Education and Training

Summary

This year's report on the education and training program of the National Sea Grant College Program follows the past year's format in describing projects in the areas of Course Development and Student Projects; Research Assistantships; Pre-College Education and Teacher Training; Non-Formal Education; Technical and Vocational Education; Sea Grant Fellowship Program; Sea Grant Fellows Program; International, and other. It also describes the thrusts that are being developed nationally by NOAA and National Science Foundation.

Introduction

The education and training mission of the National Sea Grant College Program is broad and pervasive. It aims not only to prepare specialists for all types of marine-related careers, but also to increase public awareness of and capacity to enjoy the marine environment and its resources. This mission has evolved over the past 22 years to encompass professional education, upgrading of university courses and curricula, vocational/technical training, improvement of pre-college education, continuing education, fellowship programs, and both formal and non-formal public education. Sea Grant is authorized to operate a two-way international marine science and technology sharing program, but the program does not currently have appropriated funds.

This report deals only with those projects that are explicitly labelled by Sea Grant programs as education or training.

Table 1 summarizes federal, matching and total funding for various categories of education and training projects in FY 89. The categories themselves will be described below. Inspection of the table reveals that total support of education and training projects increased by approximately $592,000 over the FY 88 level. Both federal and matching support of these projects increased during the past year.

Education and Training Projects

Education and training projects supported by Sea Grant in FY 89 fit into the following groups or categories.

Group A: Course Development and Student Projects This group includes efforts to improve undergraduate and graduate level instructional programs in marine sciences and related fields. The projects help universities introduce new knowledge and methodologies into their instructional programs. Federal support is for a relatively short period of time and only for development efforts that clearly exceed normal university resources available for this program.

Group B: Research Assistantships A number of universities support their research assistants through separate education projects in this group. It does not include projects under the Sea Grant Fellowship Program in Group F or Sea Grant Fellows in Group G below.

The estimated numbers of graduate research assistants (GRA's) who have received at least partial support from Sea Grant in recent years are shown in Table 2. Note that the table includes all the GRA's supported by Sea Grant, not just those in separate education projects.

A few details should be noted about the numbers in Table 2. They refer only to graduate research assistants (GRA's), while graduate students who work in education, Marine Advisory Service and program administration were omitted. The numbers were drawn primarily from information available in the National Sea Grant Office, and this undoubtedly provides an underestimate of the actual totals. Sea Grant Fellows were not included. All GRA's who received some financial support from Sea Grant were included; no attempt was made to measure FTE's.

Table 1

Sea Grant Education and Training Projects in FY89

(support in $000)

Group	Federal	Match	Total	Change in Total from FY88
A	$ 100	$ 271	$ 371	- 127
B	1,474	77	1,551	- 42
C	152	437	589	+ 395
D	240	583	823	+ 32
E	70	229	299	+ 13
F	102	75	85	+ 92
G	603	30	633	+ 93
H	282	210	492	+ 282
Totals	$3,023	$1,918	$4,941	+

Some concern has been expressed in the National Sea Grant College Program over the declining number of GRA's supported by Sea Grant. The data in Table 2 verify that there is reason for concern. The number of GRA's has remained approximately the same as last year, with an overall decrease experienced over the past eight years from the high point in 1980.

Group C: Pre-College Education and Teacher Training Investigators supported by these projects develop educational materials to be used in pre-college classrooms, evaluate and disseminate the materials, and instruct teachers in their use. They also provide back-up support to teachers and administrators who are trying to introduce marine and aquatic education into their school systems. Note that some pre-college educational activities are supported as part of the Marine Advisory Service, the subject of a separate report.

Group D: Non-Formal Education This group includes marine and aquatic educational activities that occur outside formal classroom structures. The potential audience is the entire American public in all its diversity. Activities typically include lectures, conferences, 4-H and Scout projects, beach walks, and radio and television shows. These activities often take place at science centers, museums and aquaria.

Sea Grant's non-formal marine educational activities are much larger than what is covered in this report, since most of it takes place under the auspices of the Marine Advisory Service.

Group E: Technical and Vocational Education This group includes projects to begin technician training, vocational training and pre-baccalaureate technical training programs that typically are offered at junior or community colleges and technical institutes. Sea Grant has maintained a cautious approach toward supporting such projects, preferring to see that potential employers are actually seeking graduates or that a shortage of trained people exists before supporting the establishment of new instructional programs.

Group F: Sea Grant Fellowship Program This group includes projects that are intended to help stimulate interest in marine careers among those (e.g. minorities, women and the handicapped) whose background or previous training might not have generated such interest. Last year, it was reported that FY 88 would be the final year of reporting on this category, since the Sea Grant Fellowship Program in this form was eliminated by P.L. 100-220; however, grants were awarded in FY 89 that fall in this category.

During FY 90, we will recategorize these educational efforts. In the meantime, we have a new postdoctoral fellowship program. This program is now under development.

Table 2

Numbers of Graduate Research Assistants (GRA's)

Supported by Sea Grant in Recent Years

Fiscal Year	GRA's
80	560
81	501
82	523
83	500
84	538
85	520
86	504
87	497
88	429
89	430

Group G: Sea Grant Fellows (John A. Knauss Marine Policy Fellowship) This program supports highly qualified and motivated graduate students while they work on marine policy issues for one year in the legislative or executive branch of the federal government. The program is intended to round out a student's academic training and give him or her some experience at the federal policy-making level. The program has been in existence since 1979 and has supported 152 students to date. P.L. 100-220 renamed it the Dean John A. Knauss Marine Policy Fellowship Program.

A document outlining the entire fellowship process was published this past year. It includes details on eligibility, deadlines, stipends and expenses, application procedures, selection, criteria, placement process, and reporting requirements. The document is attached as Appendix A to this report.

Group H: Other Education This group includes those education efforts that cannot be fit under any of the other headings given above. Projects in this category often reveal that local programs are trying new educational approaches that fall outside any preconceived scheme.

Group I: Sea Grant International Program The earlier Sea Grant International Program had begun to build a record in marine technology sharing and cooperation with developing countries. P.L. 100-220 did not abandon that earlier activity, but it enlarged and somewhat refocused the approach by putting emphasis on marine resources, wherever they may be found, and on the broad international resource aspects of marine science, education, and two-way technology sharing. An additional change involved the Sea Grant network and its capability as a resource to be used in the Caribbean Basin Initiative and to help implement the U.S./Canadian fisheries and water quality agreements. Sea Grant will activate this broadened program as soon as funds become available.

Future Plans

A formal proposal was submitted to the National Science Foundation (NSF) entitled "Interpreting Current Research on Global Environmental Issues for Teachers and Students." This was a joint effort headed by Dr. James Jones, Director of the Mississippi/Alabama Sea Grant Consortium and includes a national proposal supported by the Mississippi-Alabama Sea Grant Consortium, the Gulf Coast Research Laboratory, University of Georgia Sea Grant Program, Maine-New Hampshire Sea Grant Program, and Oregon Sea Grant Program. It was a 3-year effort requiring $2,379,198.

Unfortunately, this proposal was declined with a request from NSF to resubmit after discussions with them. Dr. Sharon Walker and Mr. Shephard will arrange to meet with NSF officials in the near future.

Lastly, a national effort is developing to put NOAA into the spotlight as a supporter of education and a plan will be developed to focus NOAA responsibilities on this effort. Sea Grant is expected to play a prominent part.

The education picture is getting brighter, with the new decade will giving us an opportunity to enhance our education capabilities.

PROJECTS

A. EDUCATION

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
1. Course Development and Student Projects			
Estuarine Planning Handbook D.D. Barile 70 Florida Sea Grant College Program		16,000	13,300
Undergraduate Ocean Internship S. Maynard 70 University of Hawaii Sea Grant College Program		22,094	43,242
Opportunities for Undergraduate Research and Development in Marine Science and Engineering A.D. Drake 61 Maine/New Hampshire Joint Sea Grant College Program		37,000	60,055
Ocean Engineering Curricula T.F. Oglivie 61 Massachusetts Institute of Technology Sea Grant College Program		0	140,320
MIT Sea Grant/Undergraduate Research Opportunities Program N. Doelling 70 Massachusetts Institute of Technology Sea Grant College Program		25,000	14,209
	SUBTOTAL:	$100,000	$271,126
	PASSTHROUGH:	0	

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
2. Research Assistantships			
Sea Grant Traineeships R.K. Dearborn 70 University of Alaska Sea Grant College Program		98,300	0
Sea Grant Trainees J. Sullivan 70 University of California Sea Grant College Program		545,320	35,388
John D. Isaacs Sea Grant Memorial Scholarship J. Sullivan 70 University of California Sea Grant College Program		10,000	2,500

Graduate Research Program R. Holmes 70 University of California Sea Grant College Program		29,165	5,000
Sea Grant Graduate Student Trainee Program J. Fawcett 70 University of Southern California Sea Grant Program		36,000	18,000
Graduate Student Support A.T. Manus 70 Delaware Sea Grant College Program		334,308	15,818
Sea Grant Trainees G.B. Mackiernan 70 Maryland Sea Grant College Program		68,700	0
Sea Grant Assistantships D.C. McNaught 62 Minnesota Sea Grant College Program		126,010	0
Sea Grant Scholars R.M. Schlenk 70 New York Sea Grant Institute		226,500	0
	SUBTOTAL:	$1,474,303	$76,706
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
3. Pre-College Education and Teacher Training		
Marine Education and Training J.R. Calkins 70 Georgia Sea Grant College Program	40,600	303,000
Special Enrichment Activities in Oceanography for Area Teachers and Students (SEA OATS II) W. Hosking 70 Mississippi/Alabama Sea Grant Consortium	9,027	7,853
Teacher Awareness of Great Lakes Issues R.W. Fortner 70 Ohio Sea Grant College Program	36,545	61,168
Marine Education: An Interdisciplinary Approach to All-level Teacher Education R.K. Tinnin 70 Texas A&M University Sea Grant College Program	35,434	17,717

A Comprehensive Marine Education Program for Puerto Rico A. Ortiz 70 University of Puerto Rico Sea Grant Program		30,000	47,600
	SUBTOTAL:	$151,606	$437,338
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
4. Non-Formal Education		
Marine Advisory Services and Education J. Fawcett 77 University of Southern California Sea Grant Program	156,766	62,345
Long Island Sound Study Public Education and Participation C. Arnold 75 University of Connecticut Sea Grant Program	0	0
Techniques For Dealing with uncertainty in Fisheries Management Information J.M. Hoening 70 Florida Sea Grant College Program	30,500	15,200
Second International Conference on Marine Debris J.R. Davidson 74 University of Hawaii Sea Grant College Program	0	0
Annual MIT Sea Grant Lecture/Series K. Hartley 70 Massachusetts Institute of Technology Sea Grant College Program	24,200	48,929
Public Education and Training Short Courses F.J. McGarry 75 Massachusetts Institute of Technology Sea Grant College Program	0	79,496
Public and Industrial Information and Education D.A. Ross 70 Woods Hole Oceanographic Institution Sea Grant Program	0	325,000
Project Marines Discovery L. Bruce 70 Mississippi/Alabama Sea Grant Consortium	16,534	12,157
Assistance with the Technology Transfer and Citizen Monitoring Workshop in New Orleans, Dec 1989 Lee 70 Rhode Island Sea Grant College Program	0	0

The Narragansett Bay Classroom W. Gray 75 Rhode Island Sea Grant College Program		10,000	36,474
Recent Advances in Limnology and Oceanography Seminar A.S. Brooks 70 Wisconsin Sea Grant Institute		1,584	3,312
	SUBTOTAL:	$239,584	$582,913
	PASSTHROUGH:	217,320	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
5. Technical and Vocational Training		
The MITSG/MMA Joint Program in Marine Education and Training G. Motte 66 Massachusetts Institute of Technology Sea Grant College Program	70,000	227,590
SUBTOTAL:	$70,000	$227,590
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
6. Sea Grant Fellowship Program		
CA Sea Grant State Fellowship Program J. Sullivan 70 University of California Sea Grant College Program	20,000	10,363
American Indians in the Marine Science J. Kramer 62 Minnesota Sea Grant College Program	49,750	7,300
Sea Grant Fellowship Program R. Hanson 70 Mississippi/Alabama Sea Grant Consortium	20,000	0
Sea Grant Marine Policy Fellowship W. Queen 70 University of North Carolina Sea Grant College Program	11,875	0
Marine Fellowship Program L.F. Guseman 70 Texas A&M University Sea Grant College Program	0	57,000
SUBTOTAL:	$101,625	$74,663
PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
7. Sea Grant (John A. Knauss) Fellows Program		
Sea Grant Fellowship - Urban A.T. Manus 70 Delaware Sea Grant College Program	30,000	0
Sea Grant Fellowship - Wickham J.C. Cato 70 Florida Sea Grant College Program	30,000	0
Sea Grant Fellowship - Wieting J.R. Van Lopik 70 Louisiana Sea Grant College Program	30,000	0
Sea Grant Fellowship - Wells M.G. Parsons 70 Michigan Sea Grant College Program	30,000	0
Sea Grant Fellowship - Nelson D.C. McNaught 70 Minnesota Sea Grant College Program	30,000	0
Sea Grant Fellowship - Wilson J.I. Jones 70 Mississippi/Alabama Sea Grant Consortium	30,000	0
Sea Grant Fellowship - Sponaugle R.E. Malouf 70 New York Sea Grant Institute	30,000	0
Sea Grant Fellowship - Baker B.J. Copeland 70 University of North Carolina Sea Grant College Program	30,000	15,000
Sea Grant Fellowship - J. Kardon B.J. Copeland 70 University of North Carolina Sea Grant College Program	30,000	15,390
Sea Grant Fellowship - Robb J.M. Reutter 70 Ohio Sea Grant College Program	30,000	0
Sea Grant Fellowship - Ballweber W. Wick 70 Oregon Sea Grant College Program	30,000	0
Sea Grant Fellowship - Rice S. Nixon 70 Rhode Island Sea Grant College Program	30,000	0

Rhode Island Sea Grant College Program Travel Funds for 1989 Sea Grant Fellows S. Nixon 70 Rhode Island Sea Grant College Program		3,000	0
Sea Grant Fellowship - Stone S. Nixon 70 Rhode Island Sea Grant College Program		30,000	0
Sea Grant Fellowship - Cunningham M.A. Davidson 70 South Carolina Sea Grant Consortium		30,000	0
Sea Grant Fellowship - Scholz M.A. Davidson 70 South Carolina Sea Grant Consortium		30,000	0
Sea Grant Fellowship - Graham L.S. Echols 70 Washington Sea Grant College Program		30,000	0
Sea Grant Fellowship - Grosse L.S. Echols 70 Washington Sea Grant College Program		30,000	0
Sea Grant Fellowship - Holtz L.S. Echols 70 Washington Sea Grant College Program		30,000	0
Sea Grant Fellowship - G. Kardon M.G. Parsons 70 Michigan Sea Grant College Program		30,000	0
Sea Grant Fellowship - Sherk M.G. Parsons 70 Michigan Sea Grant College Program		30,000	0
	SUBTOTAL:	$603,000	$30,390
	PASSTHROUGH:	0	
TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
8. Other			
NOAA Marine Engineering/Science Career Orientation E.L. Cox 70 Howard University		42,900	22,800
Sea Grant Fellowships for Minority Students Pursuing Educational Programs in the Area of Marine Sciences A.F. Spilhaus 70		6,000	3,000

American Geophysical Union Publications and Information Dissemination E.B. Coleman 76 Louisiana Sea Grant College Program		46,575	140,283
Publications Support for NOAA's Chesapeake Bay Study Merril 76 Maryland Sea Grant College Program		0	5,110
Development of a Monograph on Computer-Aided Fabrication of Marine Systems K. Masubuchi 70 Massachusetts Institute of Technology Sea Grant College Program		20,000	20,015
Sea Grant Post-Doctoral Fellows C.G. Schlenk 80 New York Sea Grant Institute		43,000	0
A Proposal for the Support of Continuing and New Activities of the National Sea Grant Depository C.J. Murray 70 Rhode Island Sea Grant College Program		105,000	0
Special Marine Education R.A. Ragotzkie 70 Wisconsin Sea Grant Institute		18,988	25,016
	SUBTOTAL:	$282,463	$216,224
	PASSTHROUGH:	22,000	
	GRAND TOTAL	$3,022,581	$1,916,950
	PASSTHROUGH	$ 239,581	

Marine Advisory Extension Services Program

Summary

Core funding for the Sea Grant Marine Advisory Services Program has been maintained at relatively stable levels during the last 6 years; however individual programs have continued to mature and even expand through cooperative programming and leveraging resources in recent years. A national meeting of Program Leaders was held in 1989 and was an effective tool for promoting interaction and planning for the increasing opportunities and challenges of the future. The entire network is becoming an integrated program in its own right; no longer is it just the local agent working on the docks with fisherman or in a fish plant with the local processor. Progressive long term planning on the regional and national level has resulted in ongoing program development for educational programming and information transfer on such issues as global climate change, vessel safety, oil spill prevention and preparedness, natural hazard preparedness, water quality, economic development of the marine community and resource conflict resolution. MAS is also beginning to focus on transferring information as appropriate from NOAA/OAR laboratories to managers and resource agency decision-makers.

Introduction

Overall base Federal funding for MAS programs remained within the same general limits of the preceding 5 years, meaning that programs are generally suffering from lack of growth. Many programs have cut what can easily be cut, FTE's have decreased from around 350 to 300, and operational support is stretched. However, matching support continued in an upward trend evident throughout the period. In many cases, States are beginning to take on a larger burden for funding the MAS programs, either through cash support from the legislatures or increasing support for salaries. We are happy to see this as it is one way to ease the fiscal burden facing MAS, and it truly expresses the real partnership that this program embraces in meeting a mixture of national, regional, and local needs.

The Federal funds devoted to MAS in FY 1989 represent 23.6 percent of total appropriated funds. This is consistent with previous years. (Table 1)

Continuing Issues

A. Regional Programs - The regional Sea Grant programs have taken on their own personalities and are functioning well in their own individual ways. The Pacific Sea Grant College Program (PASGAP), for example, encompasses the Sea Grant Programs *in toto* providing a forum for communicators, agents, specialists, directors, and even researchers to focus on issues and topics of general concern. On the Atlantic coast, the Northeast Marine Advisory Council (NEMAC) has formal membership for resource management agencies, cooperative extension, etc., while others are MAS focused. All are providing opportunities for mutual programming, training, cooperation and collaboration, resource sharing, joint workshops and publications.

The Regional Coordinator's role, passed around among individuals in the regions in varying ways, has become very important in maintaining and continuing to build momentum for national efforts. This group worked exceptionally well this year in successfully developing the first National MAS Leaders conference in 7 years. There are other emerging issues with a national focus which may well benefit by forming the Regional Coordinators into an ad hoc planning/dissemination group. Look for this type of opportunity to increase.

B. Four Year Proposal Cycles - This issue got its first trial during the year. Two programs, Florida and North Carolina, developed 4-year proposals this fiscal year, and in truth they did not differ drastically from a 2-year proposal. They contained caveats relating to potentials for staff changes,

Table 1

	Sea Grant Funds	Matching Funds	Total
FY 1984	9,016,595	6,298,500	15,315,095
FY 1985	9,484,467	7,110,190	16,599,657
FY 1986	8,984,478	6,341,659	15,326,137
FY 1987	8,976,723	6,473,179	15,449,902
FY 1988	8,803,479	7,790,102	16,593,581
FY 1989	9,198,314	8,027,654	17,225,968

budget enhancements or reductions, changing resource needs, etc., which are perfectly acceptable – even desirable – in giving the programs the flexibility needed to react to the unforseen over a longer period. The proof of success or failure will come in 4 years when the Program Leaders can assess the effects of the process on administrative effectiveness, documentation of accomplishments, and work load.

In each case, an in-depth site visit was conducted by teams composed of the program monitor, a Sea Grant Review Panel Member, a senior MAS Leader and a Sea Grant Director (in North Carolina) and a state extension Assistant Director (in Florida). I chaired both teams. These were intense field reviews; the teams met all MAS staff for briefings, civic leaders and clientele group leaders, and university administrators and agency cooperators. A long, detailed debriefing and written review were provided which contained what I hope was much more helpful feed-back than that afforded in the regular 1 or 2 year review process. The overall feeling from the affected Sea Grant Directors and Program Leaders has, I think, been quite positive, and their recommendations to their peers seem to suggest an overall satisfaction with the process. We expect nothing more than a brief progress report and additional budget detail for the second biennium, and we also expect several more programs to submit 4-year plans in the next 12 months.

C. Site Visits – Four or five years ago, we instituted a protocol to highlight MAS programs at site visits. Beside the standard presentation, we began to include field trips to selected locations to observe program activities, talk to clientele, and get a "feel" for some resource needs in the state. It worked very well. MAS Programs got well-deserved attention, site visitors enjoyed and learned from the experience (especially Sea Grant Review Panel Members), and it provided more meaningful reviews to the MAS program. In the programs in smaller states, we found we could get good overall perspective in one visit, so these visits had the potential to be repetitive very quickly. In the states with larger geographic areas, only portions of the program could be visited (eg. one agent's area) and repeated visits, but to different areas, would be more meaningful. This protocol has been interrupted by adjustments in the site visit routine in response to economic constraints. Site visits were cut back in size and in some cases occurred in Washington, D.C. rather than in the state. The Sea Grant Review Panel continues to express its interest in the field trips, and I maintain that their importance is high. It is through this process that accomplishments, working relationships, and resource issues are best expressed. It is my intention to keep them a part of site visits as appropriate, perhaps on a less regular basis for the programs in small states and not at all for programs that submit a 4-year proposal and undergo the aforementioned review as part of that process.

MAS Leaders Meeting

The first national meeting of MAS Leaders in 7 years, outside of a Sea Grant Week setting, was held in Portland, Oregon, in July. The agenda

was set by an interactive process involving input from all the Program Leaders through Regional Coordinators. A good discussion was held on such matters as the MAS role in applied research, alternative funding for innovative programs, dealing with conflict, new emerging issues, etc. A final report from the various session committees is pending, but a preliminary evaluation indicated the meeting was successful. I believe the real value is in face-to-face contact, introduction and inclusion of new leadership into the group, and cross-fertilization of ideas and experiences from across the country.

Following the MAS Leaders Meeting, a meeting was held under the joint sponsorship of the Council of Sea Grant Directors and the Extension Committee on Policy, the policy committee of the Cooperative Extension Service. This meeting, the second in what is hoped will be a continuing series, not only explored further administrative relationships between MAS, and CES, but also explored options for expanding programming efforts of mutual benefit. The meeting was well attended by both Sea Grant and CES, and even some non-CES affiliated Sea Grant Programs were active participants, recognizing that the issues-oriented program could be beneficial to them as well. Formal recommendations for ECOP and the Council of Sea Grant Directors which resulted from the meeting are as follows:

1. Hold national marine extension/advisory symposiums in the future.

- These meetings should be held every three to four years.
- The focus of these symposiums should be mutual programming opportunities between Sea Grant and the Cooperative Extension Service.
- A planning committee should be appointed by the leaders of this symposium to initiate planning efforts for the next symposium.

2. Reaffirm recommendations from the 1985 workshop held in Clearwater, Florida.

- Regional networks of Sea Grant Extension/MAS programs are important, and should be encouraged to be a major mechanism for multi-state programming.
- Efforts should be made to include a marine representative on appropriate regional Cooperative Extension committees (i.e., regional Agriculture and Natural Resource program leaders' committees).
- Mechanisms for mutual cooperation and planning between Sea Grant research and Experiment Station research should be developed.

3. Develop an interagency task force with representation from the Cooperative Extension Service and Sea Grant to focus on education about global change.

- Explore cooperation with other groups/institutions with mutual goals.
- Through interaction with Department of Commerce and USDA representatives, ensure that marine outreach efforts are represented on the national Committee on Earth Sciences.
- Formulate a plan and funding alternatives for developing educational opportunities on global change for outreach professionals.

4. Form a joint Sea Grant/Cooperative Extension Service task force to examine organizational and programmatic opportunities to increase funding for marine outreach.

- Define fundable areas of mutual cooperative programming (water quality, economic development, aquaculture, etc.).
- Define sources of funds for these program areas [CES special initiatives (issues), NOAA initiatives, national priorities, etc.].
- Actively pursue funding for these areas.

5. Examine ways to involve the broader academic community in Sea Grant and Cooperative Extension marine outreach and research activities through a cooperative effort between Cooperative Extension and Sea Grant.

6. Explore non-traditional outreach processes between Sea Grant and Cooperative Extension to

serve the needs of clientele in marine biotechnology and other high-technology areas.

7. Develop marketing strategies for marine extension program efforts.

In the coming years, it willbe incumbent upon myself and the Program Leaders to provide continual leadership in pursuing the recommendations from both meetings.

Opportunities for the Future

Like Sea Grant as a whole, MAS recently celebrated its 20th birthday. It is a maturing program which is ready and capable to take on new emerging issues in the next decade--issues that can be very important to the well-being of the nation, even the planet. It is no longer a program whose main function and projected image is the facilitator for local problems and needs "on the docks." That is a role that MAS serves well, and should never eliminate from its mission, but the expertise, motivation, capability and infrastructure are now capable of and actually functioning in leading educational and developmental programs for major national, even international efforts. It is ready to meet opportunities and challenges which we are now or soon will be facing such as: water quality, especially management of non-point source pollution and toxic contaminants; seafood safety, oil spill prevention and preparedness, vessel safety; wetland protection and mitigation; preparedness for natural hazards; management of resource conflicts; and increasing national economic development of marine resources.

Two examples of this include programming in Turtle Excluder Devices (TEDs), an ongoing effort being conducted in a highly charged atmosphere with national visibility, and the beginning of a program in global climate change education.

FY 89 was an explosive year for the TED issue. Federal regulations implementing use of TEDs went into effect for the shrimp fishery throughout the Southeast and Gulf states after being delayed several times amid considerable uncertainty, strife, and even anarchy by some local shrimpers. Despite the charged atmosphere, which even resulted in threats to their personal safety, MAS staff continue to educate the educable fishermen about their options and to transfer information and technical knowledge about the most efficient use of TEDs. They did this knowing that there were no other alternatives to their efforts and that the long-term welfare of the industry depended on efficient use of TED technology. These people, without exception, continued to act professionally and responsively, and when regulations formally did become, effective, responsible people in the industry were, for the most part, prepared. This is an excellent example of MAS' role in resource conflicts--to remain neutral to the arguments but to develop forums for discussion, negotiations and education among the parties. These sorts of issues will become, by necessity, more and more prevalent in MAS activities. Many MAS personnel are beginning some training in conflict resolution, and it is an excellent idea.

Several Program Leaders emerged from our Leaders' meeting in Portland alarmed about the volume of sensationalized news based on half-truths which was/is being circulated for general public consumption about global climate change. This group has responded to the aforementioned meeting recommendation on climate change and developing a proposal for consideration by the Interagency Committee on Earth Sciences and NOAA's Office of Climatic and Atmospheric Research. The proposal would give the group the opportunity to develop a national leadership role in climate change education based on scientifically based information and prediction, including limitations in our knowledge and capabilities. This proposal is a precursor to developing nationwide educational capability at the county/local level through MAS and the Cooperative Extension Service (USDA), and to keep educational materials for this effort complete and current. At this point, we believe the effort has great merit and promise.

Finally, I participated in a program review of the Great Lakes Environmental Laboratory (GLERL), part of NOAA's Environmental Research Laboratories. One thing which was evident was the need for GLERL to further develop its outreach. While it does a good job in transferring information by its own methods such as scientific publications, technical and policy advisory committees to the International Joint Commission, etc., it was obvious that clientele groups and cooperating agencies desired another level of information transfer from the laboratory. Resource

needs in the Great Lakes are many and growing, and the GLERL program is relevant to those needs, but several people in policy and decision-making roles in other agencies said they didn't get information as needed. As a result, we are beginning a dialogue to designate one Sea Grant MAS person as GLERL liaison who will be brought into the GLERL "inner circle" at appropriate times for meetings. Then this individual will see that the Great Lakes MAS network works to disseminate GLERL-based issues and information as these become transferrable. The GLERL Director is eager to try the concept. The issue here is that this need might exist at other ERL laboratories in your regions, and an inquiry from Regional MAS Leadership might prove beneficial

Fishing Vessel Safety Training Program - 1989 Update

Summary

Commercial fishing is one of the most dangerous industries in the United States. On average, 84 fishermen and 250 vessels are lost each year; and the number of injuries and disabilities, and the damage to vessels probably are just as alarming. Each year, the United States Coast Guard responds to approximately 3000 offshore search and rescue cases and investigates 1100 marine casualties involving commercial fishing vessels. Commercial fishing is the only major marine commercial industry for which inspection, licensing, operation, and equipment regulations, other than basic safety equipment, are essentially non-existent.

The United States approach to the fishing vessel safety problem has been to promote the acceptance and use of voluntary safety standards by the industry. In 1989, Sea Grant supported the voluntary safety standards program by making available a variety of multi-media training materials; providing sea survival and vessel safety instruction to fishermen; and providing safety and survival training curricula, materials, and courses for a growing cadre of providers of such instruction. Also, Sea Grant and the National Council of Fishing Vessel Safety and Insurance examined the feasibility of establishing a national network of fishing vessel safety programs.

During the last two years, a much higher level of vessel safety and sea survival programming has been made possible by the Saltonstall-Kennedy (S-K) financial assistance program. Institutions having Sea Grant ties received S-K awards totalling approximately one-half million dollars for establishing or continuing fishing vessel safety programs. Unfortunately, S-K funding priorities no longer include fishing vessel safety education and training programs. Without this funding, the level of effort in response to commercial fishing vessel safety issues may decline sharply, and progress to establish a national network of fishing vessel safety programs will slow considerably.

Background and Introduction

The background information provided in last year's annual report on the fishing vessel safety issue still applies. Despite the efforts of the United States Coast Guard, Sea Grant, and others for over two decades to provide and promote voluntary safety standards for fishing vessels and safety awareness and education programs for vessel crews, casualty data continue to show the industry has the poorest safety record of any industry in the nation. Clearly, short-term solutions to this situation do not exist or have not been found. Sea Grant activities continue to be part of the long-term effort to improve the situation. The goal of Sea Grant's fishing vessel safety and sea survival program is to reduce the loss of life, incident of injury, and loss of property in marine accidents. Progress toward this goal can be made if sufficient numbers of fishermen can be motivated to partake of vessel safety and sea survival education and training opportunities.

Program Status-1989

Approximately half the Sea Grant Marine Advisory Service programs are involved on a regular basis with commercial fishing vessel safety activities. The extent of involvement ranges from one to 30 activities per program per year, with activity being defined as a workshop, seminar, forum, conference, demonstration, publication, development of training materials, etc. The activities are diverse, loosely coordinated, and some may appear to respond to local rather than national needs; but these programs all are in accord with a common purpose - safety - and the sum of the local programs does in fact represent a national program. Increased networking and cooperative programming was observed in 1989.

According to the 1989 Sea Grant Directory, 77 agents and specialists list commercial fishing as a key area of responsibility, and 17 agents and specialists list commercial fishing safety as a key area of responsibility. Many of these individuals are recognized within their state or region as experts in one or more aspects of marine safety; and some individuals are recognized at the national and international levels.

An ad hoc committee of MAS agents and specialists from all Sea Grant regional networks, except the Great Lakes, met in Sitka, Alaska, to discuss the feasibility of establishing a national network of regional fishing vessel safety education programs modelled after the volunteer instructor training program developed by the Alaska Marine Safety Education Association (AMSEA). Although some committee members felt the AMSEA model might not be the best approach to safety problems in their region, the committee concluded that vessel safety programs should be coordinated on a regional basis to be most effective.

The suggested approach was to establish a network of regional committees to coordinate various groups (government agencies, private sector training interests, emergency medical and public safety groups, fishing industry representatives, insurance underwriters, safety equipment manufacturers, marine surveyors, etc.) interested in fishing vessel safety and sea survival education and training. The networks would identify the needs and problems of each region; identify, develop, and share resources to conduct training and educational programs; and collect, distribute, and exchange up-to-date sea survival and safety information. Strong regional networks would be brought together within a loose national framework coordinated by the National Council of Fishing Vessel Safety and Insurance (NCFVSI) and the National Sea Grant College Program. Since regional MAS networks already exist and some MAS programs have fishing vessel safety components, Sea Grant was thought to be the ideal vehicle to organize the aforementioned regional committees.

The committee felt initial efforts to establish a network of regional coordinating committees would require a commitment of one-half FTE per region. The cost of such an effort was estimated to be $50 K per region or $200 - $250 K for four or five regions. The committee recommended that Sea Grant work with the NCFVSI to develop a proposal for Saltonstall-Kennedy (S-K) program funding of this effort. The proposal was not considered for funding because S-K funding priorities for FY 89 did not include fishing vessel safety education and training programs. Next, the NCFVSI tried to incorporate a scaled down version of the networking proposal into an amendment to their existing S-K grant; but that request also was not considered.

As reported in last year's annual report, five institutions having Sea Grant ties received S-K awards totalling approximately one-half million dollars for establishing or continuing commercial fishing vessel safety education and training programs. Additionally, several Sea Grant programs received funds for cooperative projects with the NCFVSI which also operates largely on S-K funds. When the current grants expire, it will be difficult, without an infusion of new money, for the Sea Grant network and other organizations to maintain the same level of effort as in 1989 and previous years on commercial fishing vessel safety issues.

Outlook

Public Law 100-424, the "Commercial Fishing Industry Vessel Safety Act of 1988" was approved in September 1988. The Safety Act requires the Department of Transportation (mainly the United States Coast Guard) to prescribe regulations for the installation, maintenance, and use of mandatory safety equipment on uninspected commercial fishing vessels. The Safety Act also requires the Department of Transportation to examine and report to Congress alternative strategies for improving vessel safety including vessel inspections and the licensing and training of crew. By virtue of the Safety Act and its derivative regulations, a significantly greater number of fishing industry personnel may be motivated to participate in vessel safety and sea survival training opportunities and other programs facilitated by Sea Grant and other providers.

Two formally chartered committees have been established to advise the Department of Transportation, Coast Guard, and Congress with respect to fishing vessel safety. An Advisory Committee is assisting the Department of Transportation and Coast Guard on all matters related to fishing vessel safety and the Safety Act.

Also, the National Research Council's Marine Board has established a national committee to conduct a comprehensive assessment of fishing industry vessel and personnel safety problems and then to identify, develop, and assess alternatives to improve safety. Both committees recognize the expertise, knowledge, and experience Sea Grant personnel have to offer with respect to safety training and education and the commercial fishing industry, and members of the Sea Grant network participate in committee activities. If the Safety Act and its derivative regulations should prove to have a positive effect on fishing vessel casualty statistics in the years to come, chances are that Sea Grant, through its input to these two committees, will deserve some of the credit.

Sea Grant's Marine Advisory Service should remain abreast of the rule-making now taking place in response to the Safety Act. Sea Grant Marine Advisory Service is in a position to assist the fishing industry in understanding and preparing for the changes brought about by the new legislation.

PROJECTS

A. ADVISORY SERVICES

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. MAS Core Programs		
Alaska Marine Advisory Program D.G. Kramer 71 University of Alaska Sea Grant College Program	406,200	77,000
Sea Grant Extension Program E. Skoog 71 University of California Sea Grant College Program	680,557	395,160
Marine Advisory Services and Education J. Fawcett 77 University of Southern California Sea Grant Program	156,766	62,345
Sea Grant Marine Advisory Program N. Bender 73 University of Connecticut Sea Grant Program	135,574	226,605
Marine Advisory Services J.M. Falk 71 Delaware Sea Grant College Program	169,549	142,229
Florida Sea Grant Extension Program J.T. Woeste 77 Florida Sea Grant College Program	507,500	585,300
Advisory Services: General D.R. Amos 77 Georgia Sea Grant College Program	215,700	272,900
A/UG-1 Guam Extension Program B. Smith 71 University of Hawaii Sea Grant College Program	31,063	40,980

Extension Service B.J. Miller 71 University of Hawaii Sea Grant College Program		435,129	250,837
Marine Extension Program R.D. Espeseth 71 Illinios/Indiana Sea Grant Program		96,267	101,772
Marine Advisory Services in Louisiana Cooperative Extension Service J.F. Fowler 71 Louisiana Sea Grant College Program		209,072	498,170
Legal Advisory Service M.W. Wascom 77 Louisiana Sea Grant College Program		76,000	47,630
Ports and Waterways Advisory Service C. Beacham 77 Louisiana Sea Grant College Program		25,249	3,074
Sea Grant Marine Advisory Program B.E. Doyle 73 Maine/New Hampshire Joint Sea Grant College Program		332,000	305,863
Sea Grant Extension Program R. Adkin 73 Maryland Sea Grant College Program		210,000	283,500
MIT Sea Grant Center for Fisheries Engineering Massachusetts Institute of Technology C.A. Goudey 71 Sea Grant College Program		66,800	88,000
MIT Sea Grant/Massachusetts Liaison Service M. Hall-Arber 71 Massachusetts Institute of Tchnology Sea Grant College Program		86,600	0
MIT Sea Grant/Marine Industry Collegium J. Moore 77 Massachusetts Institute of Technology Sea Grant College Program		149,700	94,247
Marine Assistance Service A.W. White 77 Woods Hole Oceanographic Institution Sea Grant Program		106,300	0
Michigan Sea Grant Extension J. Schwartz 71 Michigan Sea Grant College Program		306,969	169,303

Minnesota Sea Grant Extension Program D. Baker 73 Minnesota Sea Grant College Program	209,080	230,070
Special Enrichment Activities in Oceanography for Area Teachers and Students (SEA OATS II) W. Hosking 70 Mississippi/Alabama Sea Grant Consortium	9,027	7,853
Mississippi-Sea Grant Advisory Service Program D. Veal 77 Mississippi/Alabama Sea Grant Consortium	147,789	208,898
New Jersey Sea Grant Marine Advisory Service New Jersey Marine Sciences Consortium Sea Grant Program A. Wypyszinski 77	148,700	205,700
Sea Grant Extension Program M.P. Voiland 77 New York Sea Grant Institute	546,216	1,000,308
Marine Advisory Service J. Murray 71 University of North Carolina Sea Grant College Program	469,412	222,953
Ohio Sea Grant Advisory Service Program J.M. Reutter 71 Ohio Sea Grant College Program	213,859	103,505
Extension/Sea Grant Program B. DeYoung 71 Oregon Sea Grant College Program	645,700	596,900
Marine Advisory Service E. Richardson 77 Rhode Island Sea Grant College Program	204,449	40,625
South Carolina Marine Extension Program M.H. Goodwin 71 South Carolina Sea Grant Consortium	185,200	250,700
Marine Advisory Services G.M. Hightower 71 Texas A&M University Sea Grant College Program	460,847	563,436
Virginia Sea Grant Marine Advisory Services W. DuPaul 71 Virgina Graduate Marine Science Consortium Sea Grant Program	558,756	328,845

Washington Sea Grant Marine Advisory Services M.S. Spranger 71 Washington Sea Grant College Program		602,000	300,400
Fishery Development D.A. Stuiber 71 Wisconsin Sea Grant Institute		48,181	43,433
Advisory Services Coordination and Field Offices A.H. Miller 77 Wisconsin Sea Grant Institute		163,291	153,068
Aquaculture Advisory Services for Great Lakes Fishes F.P. Binkowski 77 Wisconsin Sea Grant Institute		10,332	8,916
UPR Marine Advisory Services for Puerto Rico and the USVI M. Valdes-Pizzini 71 University of Puerto Rico Sea Grant Program		107,600	63,200
Virgin Islands Marine Advisory Services M.L. Coulston /654/ 71 University of Puerto Rico Sea Grant Program		45,600	34,400
	SUBTOTAL:	$9,198,314	$8,027,654
	PASSTHROUGH:	0	

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
2. Special Advisory Initiatives		
Long Island Sound Study Public Education and Participation C. Arnold 75 University of Connecticut Sea Grant Program	0	0
Development of a Pacific Island Extension Network B.J. Miller 73 University of Hawaii Sea Grant College Program	0	0
Second International Conference on Marine Debris J.R. Davidson 74 University of Hawaii Sea Grant College Program	0	0

Preparation of Technology Transfer Documents Based Upon the Corps of Engineers Containment Area Aquaculture Program C.D. Veal 77 Mississippi/Alabama Sea Grant Consortium		0	0
Evaluation of Salinity as a Variable for Use in Habitat Evaluation Procedures (HEP) Applied to Estuarine and Marine Habitats C.D. Veal 77 Mississippi/Alabama Sea Grant Consortium		0	0
A Long Island Sound Public Participation Coordinator Based in New York M.D. Voiland 75 New York Sea Grant Institute		0	0
Assistance with the Technology Transfer and Citizen Monitoring Workshop in New Orleans, Dec 1989 Lee 70 Rhode Island Sea Grant College Program		0	0
Third International Conference on Ciguatera Fish Poisoning University of Puerto Rico Sea Grant Program T.R. Tosteson 74		5,000	0
	SUBTOTAL:	$ 5,000	0
	PASSTHROUGH:	$428,620	

Marine Policy and Social Sciences

Summary

Sea Grant's program in Marine Policy and Social Science is based on the recognition that most resource management issues have sociocultural dimensions and policy implications. Sea Grant Research provides information to help manage marine resources more wisely in concert with local and national concerns, knowledge, and planning capabilities. Marine Policy and Social Sciences draw on many disciplines for methods and theories. In FY 89, total Sea Grant funding for Marine Policy and Social Science was about $2.16 million, slightly less than FY 88. Relative proportions of research in each of the topical areas has shifted slightly over the last two years, with studies in the area of commercial fishing slipping to 26% of the social science and marine policy funding, and policy and resources management studies increasing to about 60% of the Sea Grant funding (see Table II).

Marine policy research accounts for about sixty percent of FY 89 funding. It includes studies on options for managing coastal growth, estuarine governance and planning, identification of areas vulnerable to sea level rise and policy alternatives, and projects on Great Lakes water policies (see Table I). The social sciences emphasize research on aspects of commercial fishing, ranging from sociocultural effects of fishery management regimes, to studies of risk communication regarding contaminated fish. The more traditionally defined social sciences account for about 40% of the total funding in the Marine Policy and Social Sciences Program. Underrepresented are social and political aspects of aquaculture development, biotechnology, and coastal growth; coastal archaeology; and micro and macro structural changes in the fishing industry.

Introduction

Marine policy and social science research in the National Sea Grant College Program accounts for 6.3% of Sea Grant research funds and 6.7% of the total matched Sea Grant effort. Dollar value of Sea Grant support (in 1989 dollars) is $997,464 (Table I). Matching support is $936,229. Pass-through funding amounts to $226,000 from the Department of Interior for aquaculture development in the insular Pacific. Marine Policy and social science work is multidisciplinary in nature and shares theory or methods with economics, law, recreation and tourism, marine transportation, ports, and environmental studies. As a result some projects are included in more than one subject area report. Trends in funding are difficult to identify reliably, but the general level and direction are clear.

As used in this report, social science research includes projects which focus on human social behavior, cultural values and attitudes, human organizations and political behavior. Social sciences use survey, interview, and ethnographic methods to collect data, and while each discipline has different theories to explain the patterns and processes observed, all social science disciplines seek to explain and predict why people and their institutions behave as they do. Social science research provides a window on the human factors which are an integral part of most Sea Grant research areas -- from the adoption of new crab shed filtering systems and fuel-efficient workboat engines, port expansion, to concerns and attitudes of saltwater anglers -- all of these areas involve human behavior in some way. Social science helps explain whether the new innovations will be adopted, describes people's attitudes toward them, identifies what policy decisions will be faced, what political response is likely, what population shifts are imminent, how it can be financed, and what happened when we tried a particular program (evaluation).

Marine policy, although it is a recognized field in itself, draws on the work of many disciplines, from law and political science to public administration, social science, and marine

economics. It is concerned with answering questions about how we can best manage our marine and coastal resources, such as EEZ resources, wetlands, and estuaries. Other issues addressed are the proper federal/state/local government roles for managing marine resources -- critical questions in federalism and intergovernmental relations with respect to managing coastal growth or resources in the EEZ.

Since Sea Grant first started tracking the number of social science and marine policy projects in 1980, the number of projects has recovered from a nadir of 40 projects in 1984 to a high of 84 projects in 86. In FY 89 there appears to be about the same level of funding in social science and marine policy as in 1987. Again one must use caution in interpreting these figures because of the interdisciplinary nature of many projects and problems of categorizing them into specific disciplinary niches.

Social Science and Marine Policy Developments - FY 89

Several actions in fiscal year 1989 provide opportunities for social science and marine policy research activities. There is an emerging realization of the need for research on the social, cultural and policy aspects of resource management, including economic development along our coasts, and sociocultural feasibility studies of new technology such as aquaculture and biotechnology.

In the following paragraphs, some of the FY 89 developments in social sciences and marine policy are identified.

To begin with, the Arctic Research and Policy Act of 1984 (ARPA) calls for federal agencies to establish a comprehensive plan for Arctic research. While the Plan originally focused on research in the natural sciences and engineering, the final plan includes a strong section on the need for social science research. Additionally, the Polar Research Board of the National Academy of Sciences has established an ad hoc Social Sciences Committee to investigate the needs for research on Arctic problems. In FY 89 the Committee released its report, *Arctic Social Science. An Agenda for Action* (Committee on Arctic Social Sciences, Polar Research Board, National Research Council). The report identifies three areas where social science research is needed: (a) human/environmental relationships, (b) community viability, and (c) rapid social change. As a result of the report and the activities of an intergovernmental task force on Arctic social sciences, the National Science Foundation has created a position for Social Science Program Director within the Division of Polar Programs and has hired a social scientist to fill that position.

In the area of marine social sciences, the Mississippi-Alabama Sea Grant Consortium published and released the proceedings of a conference organized by Stephen Thomas, Lee Maril and Paul Durrenberger. The volume is titled *Marine Resource Utilization, A conference on Social Science Issues*. The volume has wide-ranging chapters on marine resources, but the majority are on fishing, fishing communities or fisheries management. They cover topics from work fleet formation among Alabama shrimpers, to social impacts of fishery management, to the political ecology of fishing. The proceedings are available from the Mississippi-Alabama Sea Grant Consortium (MASSGP-88-039).

As a result of a panel organized by Fritz Schuler and myself at the Second Symposium for the Social Sciences in Natural Resource Management June 1988, we have been editing and writing for a special issue of *Ocean and Shoreline Management*, which will appear in April 1990. Papers were presented by Sea Grant investigators across a wide range of types of resources and disciplines. Each of the papers deals with aspects of human reactions to marine resource change -- whether on an institutional or behavioral level. The resulting special issue will be titled "Responses to Marine Resource Change: Perspectives from the Social Sciences." It will be published as Vol. 13, #3, in April 1990.

During FY 1989, I was fortunate to have a summer intern, Robert Blinkoff, a graduate student in the Applied Anthropology Master's Program at University of Kentucky. The purpose of the internship and the project was to review the Sea Grant-sponsored social science work (excluding economics) on commercial fisheries. After almost 20 years of funding, we wanted to assess what has been contributed to theory, concepts, and practical application of the research; i.e. where social sciences have made a difference.

TABLE I

SOCIAL SCIENCE & POLICY FUNDING BY RESEARCH AREA

Total funds, including Federal
Sea Grant $, Match and Pass-Through

	FY 86	FY 87	FY 88	FY 89
Commercial Fishing	$ 390 / 30 %	$ 532 / 31 %	$ 579 / 25%	$ 568 / 26 %
Recreation and Tourism	$ 135 / 10 %	$ 216 / 13 %	$ 184 / 8%	$ 266 / 12 %
Ports, Maritime Industry	$ 150 / 12 %	$ 58 / 3.4%	$ 122 / 5%	$ 23 / 1 %
Archaeology	$ 25 / 2 %	$ -0- %	$ -0- %	$ 24 / 1 %
Policy and Resource Management	$ 607 / 47 %	$ 888 / 52 %	$1,395 / 61%	$1,280 / 59 %
Valuation	$ 22 / 1.7	NA	NA	NA
Total	$1,328/ 102.7%*	$1,696/ 99.4%*	$2,280/99.4 %*	$2,159,693/99%*

*Due to rounding

Mr. Blinkoff used library archives, in-house publications, and NMFS resources through the help of Peter Fricke. He also interviewed a sample of researchers to get their first-hand insights on these topics. The review was very successful and will be drafted into a report primarily for lay audiences this year.

Because of the nature of extension work, there are many overlaps with social sciences. A marine agent needs to be able to understand the community and identify leaders, to recognize different value systems within it, to be able to work with various cliques or subgroups within it. In order to highlight the pros and cons, I organized a session at The Society for Applied Anthropology to elaborate on the usefulness and disadvantages of the social science perspective for marine extension. Participants were Bonnie McCay, Manuel Valdes-Pizzini, Madeleine Hall-Arber, Chris DeWees and Jeff Johnson. The papers given at the session will result in a special issue of *Practicing Anthropology*, to appear in October 1990. I am in the process of editing and writing during this year.

A conference on "Values and the American Ocean" was held in Santa Barbara, CA in June of 1989. This conference sought to understand ocean policy from an eclectic perspective, using the disciplinary frameworks of historians, lawyers, policy scientists, anthropologists, and philosophers. The conference was organized by Biliana Cicin-Sain and Bob Knecht, and sponsored by the UCSB and several Sea Grant programs. The conference sought to stimulate thinking about a new framework for ocean governance, moving away from the resource-specific legislative mandates for ocean resources, and the unwieldy federal - state division of responsibilities. The conference was a call to re-think those parameters.

During FY 89 an MMS Committee to Review the OCS Environmental Studies Program has been initiated. The Committee has three panels,

one of which is on socioeconomics and is headed by Garry Brewer (Yale). The purpose of the panel is to review the adequacy of socioeconomic data for making OCS decisions -- that is, whether the quality of the scientific information would pass peer review. The committee's final report is expected toward the end of 1990.

Simultaneously the President's OCS Task Force asked the National Academy of Sciences to review the data for lease sales off California and Florida. The committee concluded that the socioeconomic data were by the far the most marginal: that the data were "inadequate" and "doubtful" for making decisions about lease sales on those three areas.

Research Topics

For purposes of discussion in this report, marine policy and social science projects are divided into five areas or clusters of research activity. These topical areas are (1) recreation and tourism, (2) commercial fisheries, (3) ports and maritime transportation, (4) marine resource management -- policy and governance, and (5) archaeology.

Recreation and Tourism

Recreational Fishing. Studies of recreational fishing seek to understand the diversity, extent, and attitudes of recreationalists on the nation's coasts, bays and Great Lakes. Most of the studies seek to understand recreational behavior in order to build predictive models of participation or to suggest methods of communication that would be useful to state and local planning efforts. The one FY 89 social science project in recreational fishing seeks to identify recreational fishing practices in Hawaii and the sociodemographics, perceptions and motivations associated with these practices. The purpose is to test whether degree of recreational fishing specialization reflects fishing pressure on popular species.

Tourism and other Recreation. Tourism research focuses on aspects of tourism such as risk management, how economic development articulates with tourism, or understanding the behavioral or attitudinal aspects of tourism. Projects in this area seek to understand motivation and behavior of tourists or attitude shifts as a result of tourism behavior. Insurance for recreational industries is an important topic, given the dramatically rising insurance premiums for small businesses. The project by Rose Pfund examines the risk management practices of tourism-related recreation industries. The project includes workshops with local recreation industries and insurance companies. In 1989, the PI developed and conducted a survey of over 900 ocean recreation businesses. The comprehensive survey covered types of insurance, legal counsel, employee training, property maintenance, and fleet liability practices of these businesses. The results of the survey will be used to assist small recreational businesses to develop better risk policies and practices. There is one diving-related project which seeks to understand and predict panic behavior in scuba divers.

Florida shorelines are subject to increasing development pressures that threaten their recreational and tourism appeal. One project will develop a geographic information system (GIS) which will contain ecological information for an environmental planning inventory to use in local government planning. This would allow planners to perceive both regional and local trends and conditions.

Commercial Fisheries

There are nine projects that fall in the general area of commercial fisheries, and they are discussed in the five subcategories below.

Sociocultural, Political and Historical. This research area has traditionally been an area of concentration for anthropologists, but many of the projects are multidisciplinary efforts with economics, sociology, or history. There are two projects here. One project addresses the responses of the spiny lobster fishery in the Florida Keys to development pressures. It focuses on factors that affect fishermen's ability or inability to unite in their opposition to local planning vectors. The other project examines the social structure of the surf clam and ocean quahog fisheries of New Jersey and in the industry's transformation under increasingly privatized fisheries management. An interesting finding to date is the extent of consultation of the industry by the Mid-Atlantic Fishery Management Council. The Council, in effect, contracts the decisions to industry.

Fisheries Management. The three research projects in this subcategory focus more on the process and effects of fishery management policies than on the fishermen themselves. One project will develop a software package for fisheries managers and scientists that will allow an assessment of uncertainty in fisheries management data. Another project will assess institutional the viability of "adaptive management" approach to resource management. Adaptive management treats implementation (management) as an experiment to gain more information. It is thus an objective itself of management. Its use in salmonid enhancement, land use planning, and in forest management (timber) will be assessed.

Aquaculture. Most social science efforts in aquaculture investigate economic aspects of fish farming, for example the economics of private planting of oyster grounds. The project included in this report is primarily extension, but has some social and policy work as part of a larger program to develop aquaculture centers in Oceania, funded by the Department of Interior. The project includes program planning and policy efforts to develop a plan for aquaculture interests including an extension effort to transfer knowledge and training for fresh water prawns to Palauans. The project implicitly includes culture and cultural attitudes as part of the extension effort.

Fisheries Development. There are two projects in this area. One investigates the effects of social networks, geography, and consumer knowledge on seafood consumption. The purpose it to understand better how consumers learn about seafood and what influences their choices, particularly with regard to analog products like surimi. The other project will identify distribution channels for seafoods in general, with a focus on Pacific Northwest seafoods. The project will look at the network of wholesalers and retailers and their pricing strategies en route to the end consumer. The information will be useful to harvesting and processing entrepreneurs who want to improve their market position.

Public Health. There is increasing concern over seafood safety and surveillance among the general public and in Congress. The National Marine Fisheries Service (NMFS) has been asked to do a feasibility study of mandatory seafood inspection and standards. Yet we have only one project in this area. The purpose is to find out what factors influence people's perceptions of risk with regard to chemically contaminated fish in the Great Lakes. The expectation is to improve the communication of risk to user populations.

Ports, Marine Transportation, Maritime Industry

World trade has doubled since 1970 and is an increasing percentage of our GNP. The number of projects in this area has declined, but the topic is a vital one. There is only one project in this area, and it deals with cargo preference and government export promotion as it applies to shipping in the Great Lakes.

Marine Resources – Policy and Governance.

Much of Sea Grant's marine policy work falls into the general area of resource management -- the oceans, coastal resources, or Great Lakes. From a policy and governance perspective, the research asks questions such as what are the most appropriate legal regimes for ocean resources? What has been our experience with governance systems for estuaries? What are model wetlands ordinances? Within the general area of resource management policy, there are three major sub-concentrations: estuaries, wetlands and coastal management; ocean policy and water policy; and non-living resources.

Estuaries, Wetlands, and Coastal Zone. The use of the term "governance" to describe systems of institutions, laws, and activities of interest groups or political factors that are often intergovernmental, multi-state and multi-resource is becoming more widespread. Sea Grant pioneered the use of the concept with the Washington Sea Grant Book *Governing Puget Sound (R.L. Bish, 1982).* The University of Rhode Island is approaching the problem of estuarine governance using comparative data from estuaries across the U.S. They will analyze water quality trends and governance patterns across multiple estuaries to provide broadly based data on estuarine management. Hennessey and Robadue have found that estuarine issues get on the political agenda because of key "focusing events" in the public eye, rather than gaining visibility via scientists' research or resource managers' appeals. They found in

general very little enforcement or evaluation of compliance with permitting or court orders; and little information on the effect of governance regimes on physical quality parameters in estuaries. An important issue in public management deals with questions of federalism, or federal-state relationships in the management of natural resources. Several related projects are pushing our knowledge forward in these areas: the project by Reiser examines federal-state relations in managing coastal growth in selected states. The project compares state growth management and regulations that range from minimal state oversight to incentive/threat systems, to intense state oversight of permitting and development in coastal growth.

A new project to compile an estuarine planning handbook has been initiated by the Florida Sea Grant Program. Local and regional plans for estuarine management programs have been mandated, and this project responds to the needs of local/regional governments for assistance in developing the plans.

One innovative, experimental project in coordination with a State resource agency, trains volunteers to monitor water quality of coastal ponds. It began under the leadership of Virginia Lee at the University of Rhode Island, and has been so successful that neighboring states developed a similar project, and a national conference was held this spring in environmental monitoring efforts from across the U.S. The Woods Hole Oceanographic Institute (WHOI) has initiated a program modeled on the efforts of the original salt pond monitoring project.

The project by Gary Yohe will identify specific areas along the Connecticut shoreline that are vulnerable to sea level rise. It will catalogue the possible social, political and economic responses to that vulnerability. During the second year of funding the investigators plan to explore sets of policy options via a series of meetings with town leaders.

Littering is a management problem in our coastal areas. Sea Grant is an active player in designing educational material and programs to decrease the amount of debris in our coastal areas. The project by Shirley Laska will survey Louisiana residents to identify the attitudinal bases of the littering problem across demographic subsets. This information will be useful in designing educational campaigns and targeting specific audiences.

Ocean Policy/Water Policy. Projects in this area address issues of federalism in the EEZ and ocean management regimes which facilitate interagency and multiparty conflict resolution in the territorial sea and EEZ. The Law of the Sea Institute at the University of Hawaii holds a major international conference concentrating on unresolved or emerging issues surrounding the Law of the Sea. The Sea Grant Marine Policy Fellowship offered by the North Carolina Sea Grant program offers stipend and tuition for a student in the social sciences, specializing in marine policy.

There are two projects on Great Lakes water policy and issues: Water diversion policies and consumptive uses of Great Lakes water. The consumptive use project analyzed consumptive uses of Great Lakes water by industry, residents and other users, and projected impacts under various future scenarios by using a hydraulic regulatory model. The results are being used by the Wisconsin Department of Natural Resources and the International Joint Commission. The state water diversion project compares policies across states for consistency and to evaluate their effectiveness. The PI also examined potential methods of averting water diversions through conservation, water pricing and/or recycling of water supplies.

We are funding one biotechnology policy project. Sagoff will investigate whether we can assess risks or regulate DNA organisms/products in marine environments under current legal and normative regimes. Finally, the Mississippi-Alabama Legal Program is included here because much of their work, such as analysis of the public trust doctrine or the planning, regulatory and liability issues surrounding artificial reefs contributes to the debate on ocean and coastal policy issues.

Non-living Resources. Projects in this category address the policy and societal implications of mineral resources in the EEZ or in territorial seas. There are no projects in this area in FY 89.

Archaeology

There are two archaeology projects funded in FY 89. The project on the Columbia River will add to our knowledge of the complexity of Lower Chinookan culture by comparing riverine and estuarine sites which are functionally and ecologically distinct. It will also provide baseline information about wildlife species distribution. The other project is not listed but the University of Rhode Island Sea Grant Program funded Dr. Kevin McBride to radiocarbon date three samples from a site on Block Island, Rhode Island. He is conducting research into the island's unique maritime adaptation. The site is also important because it represents Eastern Woodland culture just prior to the introduction of maize horticulture in the region.

Trends and Opportunities

The output of Sea Grant research is part of the dynamic work of planning, managing and evaluating natural resources management. Se Grant researchers both study and influence the way federal, state and local managers plan, manage and evaluate resource management.

The following paragraphs outline areas in addition to those mentioned in the introductory section where there are timely opportunities for social and policy sciences. Commercial fisheries is an area of continuing interest. With the depletion of many fishery stocks, the jeopardy of many watermen and baymen's livelihood due to natural disasters, and/or depletion of shellfish populations, the interest in "limited entry" management regimes, and the growing criticism of the current fishery management system, there are more than enough problems and issues to keep social scientists and marine policy researchers busy for the next two decades.

The sociocultural acceptance and political economy of aquaculture is an area which has been neglected in the U.S. Apart from economics, the social science and policy funding has been a negligible part of Sea Grant funding for aquaculture but there are many questions to be addressed here. From the policy end, we need to know the variety of coastal zone permits, laws and other requirements (state and federal) that inhibit or encourage aquaculture. Attention needs to be paid to solutions to the apparently discouraging web of permits and licenses and variations by state. It has been said that the technology for aquaculture has been developed (for at least several species), but what holds aquaculture back are the social and cultural constraints. These attitudes, beliefs, behaviors need to be identified before they can be addressed. Additionally there are questions of access to land and capital and management skills. The demographics of culturing genetically engineered animals may mean a new sociopolitical look to commercial fishing. We need to assess the likely effects of the technology of aquaculture. Is the infrastructure for the aquaculture industry available to support its growth? What are the business, social, or cultural constraints that prevent more widespread adoption of this farming method? What is the role of consumer belief system in the growth of aquaculture?

EEZ and resource extraction studies are important. The fact that mineral extraction does not seem economically feasible for another 20 years affects the salience of the topic. But by the same token, this is the time to address the policy issue of governance and management of EEZ resources. The University of Washington's Institute for Marine studies has identified legal constraints to resolution of multiple use issues in the EEZ. They plan to assess lessons to be learned from other areas of natural resource management in order to design better legal frameworks for interagency and multiparty conflicts. Some mineral resources are relatively near shore and are more economically feasible to extract: sand and gravel, and placers with precious metals. How would mining of these resources affect local communities on-shore, either through the processing facilities or through transportation terminals developed in the communities. Social science has contributed a great deal to the understanding of the "boom and bust" cycle of mining development. These methods and findings can now be applied to communities where large-scale processing facilities would be located or communities which would provide the auxiliary services necessary for offshore mining.

Seafood consumption and inspection. The development of new seafood hybrids such as hybrid striped bass or triploids (e.g. oysters) raises questions about product acceptance, substitutability and consumer perceptions regarding seafood. If

Chesapeake oysters, for example, were no longer available, would consumers know the difference if another variant or hybrid were for sale instead? Would they care? What about new species like tilapia? There is little reliable information on perceptions and attitudes toward seafoods.

During the last Congress three fish inspection bills were introduced. Some people feel seafood inspection is imminent. If a program were to be implemented, how would it affect different segments of the fishing community? How should it be financed? As mentioned previously, one project will look at pricing and market distribution channels in the Pacific Northwest. But there are other related issues that should be identified: regionalization of processing, labor markets, and distribution. On the Eastern seaboard, there have been significant changes in labor force for processing oysters and crabs. What do these changes mean for the fishermen, the industry, the consumer?

Coastal archaeology and paleoarchaeology are an important area for specialized research. Scientists are trying to understand processes currently affecting estuaries. Are the processes such as siltation and decreasing freshwater inflow cyclical over long periods of time: Have they occurred before, and if so, what happened to the fauna? What has been the past abundance of various species, and how has man's use of them changed over time? Full understanding of estuarine problems needs an historical and archaeological approach, and archaeology can provide important data for interpreting current estuarine processes. In addition, the specter of climate change looms over the globe. The relationship between climate and culture change in the past can give us insight into the future changes.

Our appreciation of the importance of wetlands and estuaries as integral parts of the ecological system has reached a high point. Scientists are studying the physical and chemical processes that maintain healthy estuaries; and social scientists are increasingly studying the governance patterns that encourage healthy estuaries and the socioeconomic impacts of the changing productivity of estuaries. The University of Rhode Island researchers are comparing several estuaries across the U.S. in terms of successful governance efforts. This is an area which could use much more attention, however. Our understanding of the groups who use wetlands -- particularly those who use wetlands for subsistence -- the local ordinances which affect them, and how to work with local groups or industry to mitigate the destruction of wetlands can use greater research. In addition, state resource managers and others have called for a broader understanding of estuarine physical changes. That is, the nitrogen, phosphorus, silt, and organic compounds that are tagged as culprits enter the estuaries largely because of humans' use of land surrounding the basin. By understanding the systematic changes in land use around estuaries, and the types of chemical or geologic phenomena that accompany it, we will be able to predict land use and runoff changes in estuaries for the future. An understanding of land use changes and demographic patterns associated with development around estuaries is essential.

Sea Grant legislation, the National Environmental Protection Act, the Coastal Zone Management Act, and the Fisheries Conservation and Management Act all mandate the use of social and cultural data as elements in making decisions regarding natural resources. Relatively limited attention has been paid to this mandate, in part because of the perception that social sciences are "soft," because of the difficulty of collecting good data, and because data bases have not been developed. The Sea Grant program can be a leader in addressing this need.

PROJECTS

SOCIAL SCIENCE & MARINE POLICY

A. Recreation and Tourism

1. Recreational Fishing:

TITLE/INVEST./INST.		FEDERAL FUNDS	MATCHING FUNDS
Recreational Fishing Practices J. Auyong 06 University of Hawaii Sea Grant College Program		16,449	43,912
	SUBTOTAL:	$ 16,449	$ 43,912
	PASSTHROUGH:	0	

2. Tourism and Other Recreation:

TITLE/INVEST./INST.		FEDERAL FUNDS	MATCHING FUNDS
Risk Management for Recreation R. Pfund 19 University of Hawaii Sea Grant College Program		13,392	17,946
Prediction and Prevention of Panic Behavior in Scuba Divers W.P. Morgan 32 Wisconsin Sea Grant Institute		51,445	15,463
A Computer-Directed Geographic Coastal Use Classification System for Ecologic Planning: The Case of the Florida Keys G.A. Antonini 38 Florida Sea Grant College Program		43,100	47,800
Demand for Resource-Based Tourism in Northern Minnesota T.D. Graham 19 Minnesota Sea Grant College Program		12,810	3,220
	SUBTOTAL:	$ 120,747	$ 84,429
	PASSTHROUGH:	0	

B. Commercial Fisheries

1. Sociocultural, Political, Historical:

TITLE/INVES./INTS.		FEDERAL FUNDS	MATCHING FUNDS
Predicting Change and Maintaining Productivity in a Fishery Transformed by Real Estate Development and Tourism S.K. Meltzoff 20 Florida Sea Grant College Program		36,900	18,400
Social and Cultural Responses to Regulation in the Surf Clam and Ocean Quahog Fisheries B. McCay 20 New Jersey Marine Sciences Consortium Sea Grant Program		6,400	7,600
	SUBTOTAL:	$ 43,300	$ 26,000
	PASSTHROUGH:	0	

2. Fisheries Management

TITLE/INVEST./INTS.		FEDERAL FUNDS	MATCHING FUNDS
Global Economic Change, U.S./Foreign Tuna Industry H.N. Scheiber 20 University of California Sea Grant College Program		6,590	13,204
Managing Adaptively: Early Experience in Western North America K.R. Lee 20 Washington Sea Grant College Program		60,000	40,300
Techniques For Dealing with Uncertainty in Fisheries Management Information J.M. Hoening 70 Florida Sea Grant College Program		30,500	15,200
	SUBTOTAL:	$ 97,090	$ 68,704
	PASSTHROUGH:	0	

3. Aquaculture

TITLE/INVEST./INST.		FEDERAL FUNDS	MATCHING FUNDS
Strengthening Aquaculture* Development in Insular Pacific Communities J.R. Davidson University of Hawaii Sea Grant College Program	04	($226,00)	0
	SUBTOTAL:	0	0
	PASSTHROUGH:	$ 226,000	

4. Fisheries Development

TITLE/INVEST./INST.		FEDERAL FUNDS	MATCHING FUNDS
Social and Cultural Dimensions of Consumer Knowledge Among Seafood Consumers: Consumer Education Implications D. Griffith University of North Carolina Sea Grant College Program	29	13,459	8,932
An Analysis of Market Channels for Pacific Coast Salmon and Groundfish R.S. Johnston Oregon Sea Grant College Program	14	30,400	29,200
	SUBTOTAL:	$ 43,859	$ 38,132
	PASSTHROUGH:	0	

5. Public Health

TITLE/INVEST./INST.		FEDERAL FUNDS	MATCHING FUNDS
Risk Perception and Communication Regarding Chemically Contaminated Fish in Lake Ontario B.A. Knuth New York Sea Grant Institute	29	9,523	15,474
	SUBTOTAL:	$ 9,523	$ 15,474
	PASSTHROUGH:	0	

C. Ports, Marine Transportation, Maritime Industry

TITLE/INVEST./INST.		FEDERAL FUNDS	MATCHING FUNDS
Cargo Preference and Government Export Promotion: Policy Implications for the Great Lakes Shipping in the Port of Duluth C.F. Runge Minnesota Sea Grant College Program	14	17,080	$ 5,670
	SUBTOTAL:	$ 17,080	$ 5,670
	PASSTHROUGH:	0	

D. Marine Resources-Policy & Governance

1. Estuaries, Wetlands & Coastal Zone:

TITLE/INVEST./INST.		FEDERAL FUNDS	MATCHING FUNDS
Estuarine Planning Handbook D.D. Barile Florida Sea Grant College Program	70	16,000	13,300
The Attitude Basis of Marine/Coastal Litter: Assessing Louisiana Coastal Users' Attitudes Toward the Environment S.B. Laska Louisiana Sea Grant College Program	20	13,678	30,005
Growth Management in Coastal Communities: Laws, Policies, and Intergovernmental Arrangements to Ensure Balanced Development A. Reiser Maine/New Hampshire Joint Sea Grant College Program	38	15,000	4,691
Citizens' Monitoring of Water Quality in Coastal Ponds A.W. White Woods Hole Oceanographic Institution Sea Grant Program	38	18,400	11,800
Applied Research Projects for Marine Resource Management Graduate Students J. Gonor Oregon Sea Grant College Program	62	49,900	28,600
Socio-Economic Assessment of Compliance with Estuarine Governance Programs J. Sutinen Rhode Island Sea Grant College Program	20	32,564	43,615

Coastal Resources Center V. Lee 39 Rhode Island Sea Grant College Program		57,487	89,110
The Governance of Estuaries: A Comparative Analysis of Institutions, Public Policy Formulation and Implementation in Six U.S. T. Hennessey 40 Rhode Island Sea Grant College Program		36,356	51,148
Comparison of Trends in Conditions and use of U.S. Estuaries V. Lee 40 Rhode Island Sea Grant College Program		97,053	48,338
Models of Water Quality Governance and the Puget Sound Experience T.M. Leschine 20 Washington Sea Grant College Program		29,400	14,800
Toward the Development of Probabilistic Scenarios of Sealevel Vulnerability Along the Connecticut Shoreline G.W. Yohe 38 University of Connecticut Sea Grant Program		21,337	18,723
	SUBTOTAL:	387,175	354,130
	PASSTHROUGH:	0	

2. Ocean Policy & Water Policy

TITLE/INVEST./INST.	FEDERAL FUNDS	MATCHING FUNDS
Law of the Sea Institute J.P. Craven 16 University of Hawaii Sea Grant College Program	22,075	67,525
An Analysis of Normative & Conceptual Issues in the Regulation of Biotechnology in the Nation's Bays and Estuaries M. Sagoff 20 Maryland Sea Grant College Program	24,800	11,700
An Analysis of Great Lakes States; Water Diversion Policies and Their Implication for Development and the Environment K.W. Easter 14 Minnesota Sea Grant College Program	22,510	7,370

Mississippi-Alabama Sea Grant Legal Program R.J. McLaughlin 15 Mississippi/Alabama Sea Grant Consortium	47,038	101,414
Sea Grant Marine Policy Fellowship W. Queen 70 University of North Carolina Sea Grant College Program	11,875	0
Consumptive Use of Great Lakes Water E.F. Joeres 20 Wisconsin Sea Grant Institute	70,819	17,421
Management Models of Wetland Wastewater Treatment B. Finney 46 University of California Sea Grant College Program	12,479	23,680
Teacher Awareness of Great Lakes Issues R.W. Fortner 70 Ohio Sea Grant College Program	36,545	61,168
SUBTOTAL:	$ 248,141	$ 290,278
PASSTHROUGH:	0	

3. Non-living Resources

SUBTOTAL:	$ 0	$ 0
PASS-THROUGH:		0

4. Archaeology

TITLE/INVEST./INST.	FEDERAL FUNDS	MATCHING FUNDS
Aboriginal Exploitation of Marine Estuarine Environments: A Thousand-Year Perspective from the Mouth of the Columbia River R. Minor 29 Oregon Sea Grant College Program	14,100	9,500
SUBTOTAL:	$ 12,100	$ 9,500
PASSTHROUGH:	0	
GRAND TOTAL	$ 997,464	$ 936,229
PASSTHROUGH:	$ 226,000	

Ocean and Coastal Law

Summary

Total funding for legal programs and projects in FY 89 decreased significantly from the FY 88 level of $915K and the FY 87 level of $1.1M. Federal funding amounted to $255K compared to $317K in FY 88 and $481K in FY 87; matching funds were $344K versus $598K in FY 88 and $624K in FY 87. However, the decrease in matching funds was attributable to a sizeable reduction in the large overmatch provided by the University of Hawaii's Law of the Sea Institute in FY 88, which accounted for almost half the matching funds that year.

Introduction

Over 80 percent of the federal funding for the legal program supports three major on-going programs. These three programs are:

The Oregon Legal Program

The University of Oregon program is the most comprehensive program funded by Sea Grant, combining specific research projects, education, and advisory services. Major research efforts funded during FY 89 focused on state management of ocean resources and areas and expansion of regional efforts. In addition, the *Federal Fisheries Management Guidebook* was further updated and publication of the *Ocean Law Memo* continued. The Ocean and Coastal Law Center continued to provide professional education and operate the specialized marine law library.

The Mississippi-Alabama Legal Program

This program is similar to the program at the University of Oregon in the extent of the interaction between research and advisory services. Although less integrated into a law school, program attorney offices are located at the University of Mississippi Law School and the attorneys have access to its faculty, students, and facilities. The attorneys are not faculty members and do not provide course offerings such as those at the University of Oregon. Educational benefits are by-products of work on research projects or the newsletter *Water Log.*

Research efforts during the fiscal year continued on the legal feasibility of wetland "mitigation banking"; the *Phillips Petroleum vs Mississippi* case; and the legal impediments to municipal oyster reefs. The program continued to publish the quarterly newsletter *Water Log* and perform a variety of outreach activities.

The Louisiana Legal Advisory Program

The Louisiana Program is oriented more strongly than the two other legal programs toward providing advisory services, although law students at Louisiana State are used as research assistants and do receive resulting educational benefits. The program responds to requests from the legislature, executive agencies, and user and interest groups, particularly with respect to fisheries issues and legal problems affecting fishermen. The result of more sustained research efforts appear in the newsletter *Louisiana Coastal Law.* The annual "Legislative Issue" summarizes recent State legislative activity affecting the environment, particularly the marine environment, under the subheadings Wildlife and Fisheries; Oil, Gas, and Minerals; Ports, Harbors, and Waterways; Pesticides; Environment/DEQ; and Other.

Other Legal Projects

Sea Grant supported two other specific projects. The first of these was the 23rd Conference of the Law of the Sea Institute which Sea Grant has supported annually on a modest basis for over ten years. This year the Conference, held in the Netherlands, was devoted to implementation of the Law of the Sea Convention through international organizations. It examined the role of such organizations in the areas of navigation, management of living marine resources, research, and protection of the marine environment.

The other project funded by Sea Grant during FY 89 was a continuation of a project started during FY 88 at the University of Maine Law School concerning growth management techniques for coastal zone management.

PROJECTS

1. Ocean Law -- Coastal

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
Mississippi-Alabama Sea Grant Legal Program R.J. McLaughlin 15 Mississippi/Alabama Sea Grant Consortium		47,038	101,414
Legal Research, Education, and Advisory Services for State Ocean Resource Managers and Users R.G. Hildreth 15 Oregon Sea Grant College Program		92,900	117,400
	SUBTOTAL:	$ 139,938	$ 218,814
	PASSTHROUGH:	0	

2. Ocean Law -- International

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
Law of the Sea Institute J.P. Craven 16 University of Hawaii Sea Grant College Program		22,075	67,525
Analysis of the New International Law of Fisheries W.T. Burke 16 Washington Sea Grant College Program		34,500	54,000
	SUBTOTAL:	$ 56,575	$ 121,525
	PASSTHROUGH:	151,100	

3. Ocean Law -- (Other)

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
		0	0
	SUBTOTAL:	0	0
	PASSTHROUGH:	0	
	GRAND TOTAL	$ 196,513	$ 340,339
	PASSTHROUGH	$ 151,100	

Division of Non-Living Resources

This Division serves as the focus for those National Sea Grant College Program activities which address non-living resources. The division supports research projects in areas of resource reconnaissance, physical, chemical, and geological processes in the hydrosphere and geosphere, technology development, environmental concerns, and socio- economic and legal issues. The goal is to develop improved capabilities for more effective utilization of non-living resources and development of new resource areas.

Program emphasis in coastal processes was on quantitative studies of water motion and the resulting sediment movement, with secondary emphasis on tidal inlets and coastal structures. The Marine Geological Resources area is strongly supportive of national efforts to conserve, develop and utilize resources in the EEZ, including sand and gravel, heavy mineral placers, manganese compounds, and hydrocarbons.

Authors

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Coastal and Ocean Processes

Summary

Coastal and Ocean Processes research and development are conducted in the following five broad areas, with the number of FY89 projects and the total funds expended in each area parenthesized: sediment transport (7/$331,464), tidal inlets and estuaries (7/$626,406), coastal oceanography (10/$656,775), coastal protection (12/$787,473), and technology development (5/$294,975). During FY89 about $1,265,000 in Federal funds, matched by more than $1,100,000 from non-Federal sources, supported research in coastal oceanographic processes, and the resulting form, manner and rate of change of the coastal and seafloor.

Much of America's shoreline is eroding. Louisiana is losing coastal wetlands at a rate of tens of square miles per year, Great Lake's shorelines experience severe erosion during periodically high lake levels, and open ocean and bay coasts in every coastal state experience erosion at varying rates. Although the most dramatic erosion occurs when hurricanes and "northeasters" strike the Gulf and Atlantic coasts, and intense storms move inland over the Pacific coast, day-to-day wave and current processes also contribute significantly to erosion. However, a capability to provide solutions to this problem is limited by our lack of knowledge and understanding of the physical forces and interactions that produce these changes. An added complication is that if sea levels rise, as many scientists concerned with global climate change believe, increased erosion and other potentially deleterious effects will result. Over half of the Sea Grant Coastal and Ocean Processes program, therefore, is directed toward enhancing our understanding of the forces that impinge on coastlines and the resulting sediment movement. In addition, some research into improved coastal protection structures is being conducted.

Tidal inlets are vitally important to navigation, biological, and water quality concerns on the Gulf and Atlantic coasts, while on the Pacific coast knowledge and prediction of the hydraulics of tidal inlets are relatively well known, increased understanding of the sediment processes and resultant morphologies controlling inlet behavior is required.

55% of the FY89 projects are directed toward topics identified in last year's annual guidance as priority issues. A more detailed discussion of the FY89 program and recommendations for future research are contained in a later section of this report.

Introduction

Rational and productive management, conservation, and utilization of living and non-living coastal resources demand an improved understanding of the physical processes influencing the quantity and quality of these resources. The primary objective of the Sea Grant Coastal and Ocean Processes Program is to support research leading to an enhanced understanding of these processes. The seaward boundary of the area of interest is the edge of the continental shelf, while the landward boundary is the limit of tidal influence. Within this region, the physical forces (e.g. tides, waves, currents, winds) and their effects on water motion, sediment transport, and other secondary processes affecting the region are investigated. The processes include short-term or catastrophic events (e.g. storms, hurricanes, El Nino's), as well as longer-term phenomena (tides, sea level rise, etc).

Understanding alone, however, does not solve the critical problems facing coastal areas. The ultimate solutions rest with man's ability to alter or anticipate the effects of natural processes by applying new knowledge to development of engineering and management tools. Therefore,

technology development and transfer are also integral parts of the Sea Grant program.

Projects in Coastal and Ocean Processes

Subprogram Area Activities

The FY89 program consisted of 41 projects (36 Sea Grant and 5 passthrough, i.e. funded by other agencies), divided into five subprograms: coastal sediment transport (7/$331,464), tidal inlets and estuaries (7/$626,406), coastal oceanography (10/$656,775), beach erosion and coastal protection (12/$787,473), and technology development (5/$294,975). Project titles, investigators, and funding are listed in the appendix.

1. Coastal Sediment Transport studies concern fundamental research on the measurement and prediction of processes controlling sediment movement and deposition in the coastal zone, and in FY89 6 Sea Grant projects and one pass through study were in this category.

In estuaries and inlets, much of the transport is induced by tidal currents. On the beach face, wave uprush and bores are the predominate forcing mechanisms. In the surf zone, incident gravity waves, wind-induced currents, and infragravity waves produce a complex set of forcing functions which yield significant transport in both the cross-shore and longshore directions. Transport in the nearshore zone and on the shelf similarly results from a combination of forces. Storms are particularly important in producing large-scale bathymetric changes in shallow water.

Laboratory efforts provide an excellent means of conducting research on fundamental sediment transport processes. Dr. N. Kobayashi (U Delaware) continued his theoretical study to examine the role of surf beat and infragravity waves on cross-shore sediment transport in the surf zone. Dr. J.H. Trowbridge (MIT) is also using controlled laboratory conditions to examine the effects of suspended sediment concentrations on near-bottom currents. Dr. J. Hunt (University of California at Berkeley) initiated a set of laboratory studies to define the response of cohesive sediments such as mud and clay to selected flow conditions.

Since sediments often serve as a medium for pollutant attachment, knowledge of transport and dispersion processes of fine-grained material is useful in defining the impact of pollutant sources on freshwater and estuarine systems. Two studies relate to this topic. Dr K. Bedford at Ohio State continued his investigations of the response of near bottom sediment motion to waves and currents in the Great Lakes. Dr. J. Wells (University of North Carolina) is examining the rates of flux and accumulation of "marine snow" in an estuarine environment. Meanwhile, in a much more exposed coastal setting, Dr. D.M. Hanes (University of Florida) initiated a field study to define the variability in natural and man-made turbidity conditions near beach nourishment sites in Florida.

2. Inlets and Estuaries research investigations concern the hydrodynamic processes of circulation, wave generation and transformation, wave/current interaction; and the sedimentary processes of erosion and deposition, sand bypassing, sediment trapping, channel stability. Knowledge gained from these studies is vitally important to improved navigation projects, water quality and pollutant dispersal mechanisms, the biological processes of recruitment and maturation, and beach nourishment for shore protection. Seven Sea Grant projects concerned inlets and estuaries in FY89.

Inlet studies were focused on collection and analysis of field data to define processes at Northeast U.S. sites. Dr. K.C. Wong initiated an analysis of the hydrodynamic regime in Delaware's inland bays, particularly sub-tidal forcing through Indian River Inlet. Dr. J. Boothroyd (University of Rhode Island) began a more comprehensive hydrodynamic/sediment transport field study in a shallow riverine system, the Pettaquamscutt Estuary. The last year of Dr. G. Ashley's (Rutgers University) study to define the depositional history of a tidal delta/shore attached ridge complex concerns analysis of several cores and seismic surveys.

The estuary projects concerned measurement and/or prediction of estuarine circulation. Dr. B.J. Kjerve (U SoCar) is expand upon his previous field studies and basic 1-dimensional models to develop improved predictions of the impacts of fresh-water inflow on

coastal lagoons and inlets. Another study on variable density situations is being conducted by Dr. G.H. Ward (University of Texas), who is developing and applying a numerical model to predict salinity intrusions into Galveston Bay. Uniform density flows in Puget Sound are being modeled by Dr. W.S. Chu at the University of Washington.

Finally, computer-aided harbor design techniques are being developed by Dr. H. Loomis at the University of Hawaii to enhance the speed and accuracy in design of small boat harbors.

3. The Coastal Oceanography subprogram concerns research to quantify and physical processes affecting the coastal ocean. During FY89, eight Sea Grant and two passthrough projects concerned coastal oceanography, with emphasis balanced between waves and large-scale circulation.

Dr. V.G. Panchang's (University of Maine) modeling study of wave transformation in coastal embayments continued for another year, while at the University of Puerto Rico, A. Mercado's project to predict extreme wave heights at coastal locations based on newly developed wave transformation models and deepwater wave hindcasts is progressing. Wave transformation of longer period incident waves is being modeled by Dr. R. Guza and Scripps Institute of Oceanography for the Southern California Bight, who will also use extensive nearshore wave measurements to verify the model results. Somewhat finer scale modeling of nearshore hydrodynamics is being initiated by Dr. I.A. Svendsen at the University of Delaware as part of a strong effort by the Delaware Sea Grant Program and the newly established Center for Applied Coastal Research at the University to focus on critically needed fundamental research on nearshore processes.

Physical oceanographic studies off the New England coast continued by Dr. W.S. Brown (U New Hampshire) in a comprehensive field investigation of water mass movement in the Gulf of Maine. These studies are complemented by a new effort by Dr. F.E. Werner (Dartmouth) to numerically simulate the tides, mixing and 3-d flow structure of the Gulf. The dynamics of large-scale oceanic vortices and their impact on offshore structures and coastal processes is the topic of a study by Dr. G.S. Triantafyllou at MIT.

Finally, in the exciting and challenging area of nearshore infragravity waves, Dr. P.L. Liu is investigating several mechanisms which transfer energy from incoming surface gravity wave groups to longer period excitations.

4. The Coastal Protection subprogram consists of research and evaluation into methods for protecting coastal areas from natural hazards. Developing a quantitative understanding of the functional effectiveness of structures and their interaction with the environment is of prime importance. However, alternative mitigation techniques are often just as effective, and research in this area can lead to either cost-effective engineering solutions or improved management strategies.

Six of the projects address improved knowledge and prediction of coastal erosion processes. Dr. W.R. Dally (Florida Institute of Technology) initiated fundamental research on the physical processes which must be accurately represented in beach erosion models. Drs. J. Fisher and M. Overton (NC State) incorporated prototype size laboratory waves and a two-dimensional beach in a continuing investigation and modeling effort related to dune erosion processes. Dr. R.G. Dean (U Florida) continued an analysis of erosional processes along the Florida coast, with emphasis on quantifying the rates and determining the causes of beach erosion. Dr. P.D. Komar (Oregon State) initiated a new field study to determine the processes causing cliff erosion along the Oregon Coast, while Dr. C.A. Johnston (U Minn) continued a similar study to determine the rates and possible causes of erosion of the Lake Superior shoreline based on historical data and trends. A study to define the role of geology and stratigraphy on Lake Michigan shoreline and bluff stability was begun by Dr. G.J. Larson and the University of Michigan.

Two of the FY89 projects concerned laboratory studies to improve design procedures and performance of shore protection structures. Dr. W.G. McDougal (Oregon State University) built upon previous Sea Grant work to develop rational design procedures for rubble mound coastal structures. Dr. R.A. Dalrymple (University of Delaware) also used laboratory facilities to investigate the development of wave-induced currents and shoreline morphology behind offshore breakwaters, and verified a numerical model of nearshore waves and currents with the laboratory data.

Model development to address critical Great Lakes shoreline changes was initiated by Dr. G.A. Meadows (U Michigan), while Dr. T. Green (University of Wisconsin) investigated the relation of Great Lakes waves and storm surges to improved design of shore protection structures. Only one project concerned beach restoration as an erosion prevention method. Dr. W. Goldberg began a study to evaluate the impacts of beach restoration on the stony corals of southeast Florida.

5. The Technology Development and Transfer subprogram supports the transfer of research results to the user communities through workshops, symposia, and other media. In addition, hardware and software are developed and refined to provide improved methods for accomplishing research in the harsh coastal environment. Four Sea Grant projects dealing with technology development were conducted in FY89. Two dealt with shallow water mapping and imaging systems (Dr. J.Jaffe, University of California), one concerned the defining optimum locations for marine diffusers (Dr. R.T. Hudspeth, Oregon State University), and one concerned application of satellite data processing to fishery oceanography in the Gulf of Mexico (Dr. A.C. Vastano, Texas A&M University).

Features of the FY89 Program

1. Funding. FY89 funds for coastal and ocean processes investigations totaled $2,697,097 41 projects, about a 1% decrease from FY88. This included $1,265,536 Federal Sea Grant (up 7%), $1,169,499 matching institutional (up 1%), and $262,058 for passthrough projects from other federal sponsors (down 50%).

TABLE 1. Responsiveness to National Office Guidance.

Priority Research Area	(% Projects)
Sediment Transport	25%
Incident Wave Processes	13%
Infragravity Wave Processes	2%
Nearshore Wave-induced Currents	2%
Coastal Tide & Wind-induced Currents	13%

2. Response to National Office Guidance. The National Sea Grant College Program Annual Report for FY88 identified several high priority research areas. A measure of the responsiveness of state programs to this guidance is shown in Table

3. Overall, 55% of FY89 coastal and ocean processes projects addressed high priority topics, and increase of 16% over FY88.

Future Development of the Coastal & Ocean Processes Program

National Trends. In recent years, there has been a widespread consensus within the coastal and nearshore physical science and engineering community that these disciplines lack strong, centralized support within the Federal government. Several agencies presently conduct relatively small inhouse programs (Navy, Interior, and NOAA); some provide minimal support for University studies (NSF, ONR, DOD); Sea Grant nominally supports about 40 projects per year; and a large inhouse program (with minor outside contracts/IPA's) is conducted by the U.S. Army Corps of Engineers Coastal Engineering Research Center to meet applied requirements. Historically, coastal engineers have been somewhat at odds with coastal scientists (e.g. geologists), and investigators in both disciplines often worked independently.

Today, however, the consistently increasing focus on socio-economic issues in the coastal zone, a dearth of knowledge of the important processes affecting the resources, and limited federal funding for R&D in this area combine to produce a real need for cooperative, multi-disciplinary approaches supported by a variety of sponsors. In response to this need, several agencies are planning to enhance emphasis on nearshore research.

The NSF Ocean Sciences Division is presently encouraging development of two long-range research plans which impact coastal and ocean processes. A Coastal Physical Oceanography (CoPO) plan is being expanded to include inter-disciplinary aspects of coastal ocean processes and a Coastal Margin Sedimentation plan concerns sediment transport aspects. NOAA has

established a Coastal Ocean Program Office to coordinate its Coastal Ocean initiative and closely related base programs, and co-sponsors a joint office with the US Geological Service to plan research and mapping activities in the EEZ, including some emphasis on nearshore activities. The USGS' Office of Marine Geology is enhancing its fundamental research of beach and wetland erosion processes in response to public concern for property losses. The Office of Naval Research is also entertaining proposals to enhance its nearshore focus. Other agencies such as FEMA, DOE, and EPA are finding that existing knowledge of the coastal environment and its impacts is inadequate to address important economic decisions. Expanded efforts to coordinate interagency activities have blossomed in the past year. Sea Grant must continue to support cooperative efforts between academia and the federal sector to obtain the data and tools necessary for intelligent utilization and protection of the nations living and non-living resources.

Research Needs. In recent years, the impacts of natural sedimentary processes (erosion, deposition, and transport) on man's activities along the coast have been increasingly expensive. Millions of dollars worth of waterfront real estate is lost each year to shoreline erosion, and property damage from coastal storms is equally as costly. Sediments deposited in navigation channels and harbors require hundreds of millions of dollars of dredging each year to insure the safe and efficient passage of waterborne commerce. These problems are being exacerbated by an ever-increasing demand for coastal resources and rapid development of coastal areas.

Solutions to such problems depend upon knowledgeable decisions by managers, scientists, and engineers. Good decisions require not only quantitative understanding of the processes, but also demand accurate models for predicting the impacts of natural and man-made changes. However, sediment transport in nearshore waters is the result of complex interactions at the sea bed between waves, currents, sediment, and bedforms. These multiphase interactions span time scales ranging from seconds to millennia, and occur in a region of significant wave nonlinearity and relatively high turbulence. Sediment transport studies are thus extremely difficult, and involve a number of technical sub-disciplines, including physical oceanography, granular-fluid physics, geology, and coastal engineering. Because of this complexity, and a past inability to make accurate field measurements, knowledge of the fundamental physics of sediment motion remains rudimentary. Consequently, existing numerical models are generally crude, and engineering design relies as much on experience and judgment as on quantitative tools.

Recent scientific and technological advancements make this an opportune time to undertake fundamental research on coastal sediment transport processes. Although the ultimate goal is to predict physical changes to nearshore environments based on time-dependent dynamical models, the behavior of complex, large scale nearshore regions on time scales of months to years can only be understood if the physical processes of smaller, simpler systems over much shorter time scales are modeled correctly. Therefore, an ordered sequence of process-oriented experiments is envisioned to investigate forcing/response mechanisms over a wide range of time and space scales. Existing models of the physics of fluid motion and particle transport should be used to define experimental needs, and results should be used to verify models and develop and test new relationships. Since research of this nature is inherently time-consuming, labor intensive, and costly, optimum progress will generally be made through coordinated multi-investigator approaches to well-defined research problems, rather than by individual investigators working independently. High priority areas of investigation are identified below.

Incident Wave Processes: Turbulence. The temporal and spatial distribution of high velocity, high frequency turbulence is important to sediment motion initiation and transport. The intensity of turbulence produced may eventually be predictable given knowledge of the incident wave characteristics. However, the precise mechanisms of energy transfer to turbulence and sediment interactions with turbulent fluctuations are unknown. Research needs include studies of:

- o turbulence generation at both the sea surface (wave breaking) and the sea bed (bottom boundary layer).
- o the role of turbulent fluctuations to the initiation of sediment motion and to the

maintenance of suspended sediment concentrations via eddy diffusion.

- the general role of fluid accelerations (large with high frequency turbulent motions) in sediment suspension.

Incident Wave Shoaling and Breaking. The shoaling and breaking of surface gravity waves is a much studied problem in nearshore processes and there is a large body of literature dealing with the idealized situation of a normally incident, monochromatic wave train propagating on a uniformly sloping beach. The linear wave theory–based expressions for radiation stress, energy density, and energy flux developed by Longuet–Higgins and Stewart (1960) have proven qualitatively correct and most features of the shoaling wave field are relatively well known. Conditions for the onset of breaking of this particularly simple wave type, and the shoreward decay of the resulting bore, have also been studied extensively in the laboratory. However, relatively little data exist for field conditions, when random wave spectra predominate.

Research needs include:

- generalization of refraction–diffraction equations to a directionally spread, weakly nonlinear, random sea.

- development of a spectral, random wave model for bore propagation in the surf zone with capabilities to predict turbulence levels and nonlinear moments of the velocity field, including the effects of infragravity waves and complex bathymetry.

- field verification of the above models.

- further quantification of breaker characteristics, including the importance of wave plunging on sediment suspension.

- wave processes over soft, muddy bottoms.

Infragravity Waves. Temporal fluctuation in incident wave heights, known as wave grouping, that occur with natural, random wave fields have long been thought to generate waves with periods significantly longer than the incident waves, i.e. infragravity waves. Recent field experiments have significantly improved our knowledge of infragravity waves and confirmed their importance on nearshore fluid and sediment motions. In addition to exhibiting standing wave structure in the cross–shore direction, infragravity wave energy at the shoreline (which is important in controlling wave run–up characteristics) was found to increase with increasing incident band energy outside the surf zone. In fact, within the surf zone incident wave heights are reduced by breaking, while the amplitudes of nonbreaking infragravity waves increase. Finally, some indications have been found that on a barred profile, resonant interactions between infragravity waves and the bathymetry could lead to amplification of discrete infragravity wave frequencies. No conclusive linkage has been found, however, between bar crest position and peak–frequency infragravity waves. Research needs include:

- Incident to infragravity energy transfer processes.

- Infragravity wave effects on beach and surf zone sediment transport.

- Tuning of infragravity waves by nearshore morphology.

- Parameterization of infragravity energy dissipation.

Wave–induced nearshore currents. Quantitative models for the dynamics of nearshore currents driven by incident waves utilize the concept of "radiation stress", the depth integrated excess momentum flux owing to the presence of waves. In a spatially non–uniform wave field, as occurs during wave shoaling and breaking, gradients in the radiation stress result in a steady force. The cross–shore component of this force drives bottom return flow and other cross–shore currents and produces changes in the mean sea surface elevation, i.e. set–up. The longshore component, non–zero when waves approach the coast obliquely, drives steady longshore currents. However, monochromatic (single frequency) wave models applied to a naturally occurring random sea yields only crude parameterizations of the physics of longshore currents. Random waves are an essential element of realistic longshore current models. Research needs include:

- o Development and field verification of random wave models for steady wave-driven currents on complex bathymetry.

- o Quantifying the energy and momentum transfer processes of a breaking, broad-banded wave field that generate longshore currents.

- o Determining the temporal and spatial variability of the vertical structure of velocity within the wave and current boundary layers under various wave and bottom conditions.

- o Quantifying rip current hydrodynamics and sediment transport processes.

Tidal and Wind-induced Currents. The traditional concept of purely wave-induced surf zone currents is often inadequate to describe longshore and cross-shore current behavior. In fact, shelf-wide tidal and wind-driven flows extend to the shoreline and in some cases may be stronger than wave-driven flows. Onshore winds may produce localized setup of water against the coast, resulting in a seaward directed flow near the bottom. Conversely, offshore winds drive surface waters away from the coast producing onshore near-bottom flows. The direct contribution of surface wind stress is very important to longshore flows on shallow, gently sloping shorefaces (e.g. Great Lakes). In certain areas tidal currents dominate shoreface sediment transport. Research needs include:

- o Quantifying the relative contributions of winds, waves, and tides to longshore and cross-shore currents through field experiments of surf zone and shelf-wide observations of tidal and wind-driven flows.

- o Determining the vertical structure of velocity within wave and current boundary layers

- o Model development of tide and wind forced nearshore currents and sediment transport.

Sediment Response to Physical Forcing. Recent fast response measurements of fluid flows and suspended sediment concentration profiles in the surf zone along with limited application of numerical models incorporating time-dependent turbulent diffusion concepts have begun to provide new insights into sediment transport in the wave dominated environment. These insights include the role of infragravity energy in driving sediment motions in the inner surf zone, boundary shear stress estimates from wave-current shear flows; and the coupling between cross-shore oscillatory velocities and the total suspended load and cross-shore particle flux. Preliminary results clearly suggest the importance of time-dependent boundary layer modeling and field experiments. Research needs include:

- o Determining suspended and bedload transport dependence on sediment size, density, and shape;

- o Quantifying the effect of bed roughness on oscillatory boundary layers

- o Suspended and bedload effects on bed shear stress

- o Turbulent transfer mechanics associated with combined wave-current boundary layers

- o Characteristics and behavior of bed-forms under combined wave and current flows

Instrumentation and Technology Development. Recent developments in acoustical and optical technologies suggest that it is feasible to measure both fluid velocity and sediment flux in the nearshore zone with high spatial and temporal resolution. High resolution measurements are essential in view of large vertical gradients in flow and sediment concentrations. Acoustic doppler current meters have worked well in inlets and coastal waters outside the surf zone. Development of similar instruments for the highly energetic surf environment would provide valuable research tools.

An additional requirement exists for a remotely-operated or in situ high-resolution surf zone bathymetric mapping system. Rapid and substantial changes in shoreline position and nearshore bathymetry during storms require frequent surveys if changes in large-scale sedimentary features (bars, troughs, etc.) are to be accurately monitored. Ongoing development of shallow-water multi-beam surveys offers a potential means to map areas outside the surf zone, but systems capable of operation in turbulent and aerated environments will be needed for inshore sites.

Continued development of remote sensing techniques, highly desirable for their capability to obtain rapid measurements over large areas, offers promise for measurements of coastal variables and bathymetry.

In summary, projects supported by the Sea Grant Coastal and Ocean Processes Program should quantitatively address the high priority research needs defined above. Interdisciplinary efforts are also necessary to define complex interactions between a wide variety of living and nonliving processes, and costs to individual programs can often be minimized by cooperative efforts between investigators, institutions, and agencies.

PROJECTS

A. Coastal Processes

1. Coastal Sediment Transport:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Experimental Studies on the Response of Cohesive Sediments J. Hunt 22 University of California Sea Grant College Program	14,414	10,921
Surf Beat and Cross-Shore Sediment Transport in Surf Zone on Natural Beaches N. Kobayashi 25 Delaware Sea Grant College Program	3,783	49,259
Coastal Turbidity Associated with Natural and Man-Induced Phenomena D.M. Hanes 25 Florida Sea Grant College Program	40,000	28,700
Field Investigation of the Transport of Mixed-Sized Sediment on Southwestern Lake Michigan Beaches. K.L. Prestegaard 46 Illinois/Indiana Sea Grant Program	0	15,310
Effects of Suspended Sediment Stratification on Coastal Currents and Sediment Transport J.H. Trowbridge 46 Woods Hole Oceanographic Institution Sea Grant Program	44,300	6,582

The Role of "Marine Snow" Vertical Flux and Accumulation of Sediments in an Estuary J. Wells 48 University of North Carolina Sea Grant College Program	12,544	23,457
The Response of Near Bottom Sediment Fluxes and Distributions to Time-Varying Flows K.W. Bedford 46 Ohio Sea Grant College Program	46,199	25,995
SUBTOTAL:	$ 161,240	$ 160,224
PASSTHROUGH:	$ 10,000	

2. Inlets and Estuaries:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Assessment and Modeling of Estuarine Flow and Transport Processes in Response to Changing Freshwater Discharge B. Kjerfve 46 South Carolina Sea Grant Consortium	67,200	32,900
Modeling Tidal Circulation and Transport in Central Puget Sound W.S. Chu 46 Washington Sea Grant College Program	29,600	16,200
An Analysis of the Hydrodynamic Regime in Delaware's Inland Bays K.C. Wong 46 Delaware Sea Grant College Program	15,478	28,777
Computer-Aided Harbor Design H. Loomis 23 University of Hawaii Sea Grant College Program	48,288	82,453
Seismic Strategraphy and Depositional History of the Tidal Delta-Shore Attached Ridge Complex, Barnegat inlet, New Jersey G. Ashley 39 New Jersey Marine Sciences Consortium Sea Grant Program	29,700	30,400
Circulation and Sediment Transport in a Shallow Inlet-Estuarine System: Pettaquamscutt River J. Boothroyd 46 Rhode Island Sea Grant College Program	50,000	145,265

Predictive Methods for Salinity Intrusion in Galveston Bay G.H. Ward 46 Texas A&M University Sea Grant College Program		31,548	18,597
	SUBTOTAL:	$ 368,614	$ 354,592
	PASSTHROUGH:	90,000	

3. Coastal Oceanography:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Southern CA Waves: Model Verification & Utilization R. Guza 25 University of California Sea Grant College Program	38,380	13,266
Numerical Modelling Nearshore Hydrodynamics I.A. Svendsen 26 Delaware Sea Grant College Program	5,460	43,455
Directional Wave Collection and Analysis - Kings Bay, Georgia H. Wang 25 Florida Sea Grant College Program	0	17,000
Lake-Level variation in Lakes Michigan and Huron: Magnitude and timing of past and future fluctuations. N.C. Hester 46 Illinois/Indiana Sea Grant Program	0	58,130
Evolution of Wave Spectra in Bays - Calculation of Wave Conditions in Bays V. Panchang 46 Maine/New Hampshire Joint Sea Grant College Program	35,862	8,586
Water Mass Evolution and the Circulation and Nutrient Environment of the Gulf of Maine W.S. Brown 50 Maine/New Hampshire Joint Sea Grant College Program	53,000	27,411
Numerical Analysis of Tides, Mixing, and Three-Dimensional Flow-Structure in the Gulf of Maine F.E. Werner 50 Maine/New Hampshire Joint Sea Grant College Program	9,700	0

The Dynamics of Large-Scale Vortices in the Ocean and Their Impact on Offshore Structures and Coastal Processes G.S. Triantafyllou 24 Massachusetts Institute of Technology Sea Grant College Program	50,000	12,001
Surf Beat Dynamics: Long Wave Excitations Through the Refraction, Diffraction, and Breaking of Wave Groups P.L. Liu 25 New York Sea Grant Institute	32,033	32,891
Extreme Wave Heights for Puerto Rico and the U.S. Virgin Islands A. Mercado 25 University of Puerto Rico Sea Grant Program	25,100	65,800
SUBTOTAL:	$ 249,535	$ 278,540
PASSTHROUGH:	$ 128,700	

4. Beaches and Shore Protection:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Measuring Overwash on Barrier Island (supplement) R.T. Guza 25 University of California Sea Grant College Program	0	7,556
Simulation Modeling of Dune Erosion J. Fisher 25 University of North Carolina Sea Grant College Program	37,432	13,633
Enhancing the Underlying Physics of Beach Erosion Modeling W.R. Dally 25 Florida Sea Grant College Program	33,100	32,700
Offshore Breakwaters: Waves and Currents R.A. Dalrymple 25 Delaware Sea Grant College Program	11,995	33,271
Florida's Erosion Problem: Toward an Improved Understanding of Rates and Causes R.G. Dean 25 Florida Sea Grant College Program	40,500	20,600

Field Experiment Evaluation of the Effects of Beach Restoration on Stony Corals of Southeast Florida W. Goldberg 28 Florida Sea Grant College Program		0	18,200
Geology and Stratigraphy of the Lake Michigan Shore and Its Influence on Erosion and Bluff Stability G.J. Larson 39 Michigan Sea Grant College Program		34,935	18,916
Numerical Modelling of Shoreline Evolution G.A. Meadows 46 Michigan Sea Grant College Program		25,287	13,938
Predicting Lake Superior Shoreline Erosion from Coast Characteristics and Historical Trends C.A. Johnson 39 Minnesota Sea Grant College Program		24,540	4,660
A Rational Analysis and Design Procedure for Rubble Mound Coastal Structures W.G. McDougal 25 Oregon Sea Grant College Program		93,700	80,200
Problems and Processes of Sea Cliff Erosion on the Oregon Coast P.D. Komar 39 Oregon Sea Grant College Program		74,900	30,900
The Relation of Great Lakes Waves and Storm Surges and Its Effect on Coastal Design T. Green 25 Wisconsin Sea Grant Institute		28,170	18,340
	SUBTOTAL:	$ 404,559	$ 292,914
	PASSTHROUGH:	0	

5. Technology:

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Advanced Development of 3-D Ultrasonic Imaging System J. Jaffe 28 University of California Sea Grant College Program	25,316	6,000
Shallow Water Swath-Mapping Systems J.S. Jaffe 39 Woods Hole Oceanographic Institution Sea Grant Program	53,000	7,779

Siting of Marine Diffusers R.T. Hudspeth 25 Oregon Sea Grant College Program		45,600	22,500
Satellite Analyses for Fishery Oceanography in the Gulf of Mexico A.C. Vastano 50 Texas A&M University Sea Grant College Program		54,472	30,000
Passive Artificial Ventilation of Hypoxic Estuaries L.D. Wright 24 Virginia Graduate Marine Science Consortium Sea Grant Program		0	16,950
	SUBTOTAL:	$ 178,388	$ 483,229
	PASSTHROUGH:	33,358	

Marine Geological Resources

Summary

Research related to marine geological resources is supported by six institutions involving 22 projects. Topics include improving our understanding of the formation of heavy mineral deposits, pursuing studies related to evaluating potential mining of cobalt-enriched manganese crusts on Hawaiian seamounts, and evaluating the economic and political implications of various mineral resources within the EEZ.

Significant developments resulting from recent Sea Grant research include addressing the environmental considerations related to the potential mining of cobalt-enriched manganese crusts on the Hawaiian seamounts. Through these studies, baseline information will be gathered of the geological setting, physical oceanography, chemistry, and water quality to assess any mining impact on the environment. The University of Hawaii's follow-on program on the geology, geochemistry, and economies of crust deposits is major, comprehensive, and strongly supported by the state.

The polymetallic sulfide deposits found in conjunction with ocean spreading centers is being addressed through Sea Grant supported research. These studies include determining the long-term behavior of the vent systems, and the technology for sampling which will aid economic determination of the significance of these deposits.

Introduction

TABLE I

SEA GRANT TASKS PERTINENT TO MARINE GEOLOGIC RESOURCES ACTIVITIES

No.	Descriptor
09	Geological Oceanography
10	Mineral Resources--other (specify)
14	Marine Economics
15	Ocean Law--Coastal
16	Ocean Law--International
22	Seafloor Engineering
23	Vessels and Platforms
25	Coastal Engineering
27	Dredging
36	Ports, Harbors, and Offshore Terminals
39	Coastal Zone Management--Natural Sciences & Engineering
41	Pollution--oil spills
44	Pollution--metals
45	Pollution--other (specify)
46	Environmental Models--physical processes
49	Applied Chemical Oceanography
50	Applied Physical Oceanography

The marine geologic resources program of the National Sea Grant College Program approaches research opportunities and problems within the context of four major categories: resource research and assessment, technology development, environmental assessment, and the assessment of socio-economic/legal issues. This report focuses on research related to specific mineral commodities that were identified from 17 Sea Grant Program tasks (Table 1) and grouped into the four categories mentioned above (Table II). Attention has been given to individual projects in the summary of present activities. Program structure is also summarized below.

The Sea Grant marine geologic resources program consists of 22 projects. Total program support is $1,241.4 thousand of which $755.1 thousand is derived from Federal

TABLE II

CATEGORIES OF OPERATIONS INVOLVED IN MARINE GEOLOGICAL RESOURCES PROGRAMS SHOWING ATTENDENT FUNCTIONS AND TASKS

Operations Category	
1. Resource Research and Assessment (Exploration, Recovery)	
Functions	Tasks
Data Collection	- Surveys; 2 and 3 dimensional sampling; field and laboratory
Data Evaluation	- resource assessment
Research	- processes; sampling theory
2. Technology Development (Exploration, Recovery, Beneficiation, Geological/Geophysical Consideration of Offshore Structure Engineering	
Operation	- exploration systems; techniques; extraction systems; concentration systems
Assessment	- systems suitability; profit and loss
Instrumentation	- system analysis; innovative equipment or operation; R&D on improvements and applications
3. Environmental Indices	
Data Collection	- temporal and spatial (baselines; operations monitoring; post-operations)
Data Evaluation Research	- impact assessment
Research	- processes; innovative equipment; operation
4. Socio-economic - Legal Aspects	
Economic impact	- corporate, state, regional
Sociological Impact	- industrial, state, regional
Legal Aspects	- law of the sea, coastal zone

appropriations. The total funding is nearly equal that of last year. The low level continues to be attributable to several factors: no activity in three commodities; depressed commodity prices; and continued no activity in support of oil and gas related activities (Table III). Additional factors are discussed in each commodity section. During FY 89, 6 of the 30 Sea Grant institutions had one or more projects in marine geologic resources (Table IV).

TABLE III

Federal Funding for the Marine Geological Resources Program Over the Last Four Fiscal Years

MARINE GEOLOGICAL RESOURCES

($x10³/No. of projects

Commodity	FY 86	FY 87	FY 88	FY 89
Sand, Gravel and Shells	26.5/1	0/0	0/0	0/0
Manganese Oxide Nodules or Crusts	52.8/2	136.4/3	93.8/1	146.9/7
Phosphate Rock, Polymettalic Sulfides and Venting	97.3/4	187.2/4	418.0/8	309.9/8
Heavy Mineral Placers	134.4/3	111.1/3	58.9/3	35.1/1
Petroleum	340.8/10	106.8/4	41.2/4	0/0
Ground Water	16.8/1	36.5/2	43.9/1.	0/0
Other	263.5/6	0/0	136.3/5	263.2/5
TOTAL	932.1/28	578.0/16	792.1/22	755.1/22

TABLE IV
FY 89

GRANTEE EFFORT IN MARINE GEOLOGIC RESOURCES

Grantee Institutions	No. of Projects	SG($x10³)	M	Total
California	1	65.5	16.1	81.6
Hawaii	11	219.0	170.8	389.8
Mississippi/Alabama	1	60.0	44.1	104.1
Oregon	1	35.1	39.9	75.0
Washington	3	147.3*	65.3	212.6*
WHOI	5	228.2*	150.1	378.3*
TOTALS	22	755.1*	486.3	1241.4*

* All or in part passthrough

TABLE V
FY 89

MARINE GEOLOGICAL RESOURCES STUDIES
SUMMARY STUDIES

Commodity	Resource Research & SG ($X10^3) M	Technology Development SG ($X10^3) M	Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M	Totals
Sand Gravel & Shell	No Activity	---	---	---	---
Manganese Nodules or Crusts	137.6 108.3			9.3 10.8	146.9 119.1
Phosphate Rock, Polymetallic Studies and Venting	259.5* 125.2	50.4 23.3			309.9 148.5
Heavy Mineral Placers	35.1 39.9				35.1 39.9
Petroleum	No Activity	---	---	---	---
Ground Water	No Activity	---	---	---	---
Other		53.0 7.8	78.9* 44.0	131.3 126.9	263.2 178.7
Totals	432.2 273.4	103.4 31.1	78.9* 44.0	140.6 137.7	755.1 486.2

* All or in part passthrough

TABLE VI
FY 89

SAND, GRAVEL, AND SHELLS

Grantee Institution (P.I.)	Resource Research & SG ($X10^3) M	Technology Development SG ($X10^3) M	Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M	Totals
	No Activity	---	---	---	---

Summary of Present Activities

Sand, Gravel, and Shells (Table VI)

Through the years, Sea Grant has supported numerous research projects addressing marine sand and gravel. These projects have generally focused on the assessment of availability and/or quantity of this resource and the economic feasibility of exploitation. Despite favorable findings, and thriving offshore mining ventures in other countries, there continues very little interest for similar mining within the United States.

Presently there is no research activity underway within Sea Grant for the 3rd consecutive year, indicating there are no presently perceived research needs. The apex of the New York Bight is the site of a sand mining operation by McCormack Aggregates. Annual production is on the order of 1.0 million cubic meters. Occasional mining occurs in the Arctic for use in creating offshore islands for oil drilling and production platforms.

Manganese Oxide Nodules and Cobalt-Manganese Crusts (Table VII)

One previous project organized among several scientists at the University of Hawaii to conduct research on the cobalt-manganese crusts found on seamounts in the EEZ of the Hawaiian archipelago has led to a major focused program for Co-rich crusts of Hawaiian Seamounts. These studies reflect strong interest in the state to assess the resource.

Seven different researchers are conducting research on crusts, six related to discovery and resource assessment and one addressing economic issues. Four projects (De Carlo, Malahoff, Yeho and Mahoney) related to crust stratigraphy at scales emerging from geologic time to isotopic composition and processes as minute as microbially mediated deposition (Cowen). One project is investigating the possibility of a new industrial product from crust matrices (Andermanne) and one project is directed toward alternate economic deposits (Wiltshire).

TABLE VII
FY 89

MANGANESE OXIDE NODULES OR CRUSTS

Grantee Institution (P.I.)	Resource Research & SG ($X10^3) M		Technology Development SG ($X10^3) M	Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M		Totals
University of Hawaii							146.9 119.1 (7)
(Andermann)	9.7	24.7					
(Cowen)	25.4	18.2					
(De Carlo)	21.4	11.9					
(Mahoney)	37.8	29.2					
(Malahoff)	24.9	13.0					
(Yeh)	18.4	11.3					
(Wiltshire)					9.3	10.8	
Totals	137.6	108.3 (6)			9.3	10.8 (1)	

TABLE VIII
FY 89

PHOSPHATE ROCK, POLYMETALLIC SULFIDES, AND VENTING

Grantee Institution (P.I.)	Resource Research & SG ($X10^3) M		Technology Development SG ($X10^3) M		Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M	Totals	
California							65.5	16.1 (1)
(Anderson)	65.5	16.1						
University of Hawaii							72.1	51.7 (3)
(Karl)	22.0	21.7						
(Malahoff)	25.0	15.0						
(McMurty)	25.1	15.0						
University of Washington							147.3	65.3 (3)
(Delaney)	66.9	42.0						
(Delaney)	30.0*	---						
(Johnson)			50.4	23.3				
Woods Hole Institution							25.0	15.4 (1)
(Cann)	25.0	15.4						
Totals	259.5*	125.2 (7)	50.4	23.3 (1)			309.9	148.5 (8)

*All or in part passthrough

Polymetallic Sulfides, and Venting (Table VIII)

Eight research projects address polymetallic sulfides and venting processes, this year again the most active and diverse field. Delaney (University of Washington), using a multidisciplinary steering committee, continues managing a national scientific program to study the world circling ridge systems in a major NSF program. In a second project Delaney and associates are undertaking a time-series experiment focusing in the relationship between earthquake activity and hydrothermal output. At the University of Hawaii, Karl, Malahoff, and McMurty continue their coordinated studies of processes on the growing new island of Hawaii presented by Loihi undersea volcano. This is the 2nd of a 3 year study of the geology one structure of Loihi submarine volcano in order to provide knowledge concerning the nature of hydrothermal mineral resources there, and by analogy, on other submarine volcanoes of the Pacific. At Oregon State University, Carey, et al. continue their study of the character, distribution, and geological factors of cold water venting processes in the subduction zone and upper continental slope offshore Oregon.

Traditional resource assessment studies are directed toward the mineral resources. However, in a new and unique effort, Anderson at UCal/San Diego (Scripps) will conclude a two year project to examine the feasibility of a seafloor geothermal power converter to exploit the thermal flux of hot vents. Success would have major consequence to the further development and then deployment of ocean bottom observatories. At Woods Hole Oceanographic Institute, Cann is initiating an investigation of the ability to estimate the rate of supply of heat and metals to black smoker vent fields.

In a cooperative project with industry and Navy, investigators at the University of Washington (Johnson) will conclude development and field test a deep ocean coring drill.

TABLE IX
FY 89

HEAVY MINERAL PLACERS

Grantee Institution (P.I.)	Resource Research & SG ($X10^3) M	Technology Development SG ($X10^3) M	Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M	Totals
Oregon State University					35.1 39.9 (1)
(Peterson)	35.1 39.9				
Totals 39.9	35.1 39.9 (1)				35.1 (1)

Heavy Mineral Placers (Table IX)

Research interest in heavy mineral deposits continues but as in other commodities, the level is down. At Oregon State University, Peterson, will continue research designed to develop a conceptual model for titanium and zirconium placer deposits on the Oregon continental shelf.

At present, there are no industry partners in Sea Grant research on placers. However, industry is known to continue its interest in potential for placers offshore Georgia, and for the third consecutive year gold is being dredged offshore Nome, Alaska.

Petroleum (Table X)

This year no research related to petroleum is being conducted. For many years, the thrust has been in improved design of structures (both production and exploration platforms) and improved understanding of marine "soil" mechanics. Principal player in both arenas was the Massachusetts Institute of Technology (MIT). Largely as a result of Sea Grant support, the MIT departments involved were successful in establishing major research centers with support from the petroleum industry. Research in these areas is now funded by industry without need for Sea Grant at this time.

TABLE X
FY 89

PETROLEUM

Grantee Institution (P.I.)	Resource Research & SG ($X10^3) M	Technology Development SG ($X10^3) M	Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M	Totals
	No Activity	---	---	---	---

TABLE XI
FY 89

GROUND WATER

Grantee Institution (P.I.)	Resource Research & SG ($X10^3) M	Technology Development SG ($X10^3) M	Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M	Totals
	No Activity	---	---	---	---

Ground Water (Table XI)

Never a large component, there is no activity to report.

TABLE XII
FY 89

OTHER

Grantee Institution (P.I.)	Resource Research & SG ($X10^3) M	Technology Development SG ($X10^3) M	Environmental Assessment SG ($x10^3) M	Socio Eco. Legal SG ($10xM^3) M	Totals
Mississippi/Alabama					60.0 44.0 (1)
(Schroeder)			60.0 44.0		
Woods Hole Oceanography Institute					203.2* 134.7 (4)
(Broadus)				45.4 40.9	
(Jaffe)		53.0 7.8			
(Lobel)			18.9*		
(Ross)				85.9 86.0	
Totals (5)		53.0 7.8 (1)	78.9* 44.0 (2)	131.3 126.9 (2)	263.2* 178.7 (5)

* All or in part passthrough

Other (Table XII)

Five projects are grouped into this category this year, and span a wide diversity of geologic research.

At WHOI, Broadus will conclude his research to develop and test the hypothesis that investment in exploration and development for non-fuel minerals are cyclical phenomena related to cycles in mineral commodity markets and Ross will pursue international cooperative efforts. Jaffe is pursuing development of a shallow water swath mapping system and Lobel is to carry out oceanographic studies to assess the environmental effects of the deep ocean disposal of brine.

In an investigation of potential major benefit to fisheries, Schroeder (Miss/Ala) will study the nature and distribution of hard bottoms on the continental shelf off Mississippi and Alabama.

Trends and Assessment

The continual low level of marine geologic research supported by Sea Grant this year, compared to previous years (Table III) can be explained by several items: the withdrawal from the program of many petroleum-related projects, sand, gravel, and shells which have no activity, and depressed prices for mineral commodities. All reasonably can be assumed to continue that way in the near future. Sand and gravel is an arena for which major issues, amenable to solution through academic based research, have been answered. Nevertheless, there continues to be needs and opportunities for other commodities, as pointed out below. The need for an aggressive research program to address nonliving resources of the oceans and large lakes stems from many considerations. Principal among these is that the territory of the United States was more than doubled by the EEZ proclamation. Another way of looking at this fact is the realization that 60% of the United States is underwater. One of the major tasks implied by this proclamation is to assess the potential of the EEZ and the adjacent seabed for contributing to the future resource needs suitable for economic stability and national security.

Several recent developments continue to reinforce that belief. There is nothing to change findings of the Office of Technology Assessment (of the U.S. Congress) report (July, 1987) which concludes that in the near future it is unlikely the EEZ will be a significant source of minerals (other than oil, gas, and sulfur). This report titled, "Marine Minerals: Exploring Our New Ocean Frontier," finds that due to:

> "...economic uncertainties and financial risks of EEZ mining, it is doubtful that the private sector will undertake substantial exploration in the EEZ until more is known about marine minerals. Preliminary reconnaissance and exploration by the Federal Agencies to determine mining opportunities, as well as assurances from Congress that the Federal Government will provide an appropriate administrative framework and economic climate to conduct business offshore, probably will be needed to interest the private sector in further prospecting and possible development. The possible strategic importance of some EEZ minerals is additional justification for the United States to maintain momentum in exploring its offshore public domain. We know too little about the mineral resource potential of the EEZ to judge its long-term commercial viability or its strategic value in supplying critical minerals in times of emergency" (p.23-24).

The Bureau of mines (Open File Report 28-88, Potentially Critical Materials) recently identified 14 materials which increasingly are becoming useful in high technology fields but are available from U.S. sources in only limited quantities, and with inadequate reserves. In the group are zirconium and the platinum group metals (PGM) rhodium and ruthenium (for electrical, electronics, and chemical industries). Major sources of these metals, especially the PGM's, are South Africa and the Soviet Union. Potential sources for the U>S. are in heavy mineral placer deposits.

Questions addressing the polymetallic sulfide minerals being deposited near the deep ocean hydrothermal vent systems are just beginning to be answered. Sea Grant support of this research, while still far from being major in terms of funding level and number of projects, has increased over previous years. Additional research is being directed at other venting systems. Much research remains to be conducted on the submarine processes and the ecosystems associated with the spreading centers and other venting regions on the ocean floor. Ultimately, research on submarine hydrothermal systems will provide us with new information on rift zone environments and, perhaps, provide an alternate means of mineral supply for certain metals.

Research related to heavy mineral placers continues, and may offer pay off in the near term. A corporation is presently recovering gold from state waters offshore Nome, Alaska, and other corporations have exploration activity underway in waters offshore Georgia. The DOI EEZ hard mineral leasing program is continuing to be implemented on a case-by-case basis, partly in response to anticipated industry interest. However, immediate industry interest in offshore hard minerals is not strong due to environmental and regulatory considerations and the currently

depressed mineral market. As market conditions improve, interest in EEZ hard minerals can be expected to increase. The MMS established a state-federal Placer Minerals Task Force for offshore Georgia. The MMS has indicated if will continue to fund the Task Force on Georgia Phosphate (offshore) and other offshore heavy mineral resources. A similar Placer Minerals Task Force has been established for Offshore Oregon.

The Bureau of Mines recently established the Marine Minerals Technology Center, and extramural grant based program. It has two divisions, the Continental Shelf Division located at the Mississippi Minerals Institute, University of Mississippi, and the Ocean Basins Division located at the University of Hawaii. So far the program has attracted a number of PI's who have taken part in past Sea Grant supported projects. Because the MMTC Divisions are federally supported, the work cannot be considered match under Sea Grant requirements, effectively precluding cooperative activities. On the positive side, past Sea Grant support has sustained the small cadre of marine minerals people and trained new persons who now work in the Bureau of Mines MMTC arena.

The MMTC and Sea Grant cooperate and communicate on several levels. Importantly, the MMTC now co-sponsors the annual Underwater Mining Institute (UMI) which is an educational forum uniting the common interest of academia, government, and industry to provide a balanced perspective on the investigation and effective use of mineral resources from the sea. The Annual Dredging Seminar at Texas A & M University is a similar education forum. Both programs provide Sea Grant with a unique opportunity to communicate research program requirements and projects with industrial application to industry representatives, and to seek cooperative support from the private sector for marine geologic resource projects. The recent decision to annually change the UMI meeting site will enhance what is already a successful forum for communication. Sea Grant program directors should be encouraged to participate at these forums or send prospective principal investigators to seek support for projects in this research effort.

Recommendations

The Exclusive Economic Zone (EEZ) proclamation, the OTA report, and the Bureau of Mines report on Potentially Critical Materials have provided an opportunity and, as a government organization, charged us with the responsibility of developing a more comprehensive understanding of the immense geographic area within 200 nm of our coastline. This knowledge should address, among others: assessing seafloor minerals, studying processes which produced these deposits, developing new technologies for exploring and recovering ocean minerals, analyzing the legal and economic aspects of seabed mining, and studying the issues related to ocean waste disposal.

Mineral Assessment: NOAA and the United States Geological Survey (USGS) are mapping and charting the EEZ with new swath mapping devices which measure geological and geophysical characteristics. These bathymetric maps can in turn be used as a basis for locating, and interpreting the processes of, mineral formation on the seafloor, such as topographical maps served prospectors of the western frontier. There is then, a need to identify on a regional basis potential mineral deposits of polymetallic sulfides, placers, and heavy metal crusts.

Processes Which Create Mineral Deposits: Assessment of mineral resources is enhanced by understanding the chemical and physical processes associated with mineral accumulation. Understanding the processes of formation, plus a knowledge of the regional geology makes it possible to improve resource estimates of marine deposits, and apply the knowledge gained to strategies for exploration on land. Research is required which will unravel the physical and chemical processes responsible for seafloor mineral deposits of polymetallic sulfides, cobalt and manganese crusts, and heavy mineral placers.

Technology for Exploration and Recovery: Improved technology may be applicable to a variety of minerals in different geological settings and can often reduce the high cost of working in the marine environment. Sea Grant researchers have developed technologies to: explore for mineral deposits using gamma radiation detection devices; conduct elemental assays at=sea to determine mineral enrichment; better understand the physical processes active at ocean spreading centers through the implantation of sophisticated monitoring devices; remove toxic byproducts from wastes resulting from ore processing; and improve the safety of offshore drilling structures. There is

TABLE XIII

COMPARISON OF FY 1989 PROGRAM WITH FY 89 PRIORITIES FOR MARINE GEOLOGIC RESOURCES

FY 1989 Priority	No. of Projects in FY 1989	Institutions
Assessments of EEZ hard mineral and newly discovered deep sea minerals, particularly those of strategic significance.	14	University of California University of Hawaii Oregon State University Woods Hole
Development of a suite of monitoring techniques that accurately sense changes in the marine environment due to extraction activities, and which can be run in an efficient and cost-effective manner.		
Refinement or development of mineral exploration and prospecting technology that conserve time and energy.	2	University of Washington Woods Hole
Studies supporting the objectives of NOAA's Ocean and Coastal Resource Management's deep seabed mining marine environmental research plan.		
Analysis of political and economic incentives for exploration and exploitation.	2	University of Hawaii Woods Hole
Provide adequate research on marine geologic resources in the EEZ to provide data necessary for rational decisionmaking and management, including the use of the sea or subseafloor for storage of waste.	5	Hole University of Hawaii Oregon State University Woods Hole
Total projects and institutions supported in FY 89	23	5

a need to continue to develop technology to enhance rapid and precise exploration surveys, particularly for heavy mineral placer deposits, cobalt-enriched manganese crusts, and polymetallic sulfides, and tools for recovering and processing these new resources.

Environmental Studies: environmental concerns arising from the exploitation of nonliving marine resources remain a major concern and have been studied at a number of Sea Grant institutions. These have included work on the impact of: manganese nodule mining on benthic organisms, environmental aspects of suction cutter-head dredging, problems associated with disposing of the byproducts of processing manganese nodules, containment of oil spills or dredged material, ground water contamination, and comparative effect of biota of oil and oil dispersions fluids. These and related studies indicate that different geological, oceanographic and meteorological conditions will clearly affect ocean miners. Research is needed to determine the environmental consequences of mineral resources recovery with

special attention to the sediment plume produced by recovery operations at the mining site, possible toxic trace metals associated with mineral recovery or processing, displacement of bottom communities, and coastal zone impacts from offshore mining.

Policy Studies: Key to the successful development of mineral resources of the EEZ and adjacent areas is a thorough understanding of the incentives which stimulate investment in frontier areas and of the legal and regulatory arrangement needed to balance resource recovery and environmental protection. To facilitate accelerated mineral recovery off the coast of the United States, an analysis is needed of political and economic incentives for exploration and exploitation of these resources as well as legal and regulatory conditions for developing offshore mining and waste disposal in the Exclusive Economic Zone.

Waste Disposal in the Ocean: The assimilative capacity of the oceans and seafloor are a potential vast resource. Yet limited knowledge about the long-term effects of dumping wastes in the oceans has made design of a balanced program of land and marine disposal extremely difficult. Storage of radioactive wastes is a particularly vexing issue, as is the technical feasibility of insulating wastes from the marine environment by covering the disposed materials with clean sediment. The decreasing land area available for waste disposal in large coastal urban areas requires a research program to evaluate the environmental, economic, legal, and political aspects of disposal or storage of wastes in the ocean. The large range of unknowns about the consequences of this ocean makes it imperative that work accelerate on topics as diverse as sewage and dredge disposal, general land runoff into the sea, and the impact of low and high level radioactive wastes on the marine environment.

Data Management: A longstanding problem is the formatting and storage of data. Research is needed to improve the processing, protection, access, and application of geophysical and geological information. Toward this goal, NOAA and the Colorado School of Mines recently established a Cooperative Institute for Geodata Management and Application. The intent of the Institute is to include researchers from industry and other government agencies and universities. Sea Grant researchers are encouraged to participate in this effort by targeting specific mineral commodity groups for improved archiving and storage of existing information of value to exploration and exploitation activities.

Sea Grant researchers have been quite responsive to these national needs. As indicated in Table XIII, of the 22 projects in nonliving resources, most can be identified with one or more of the various priority areas identified for FY 89. The priority areas for FY 90 remain similar with those of the previous year and reflect the research issues discussed above. For FY 90, the priority areas are:

High Priority Research

- Assessment of EEZ hard mineral and newly discovered deep sea minerals (polymetallic sulfides and cobalt-rich manganese crusts), particularly those of strategic significance.
- Development of a suite of monitoring techniques that accurately senses change in the marine environment from extraction activities, and which can be conducted in an efficient and cost-effective manner.
- Refinement or development of mineral exploration and prospecting technology and practices that conserves time and energy.
- Studies supporting the objectives of NOAA's Ocean and Coastal Resource Management's deep seabed mining marine environmental research plan.
- Provide adequate research on marine geologic resources in the EEZ to provide data necessary for rational decision making and management, including the use of, the sea or sub-seafloor for storage of waste.

- o Improve the processing, protection, access, and application of geophysical and geological information.

Low Priority Research

- o Assessment of marine sand and gravel resources.
- o Resource research and assessment of manganese nodules.
- o Economics of deep seabed nodule mining activities.

PROJECTS

A. Marine Geology and Geological Resources

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
1. California		
Black Smoker: Vents for Ocean Thermal Power V. Anderson /40/ 22 University of California Sea Grant College Program	65,537	16,137
SUBTOTAL:	$ 65,537	$ 16,137
PASS-THROUGH:	0	
2. Hawaii		
TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Microbial Geochemistry J.P. Cowen 09 University of Hawaii Sea Grant College Program	25,354	18,213
Biostratigraphy to Date Crust E.H. De Carlo 09 University of Hawaii Sea Grant College Program	21,414	11,898
Stratigraphic History of Crusts A. Malahoff 09 University of Hawaii Sea Grant College Program	24,938	13,041

Geology of Hydrothermal Systems A. Malahoff 09 University of Hawaii Sea Grant College Program	25,006	15,001
Isotopic Stratigraphy J. Mahoney 09 University of Hawaii Sea Grant College Program	37,755	29,223
Geochemistry of Vent G. McMurtry 09 University of Hawaii Sea Grant College Program	25,118	15,000
Stable Isotope Studies of the Cobalt-Rich H. Yeh 09 University of Hawaii Sea Grant College Program	18,405	11,266
Alternate Economic Deposits J.C. Wiltshire 10 University of Hawaii Sea Grant College Program	9,280	10,800
Crusts Magnetic Materials G. Andermann 10 University of Hawaii Sea Grant College Program	9,705	24,698
Microbiology and Chemistry of Vents D. Karl 32 University of Hawaii Sea Grant College Program	22,000	21,652
SUBTOTAL:	$ 218,975	$ 170,792
PASSTHROUGH:	0	

3. Massachusetts/Woods Hole O.I

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Estimation of Supply Rate of Heat and Metals to Black Smoker Vent Fields J.R. Cann 09 Woods Hole Oceanographic Institution Sea Grant Program	25,000	15,400
International Marine Science Cooperation Program D.A. Ross 20 Woods Hole Oceanographic Institution Sea Grant Program	85,900	86,010
Cyclical Behavior in Marine Minerals Exploration and R&D: Signals, Sources, and Implications J.M. Broadus 14 Woods Hole Oceanographic Institution Sea Grant Program	45,400	40,863

Shallow Water Swath-Mapping Systems J.S. Jaffe 39 Woods Hole Oceanographic Institution Sea Grant Program	53,000	7,779
Oceanographic Investigations, Johnston Atoll, for Assessing the Impacts of Deep Ocean Disposal of Liquid Brine from the Jacad P.S. Lobel 45 Woods Hole Oceanographic Institution Sea Grant Program	0	0
SUBTOTAL:	$ 209,300	$ 150,052
PASS-THROUGH:	$ 18,905	

4. Mississippi/Alabama

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Continental Shelf Hardbottom Environments: Distribution, Classification and Biology W. Schroeder 40 Mississippi/Alabama Sea Grant Consortium	60,000	44,119
SUBTOTAL:	$ 60,000	44,119
PASSTHROUGH:	0	

5. Oregon

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Investigation of Sources, Geometries and Compositions of Potential Titanium- and Zirconium-bearing Placer Deposits C.D. Peterson 09 Oregon Sea Grant College Program	35,100	39,900
SUBTOTAL:	$ 35,100	$ 39,900
PASSTHROUGH:	0	

6. Washington

TITLE/INVES./INST.	FEDERAL FUNDS	MATCH FUNDS
Co-variation in Hydrothermal Output and Earthquakes Activity: A Ridge Crest Time-series Experiment J.R. Delaney 09 Washington Sea Grant College Program	66,900	42,000

A Proposal to Develop a Deep Ocean Rock Coring Drill H.P. Johnson 09 Washington Sea Grant College Program		50,400	23,300
Ridge Planning Office J.R. Delaney /601/ 09 Washington Sea Grant College Program		0	0
	SUBTOTAL:	$ 117,300	$ 65,300
	PASS-THROUGH:	30,000	

Diving and Physiology, Safety and Technology Development

Summary

To ensure that NOAA remains in the forefront of diving research providing scientists with state-of-the-art undersea capabilities and ensuring maximum safety, an emphasis within Sea Grant must be placed on new diving related research, both of a fundamental and applied nature.

Six research projects addressing different aspects of diving were conducted FY '89 by Sea Grant institutions using Federal funds which totalled $431,238. In addition, the supporting organizations provided more than $132K in matching funds.

Discussion

Sea Grant's Annual Program Guidance document for 1989 states that the emphasis on diver physiology remains constant, and includes efforts that focus on safety and survival of commercial and recreational divers. Oxygen toxicity, sensitivity to carbon dioxide, and onset of bubbles in the body all limit in some way our ability to work safely and effectively in the oceans and on the sea floor. Accordingly, high priority should be placed in research in these areas.

There will always be a need for "wet" diving in undersea related research. While the remotely operated vehicle, may be able to perform some tasks presently performed by divers, they cannot provide the mobility, manipulative diversity, nor the decision capability of a diver in situ at the research site. ROV's however, are and will be valuable as adjunct tools used in support at depths where divers cannot operate.

It is therefore imperative that all aspects of diving related research from hyperbaric physiology at the cellular level to the development of operational equipment be continued and enhanced. The ultimate objectives are to enhance the capabilities and effectiveness of the researchers in the water and to further ensure their safety and well-being, has been legislatively mandated by the U.S. Congress.

In addition to responding to NOAA's programmatic requirements for both operational and scientific diving support, NOAA's diving research program responds to the direction provided by the 1978 Outer Continental Shelf Lands Act Amendment, Section 21 (e):

> "The Secretary of Commerce, in cooperation with the Secretary of the Department in which the Coast Guard is operating and the Director of the National Institute for Occupational Safety and Health, shall conduct studies of underwater diving techniques and equipment suitable for protection of human safety and improvement diver performance. Such studies shall include, but need not be limited to, decompression and excursion table development and improvement and all aspects of diver physiological restraint and protective gear for exposure to hostile environments."

The Secretary of Commerce gave the responsibility for implementing this section to NOAA. In addition to sponsoring the actual research, NOAA serves as a bridge between basic research and applied and operational aspects of diving; provides "outreach" to all sectors of the diving community; and serves as a "focal point" for diving research within the federal agencies.

In 1985, a special review committee, headed by Dr. Feenan Jennings was charged by the Administrator of NOAA to conduct an in-depth review of NOAA's undersea program and provide

recommendations for its future direction. The final report stated that NOAA was responsible for:

> "...Fundamental research and applied research and development driven by a mission to support the nation's civilian needs and interests in ocean exploration, industrial and economic development, conservation of coastal and oceanic resources, and knowledge to support effective management of the nation's ocean affairs."

With respect to diving research the panel made the following recommendations:

> "NOAA continue its biomedical and diving safety research and public awareness activities as part of the national undersea research program."

> "NOAA consult with the National Institute of Health, the Navy and other relevant agencies and organizations to identify the highest priority research needs in this area and to develop a coordinated, national effort to address those needs."

Sea Grant can and should play a major role in this area. While in the past, NOAA's Diving research activities primarily emphasized hyperbaric physiology, the program has been expanded to include the areas of at-sea operations, safety, emergency response, medical considerations, environmental effects, technology development, and data dissemination.

The nature of the expanded scope will include but not be necessarily limited to:

1. Fundamental hyperbaric physiological research - all levels from cellular to systemic.

2. Practical Operations - procedures, constraints, physical and technological limitations, table development, and topside support requirements.

3. Safety - certification/training requirements, epidemiological information on diving related accidents and fatalities, and diving accident management.

4. Medical aspects - treatment of diving related accidents, hyperbaric equipment, emergency equipment, procedures and protocol, diving in remote locations.

5. Environmental impacts on divers - hazardous materials and pathogens, ambient temperatures, and psychological concerns.

6. New technology development - "tools" to complement the diver's capability systems that enhance his underwater abilities and equipments and procedures that increase his or her safety and well being.

7. Data dissemination - workshops/symposiums, papers, abstracts, bibliographies, and data repositories.

These activities are applicable to the entire diving community including all levels of government, academia, industry, research organizations, military, and recreational sectors.

In looking to the future, numerous scientific areas and topics related to diving should be examined. These efforts would involve administrators and researchers from government, academia, industry, private research groups, and the recreational diving sectors. They, in turn, would provide a synergism for the solution of the various problems.

Six research projects addressing different aspects of diving were conducted FY '89 by Sea Grant institutions using Federal funds which totalled $431,238. In addition, the supporting organizations provided more than $132K in matching funds.

Objectives for FY '89 Projects

1. Applied Physiology of Diving

   a. To verify the hypothesis of interspecies conversion of decompression tables.

   b. To quantify and evaluate the physiological responses to diving, compression, and decompression, including avoidance of decompression

sickness and improvement of diving safety.

2. Microbiological Hazards Associated with Diving in Polluted Waters: An Epidemiological Study

   a. To determine if rapid serological techniques can be adapted.

   b. To provide a field hazards test kit.

   c. To determine if divers exposed to polluted waters are at risk of contracting waterborne diseases.

   d. To develop a computerized datasystem for assessing potential hazards of diving in polluted waters.

3. Prediction and Prevention of Panic Behavior in SCUBA Divers.

   a. To evaluate the predictive power of the PI's recently developed laboratory model under realistic diving conditions to validate the model's ecological validity.

   b. If the existing laboratory model proves to be generalizable, and they are able to predict performance and panic behavior in pool and lake settings, they will then proceed to focus on the efficacy of selected behavioral techniques designed to prevent panic behavior and enhance performance.

   c. If the existing laboratory model is found to lack ecological validity, an effort will be made to refine the model prior to evaluating intervention strategies.

4. Studies in Decompression

   a. To take advantage of two significant discoveries by this research group, two studies are proposed:

   b. Bone necrosis -- use the U.W. sheep model of dysbaric osteonecrosis to define the pathogenesis and course of that disease with emphasis on detection and treatment.

   c. Decompression sickness (DCS) types and incidence -- further define the influence of dive profile on the incidence and avoidance of serious forms of DCS.

5. Body fluid balance during a 7-day Nitrox saturation dive at 2.5 ATM.

   a. To examine the dependence of hyperbaric diseases on gas density and increased fluid intake.

   b. Measure dehydration of divers exposed to high pressure.

   c. Examine interaction between suppression of insensible water loss and hyperbaric diuresis.

6. Decompression Sickness: Pharmacological Control of Inert Gas Elimination

   a. To enhance the rate of tissue nitrogen elimination during normoxic breathing by using cardiovascular drugs and/or carbon dioxide.

   b. To reexamine the most effective cardiovascular agents under hyperoxic conditions commonly encountered in diving situations.

PROJECTS

TITLE/INVES./INST.		FEDERAL FUNDS	MATCH FUNDS
Applied Physiology of Diving Lin, Yu-Chong University of Hawaii Sea Grant College Program		31,299	24,337
Microbiological Hazards Associated with Diving in Polluted Waters: an Epidemiological Study Colwell, Rita R. University of Maryland, College Park		151,000	0
Decompression Sickness: Pharmacological Control of Inert Gas Elimination Claes E.G. Lundgren State University of New York at Buffalo		57,636	43,997
Studies in Decompression Lanphier, Edward University of Wisconsin, Madison		132,783	38,085
Body Fluid Balance During a 7-day Nitrox-saturation Suk Ki Hong New York Sea Grant Institute		6,975	10,555
Prediction and Prevention of Panic Behavior in Scuba Divers Morgan, William P. University of Wisconsin, Madison		51,445	15,463
	SUBTOTAL	$ 431,238	$ 132,437
	PASSTHROUGH	$ 157,975