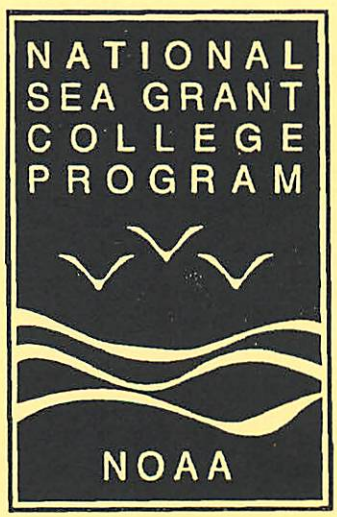
Sea Grant Review

1990 through 1992



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
November 1993

The National Sea Grant College Program, a unique partnership with public and private sectors combining research, education and technology transfer for public service, is the national network of universities meeting changing environmental and economic needs of people, industry and government in coastal, ocean, and Great Lakes states.

CONTENTS

INTRODUCTION

Between 1978 and 1989, the National Sea Grant Office staff issued an annual document which combined program reports discussing each subject area and a listing of the projects funded during that fiscal year. While program reports were not published in fiscal years 1990 and 1991, the funded project lists were issued as *Projects '90* and *Projects '91*. This year, two documents have been prepared, *Projects '92* and this *Sea Grant Review: 1990 through 1992* which summarizes the status and achievements of each subject area during the past three years.

Sea Grant supports multidisciplinary research and outreach activities that encompass 18 broad subject areas. These areas fall within five major classifications—Living Resources, Human Resources, Technology and Commercial Development, Environmental Studies, and Non-Living Resources. This review's organization reflects that classification system.

Although significant accomplishments are reported for each subject area, the level of effort among areas varies. Outreach funding, Marine Advisory Services (MAS) and communications, has increased by approximately 16 percent over the last nine years. However, the difference between that increase and inflation has resulted in a loss of 66 positions in MAS alone. Sea Grant is committed to education, teacher training, and marine literacy but, despite this, the downward funding trend of the 1980s continues. The biological sciences, particularly in fisheries, environmental studies and aquaculture, continue to receive the greatest proportion of the research dollar. The marine biotechnology level of effort continues to increase, but effort has decreased in all other subject areas. This trend is disturbing, because it is in areas such as ocean engineering, marine economics, and social science and marine policy that Sea Grant historically has had its greatest impact.

The Sea Grant directors shape programs to exploit the strengths of participating institutions, to focus on regional and national issues, and to address priorities set by the National Sea Grant Office for research, education and training, and advisory services. Decentralized, day-to-day management results in effective cooperation in marine affairs among academic institutions and federal, state and local governments.

The research programs, while normally dealing with local, state, or regional topics produce results of generic importance that advance science, solve problems, and exploit opportunities for the wise use and development of the nation's marine, coastal, and Great Lakes resources. Peer review is used to select these projects and reconcile proposals with budgets. Successful proposals often have an applied focus even if application relates to the very long term. The combination of research, education, and advisory services in a single program makes technology transfer much more effective. Sea Grant encourages researchers, educators, and advisory personnel to work across institutional and program lines, and such cooperation and collaboration have proven successful.

SEA GRANT PROGRAM DIRECTORS

***ALASKA**
Mr. Ronald Dearborn, Director
Alaska Sea Grant
University of Alaska
304 Eielson Bldg.
Fairbanks, AK 99775-5040
907/474-7086

***CALIFORNIA**
Dr. James Sullivan, Director
California Sea Grant
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093
619/534-4440

***CONNECTICUT**
Dr. Edward C. Monahan, Director
Connecticut Sea Grant
University of Connecticut
1084 Shennecossett Road
Groton, CT 06340
203/445-3457

***DELAWARE**
Dr. Carolyn Thoroughgood, Director
Delaware Sea Grant
University of Delaware
Robinson Hall, Room 111
Newark, DE 19716
302/831-2841

***FLORIDA**
Dr. James C. Cato, Director
Florida Sea Grant
University of Florida
Building 803
Gainesville, FL 32611
904/392-5870

***GEORGIA**
Dr. Mac Rawson, Director
Georgia Sea Grant
University of Georgia
Ecology Building
Athens, GA 30602
706/542-7671

***HAWAII**
Dr. Jack R. Davidson, Director
Hawaii Sea Grant
University of Hawaii
1000 Pope Road, Room 223
Honolulu, HI 96822
808/956-7031

+ILLINOIS-INDIANA
Mr. Robert Espeseth, Coordinator
University of Illinois
Room 104, Huff Hall
1206 S. Fourth St.
Champaign, IL 61820
217/333-1824

Joseph T. O'Leary, Co-coordinator
Purdue University
Dept. of Forestry and
Natural Resources
1200 Forest Products Bldg.
W. Lafayette, IN 47907
317/494-3622

***LOUISIANA**
Dr. Jack R. Van Lopik, Director
Louisiana Sea Grant
Louisiana State University
128 Wetland Resources
Baton Rouge, LA 70803-7507
504/388-6710

***MAINE**
Dr. Robert E. Wall, Director
ME/NH Sea Grant
University of Maine
14 Coburn Hall
Orono, MN 04469-0114
207/581-1436

***MARYLAND**
Dr. Christopher F. D'Elia, Director
Maryland Sea Grant
University of Maryland
0112 Skinner Hall
College Park, MD 20742
301/405-6371

***MASSACHUSETTS**
Dr. Chrys. Chryssostomidis
MIT Sea Grant
Massachusetts Institute
of Technology
Bldg. E38, Room 330
77 Massachusetts Avenue
Cambridge, MA 02139
617/253-7131

***MICHIGAN**
Dr. William Vorus, Director
Michigan Sea Grant
University of Michigan
4107 I.S.T. Building
2200 Bonisteel Boulevard
Ann Arbor, MI 48109-2099
313/763-1437

***MINNESOTA**
Dr. Steven Laursen, Acting Director
Minnesota Sea Grant
University of Minnesota
Room 302
1518 Cleveland Avenue, North
St. Paul, MN 55108
612/625-9288

***MISSISSIPPI-ALABAMA**
Dr. Jesus B. Tupaz, Inter. Director
MS/AL Sea Grant Consortium
P.O. Box 7000
703 East Beach Drive
Ocean Springs, MS 39564-7000
601/875-9341

***NEW HAMPSHIRE**
Dr. Ann Bucklin, Director
ME/NH Sea Grant
University of New Hampshire
Kingman Farm
Durham, NH 03824
603/749-1565

***NEW JERSEY**
Dr. George Klein, Director
NJ Marine Sciences Consortium
Building No. 22
Ft. Hancock, NJ 07732
908/872-1300

***NEW YORK**
Dr. Anne McElroy, Director
New York Sea Grant Institute
Nassau Hall
Stony Brook, NY 11794-5000
516/632-6905

***NORTH CAROLINA**
Dr. B. J. Copeland, Director
North Carolina Sea Grant
North Carolina State University
Box 8605
Raleigh, NC 27695-8605
919/515-2454

***OHIO**
Dr. Jeffrey M. Reutter, Director
Ohio Sea Grant
Ohio State University
1541 Research Center
1314 Kinnear Road
Columbus, OH 43212
614/292-8949

***OREGON**
Dr. Robert E. Malouf, Director
Oregon Sea Grant
Oregon State University
Administrative Services Bldg.-A320
Corvallis, OR 97331-2131
503/737-3396

***PUERTO RICO**
Dr. Manuel Hernandez-Avila, Director
Puerto Rico Sea Grant
University of Puerto Rico
Department of Marine Science
P.O. Box 5000
Mayaguez, PR 00681-5000
809/832-3585

***RHODE ISLAND**
Dr. Scott W. Nixon, Coordinator
Rhode Island Sea Grant
University of Rhode Island
Narragansett Bay Campus
Narragansett, RI 02882-1197
401/792-6800

***SOUTH CAROLINA**
Ms. Margaret Davidson, Director
South Carolina Sea Grant Consort.
287 Meeting Street
Charleston, SC 29401
803/727-2078

+SOUTHERN CALIFORNIA
Dr. Douglas Sherman, Director
U. of Southern California Sea Grant
Hancock Institute for Marine Studies
University Park
Los Angeles, CA 90089-0341
213/740-1961

***TEXAS**
Mr. Feenan Jennings, Director
Texas Sea Grant
Texas A&M University
1716 Briarcrest Drive, Suite 702
Bryan, TX 77802
409/845-3854

***VIRGINIA**
Dr. William L. Rickards, Director
Virginia Graduate Marine Sciences Consortium
Madison House - 170 Rugby Road
Charlottesville, Virginia 22903
804/924-5965

***WASHINGTON**
Mr. Louie S. Echols, Director
Washington Sea Grant
University of Washington, HG-30
3716 Brooklyn Avenue, N.E.
Seattle, WA 98105-6716
206/543-6600

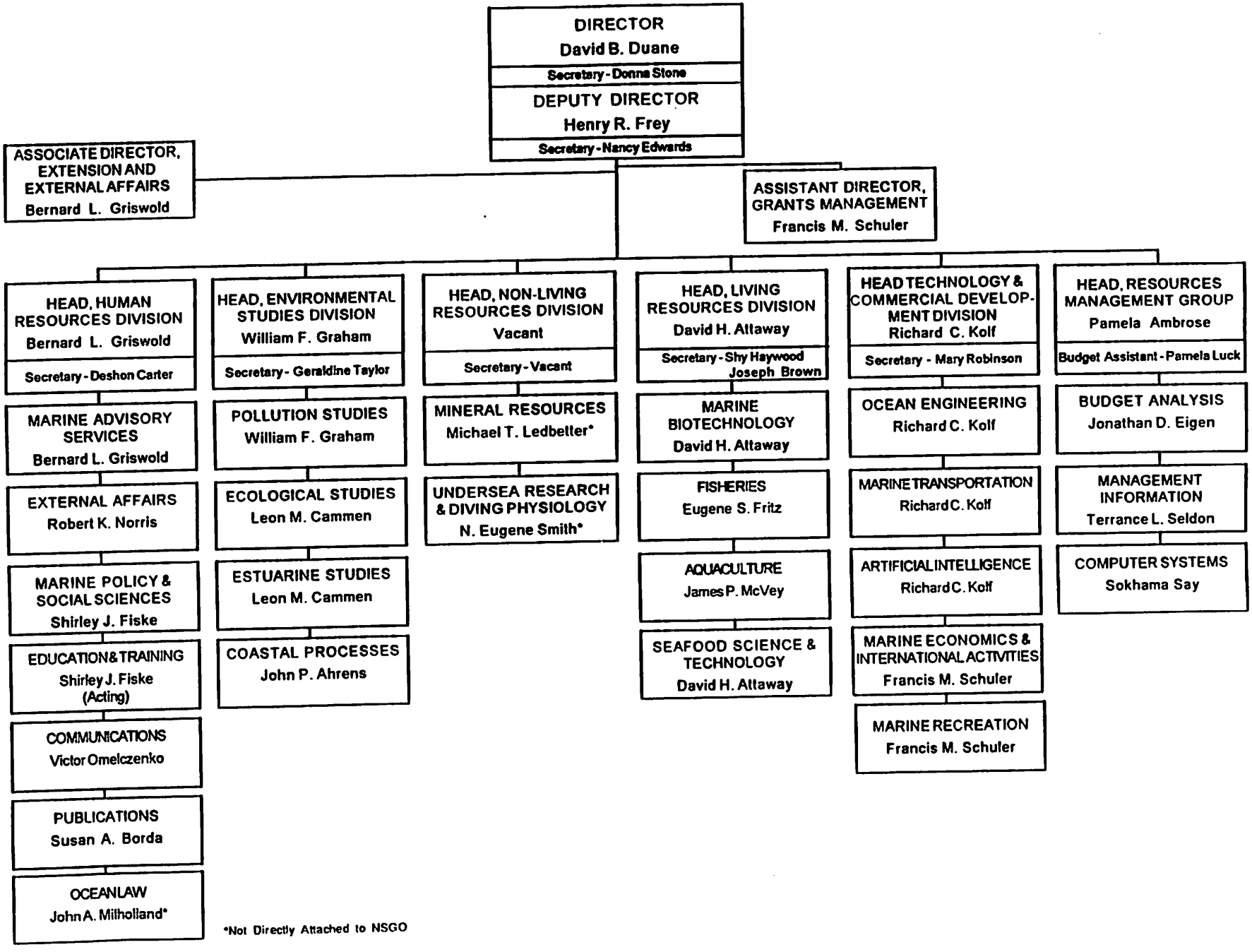
***WISCONSIN**
Dr. Anders Andren, Director
Wisconsin Sea Grant
University of Wisconsin-Madison
1800 University Avenue
Madison, WI 53705
608/262-0905

+WOODS HOLE
Dr. Judith McDowell, Director
WHOI Sea Grant
Woods Hole Oceanographic Institution
CRL 209
Woods Hole, MA 02543
508/548-1400 ext. 2665

* Sea Grant College (Total 26)
(ME/NH=1)

\+ Institutional Program (3)

NATIONAL SEA GRANT OFFICE



*Not Directly Attached to NSGO

SEA GRANT TECHNICAL STAFF

Following is a listing of Sea Grant's technical staff, their subject area(s), and their phone numbers. They can be reached at the following address:

National Sea Grant College Program
National Oceanic and Atmospheric Administration
1315 East-West Highway
SSMC3, 11th Floor
Silver Spring, MD 20910

Living Resources **301/713-2451**
Aquaculture - Dr. James P. McVey
Fisheries - Dr. Eugene Fritz
Marine Biotechnology - Dr. David H. Attaway
Seafood Science and Technology - Dr. David H. Attaway

Human Resources **301/713-2431**
Marine Advisory Service - Dr. Bernard Griswold
Zebra Mussels - Dr. Bernard Griswold
Education and Training - Dr. Shirley Fiske
Social Science and Marine Policy - Dr. Shirley Fiske
Communications - Mr. Victor Omelczenko
Ocean Law - Mr. John Milholland

Technology and Commercial Development **301/713-2445**
Ocean Engineering - Dr. Richard C. Kolf
Marine Economics - Dr. Francis M. Schuler
Marine Recreation - Dr. Francis M. Schuler
International Activities - Dr. Francis M. Schuler

Environmental Studies **301/713-2435**
Coastal Processes - Mr. John P. Ahrens
Environmental Studies - Dr. William F. Graham
Dr. Leon Cammen

Non-Living Resources **301/713-2713**
Marine Geological Resources - Dr. Michael T. Ledbetter
Diving Physiology, Safety, and Technology - Mr. N. Eugene Smith

LIVING RESOURCES

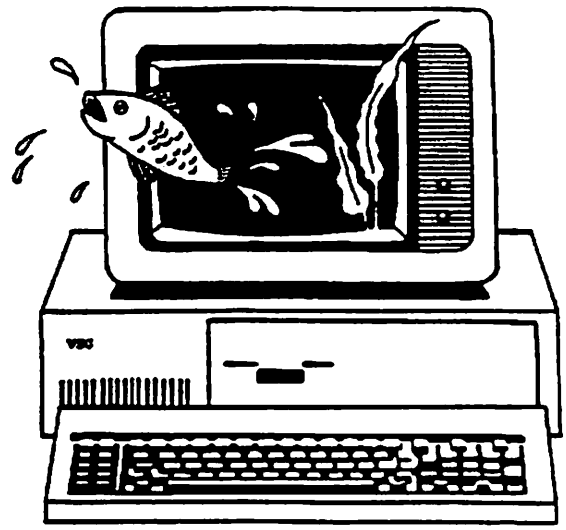
CHAPTERS

Living Resources

The four reports in this section cover aquaculture, marine biotechnology, fisheries, and seafood science. They discuss fundamental and applied research and its relevance to commercial development, industrial processing, and resource management. The reports not only provide examples of accomplishments and lists of recent publications, but suggest priorities and opportunities for future research.

Support for aquaculture, marine biotechnology, and seafood science has remained constant in recent years at $4.2/$2.8 million, $2.5/$1.7 million, 4.0/3.0 million, and $1.2/$0.9 million in federal/matching funds respectively. This reflects overall level funding for the National Sea Grant College Program during the same period. The apparent funding increase for marine biotechnology in fiscal year 1992 is primarily a result of including, for the first time, research that uses molecular techniques, especially DNA technology, to address resource management and environmental issues. Previously, research of this type was included only under fisheries or environmental studies. Some other types of research may be duplicated in more than one report because the boundaries between topics are not precise. Federal Sea Grant investment in fisheries research has declined 12 percent to $4 million since implementation of modified procedures for funding of proposals. Concurrently, however, fisheries research support with money provided by other federal programs, especially the Coastal Ocean Program, grew by 275 percent to $1.8 million.

The National Sea Grant College Program emphasizes research on living resources of the oceans and Great Lakes. In fiscal year 1992, about 27 percent of the program's federal funds, approximately $11 million, was used for this research. These funds, supplemented with approximately $10 million in nonfederal matching funds and "pass through" funds, supported 300 projects. A companion report—*Projects '92*—provides project titles, investigators, program affiliations, and the amount of federal, matching, and pass through funds.



Aquaculture

Introduction

The next two decades will see a dramatic change in the way seafood products are obtained. An increasing proportion of the seafood supply will come from aquacultural production, especially high market-value products. Today, many underdeveloped countries in tropical areas are gearing up for aquaculture production, primarily through shrimp culture. In 1991, approximately 28 percent of the world's shrimp was produced on farms. This production was valued at over $2 billion at wholesale prices. In 1992, the total hectares devoted to shrimp aquaculture, worldwide, was estimated at 1,000,000 (*World Shrimp Farming*, 1992). The United States has a small shrimp farming industry in South Carolina, Texas, and Hawaii which produce $6-8 million worth of shrimp.

In 1991, the United States imported 540 million pounds of shrimp valued at $1.9 billion (NMFS, *Fisheries of the United States*, 1991). Additional imports of high cost such as salmon, lobster, mollusks and other seafood brought the total seafood imports to $5.7 billion. With exports of $2.3 billion, the U.S. was left with a trade deficit of $2.9 billion in edible seafood. This is a definite improvement over recent years when the U.S. seafood trade deficit was as high as $5 billion. Increased U.S. aquacultural production has certainly contributed to this trade balance improvement, and the National Sea Grant College Program has provided a significant contribution to technology and outreach for this to happen.

How can the U.S. increase fisheries production even further to offset the large seafood trade deficit? An increase in traditional fisheries production cannot be expected unless major habitat improvement and restoration projects are initiated. In fact, worldwide commercial fisheries declined in 1990 for the first time in 12 years. 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 such as shrimp, lobster, and salmon. The latter approach is the most likely because Americans demand high-quality, recognizable seafood. Aquaculture production has increased at an annual rate of approximately 20 percent over the past decade. This rate is expected 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 College Program and by other agencies is responsible for expected increases in U.S. aquaculture investments and production over the next decade. In South Carolina, Sea Grant pond production research has shown that the use of aerators can provide yields of 20,000 kg/ha/yr of shrimp and can 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. New vaccines are being developed for salmonids that will make production more dependable and profitable. Improved strains of clams and

Analysis of Aquaculture Projects and Funding Fiscal Years 1979 to 1992
(thousands of dollars)

Year	No. of Projects	Federal Funding	Match Funding	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	8,135
1986	110	4,550	3,263	7,813
1987	121	4,544	3,111	7,655
1988	102	4,100	3,088	7,188
1989	94	3,637	2,861	6,498
1990	102	4,120	2,956	7,076
1991	105	3,856	2,906	6,762
1992	99	4,216	2,828	7,044

Table 1

oysters are now available for commercial production. Better knowledge of nutritional requirements for aquatic species has led to improved diets for a variety of species which has increased growth and survival, and engineering advancements have improved opportunities for water reuse systems and offshore production systems.

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

- Reduction of the foreign trade deficit.
- Increase of supplies of domestically produced, top quality seafood.
- 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 U.S. 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, many technical and socio-economic problems need to be solved before it can reach its full potential in order to help overcome the foreign trade deficit in fishery products.

For 25 years, Sea Grant has taken a strong role in developing aquaculture technology for marine, estuarine, and Great Lakes species. The National Aquaculture Act of 1980 and the National Aquaculture Development Plan of 1983 have provided a basic outline for Sea Grant's research. The plan was recently updated through efforts of the Joint Subcommittee on Aquaculture and a marine aquaculture analysis was put forth by the National Research Council. The National Sea Grant Office provides yearly guidelines to Sea Grant institutions in order to focus research proposals on 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 research needed to support the developing industry.

This report attempts to describe the projects funded for FY 1992 in relation to the areas and species designated in the yearly guidance document and to look at future directions for Sea Grant-funded aquaculture research.

Analysis of FY 1992 Aquaculture Projects and Funding

FY 1992 level of funding and number of projects remained approximately the same when compared to recent years (see Table 1). In fact, the funding levels for aquaculture-related projects has not changed significantly since 1980, despite the overall level funding experienced by Sea Grant.

In 1992, Sea Grant devoted $4,216,000 to aquaculture projects which included $269,345 in pass through funds from other agencies and was

matched by $2,828,000 of state funds for a total of $7,044,000. Funding was distributed through a competitive grants process based on peer review. The sustained funding level over the past two decades reflects the continued strong interest in aquaculture research by the individual Sea Grant institutions. Strong interest is also indicated by the relatively high level of matching funds for the aquaculture projects compared to the minimum 2:1 ratio that is required by law.

Aquaculture-related projects account for approximately 10.5 percent of the total Sea Grant budget for FY 1992. Marine Advisory Services (MAS) efforts in that area would add another 2.5 percent. The MAS program estimates that its aquaculture support has increased from a level of 10 percent to a level of 12 percent over the past five 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 2 compares the number of projects and the funding levels for FY 1988 through FY 1992 for these areas.

During the past few years, pass through funds have become more important for all programs due to level funding for the overall Sea Grant program, so they are included in the total budget allocated for aquaculture research in all the tables.

In 1992, the relative mix of projects remained about the same as in previous years even though many investigators and institutions have changed. Projects related to genetics and selective breeding and to physiology/endocrinology continue to receive emphasis and reflect the need to gain better control of organisms that are being grown in intensive culture conditions, which are considerably different from what is found in nature. It is becoming more important to understand the underlying physiological and endocrine systems of aquacultural species to 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.

Policy and economics projects increased again in FY 1992 and, given the stated needs of the industry, additional effort should be made to recruit social scientists and economists to conduct projects in these areas.

A Comparison of Funding for Subject Areas in FY 1988 Through FY 1992

	Amount of federal $ (# of proj.)				
Subject Area	1988	1989	1990	1991	1992
1. Aquaculture Systems	589(15)	411(14)	574(19)	704(19)	638(17)
2. Genetics	1,392(30)	1,304(27)	1,082(26)	1,087(25)	1,019(21)
3. Physiology/ Endocrinology	750(21)	922(20)	1,092(23)	7 98(20)	1,382(25)
4. Nutrition	318(11)	249(8)	210(9)	260(11)	247(9)
5. Disease/ Parasites	564(17)	596(17)	644(15)	832(20)	624(17)
6. Policy/ Economics	4(1)	0	401(6)	24(1)	94(5)
7. Other	483(7)	155(8)	117(4)	231(9)	212(5)
Total	4,100(102)	3,637(94)	4,120(102)	3,856(105)	4,216(99)

Table 2

A Comparison of Funding for Species in FY 1986/FY 1992

Species	No. of Projects		Federal Funding (K)	
	86	92	86	92
Fish				
General	12	13	358.3	651.7
Salmon	23	11	980.6	488.9
Striped Bass	1	3	26.8	178.2
Hybrid Striped Bass	4	2	128.0	155.7
Red Drum	1	4	15.4	144.1
Sturgeon	2	3	28.2	86.2
Lake Trout	2	0	28.0	0.0
Dolphin Fish (Coryphaena)	2	2	44.5	23.7
Croaker	0	1	0.0	cont.@
Flounder	0	2	0.0	29.8
Yellow perch *				
Walleye*				
Crustacean				
General	4	6	108.8	300.5
Prawn	2	0	105.2	0.0
Blue Crab	2	0	54.2	0.0
Marine Shrimp	11	8	461.1	274.0
Mollusk				
General	9	1	222.5	cont@
Hard Clam	9	3	287.4	222.3
Scallop	3	0	143.5	0.0
Oysters	12	4	414.7	186.8
Abalone	0	3	0.0	128.1
Mussel	0	2	0.0	72.6
Bacteria	0	2	0.0	59.3
Virus	0	2	0.0	76.5
Plants				
Higher Plants	1	2	42.1	27.6
Algae	5	9	259.0	409.8
Other	3	12	74.5	411.8

* Contained in Other "General" Projects

@ Continuing projects without additional budget

Table 3

Species Funding Analysis

Table 3 provides information on the species that have received research attention in FY 1986 and 1992. These years were chosen to give a good spread for comparison. An analysis of the FY 1992 funding by species relative to the Sea Grant Aquaculture Plan shows good agreement with the plan. More than 75 percent of the species mentioned in the plan have one or more projects assigned to them. For the most part, species not covered by FY 1992 projects are minor ones that may be developed later after the higher priority species are addressed.

In comparing FY 1986 to FY 1992, several trends can be deduced. More resources are being applied to projects that are not associated with a specific species and that are more general in nature. Salmon projects which were above $1 million in the early 80s have declined to about $600 thousand, which is more in line with funding for the other major species. Hybrid striped bass and striped bass are both important in view of the still developing hybrid striped bass production industry. No projects on lake trout, freshwater prawn, blue crab, and scallops were included in the FY 1992 project list compared to FY 1986, indicating the dynamic character of Sea Grant funding. There was a dramatic increase in projects related to marine algae as the commercial potential of this broad group is becoming evident. This could be a growing area of research opportunity since algae lend themselves to biotechnology applications.

It is becoming more important to investigate marine finfish species that are good aquaculture candidates as both Asia and Europe are investing heavily in this group of fishes.

Work continues on the genetic manipulation of mollusk species. New strains and gene combinations are being tested and evaluated. More work is expected in this area since mollusks lend themselves to genetic studies.

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 an economical growout to marketable size. Interest continues in enhancement programs for these species and there are opportunities for work on stock improvement as well as development of broodstock strains.

The above analyses shows the dynamic character of Sea Grant funding with different species receiving fluctuating attention from year to year. In order of projects and resources, salmon, marine algae, marine shrimp, hard clams, red drum, and striped bass and their hybrids are well represented this year. Some projects on marine finfish were lost and there are no projects on freshwater prawns.

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
- Genetics/Selective Breeding
- Disease/Parasites
- Crustacean Reproduction

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 4 provides a summary of research activity by the various Sea Grant institutions.

In terms of projects and dollars, California, Washington, Texas and Maine/New Hampshire are the top four ranked Sea Grant aquaculture programs for FY 1992. As a result of an expanding salmon and mussel aquaculture industry, this is the first time that Maine/New Hampshire Sea Grant has been in the top nine programs. California Sea Grant, with its broad range of projects that tend to be high tech, has made a special effort to include species of interest to the state's industry. Washington Sea Grant continues its strong salmon aquaculture program with projects on fish disease, nutrition, and genetics. Texas Sea Grant funds projects devoted to shrimp and finfish aquaculture and has shifted its emphasis to more basic research using biotechnology and endocrinology to obtain greater control and understanding of shrimp and fish reproduction.

Because of a general reduction in projects, Hawaii Sea Grant has slipped from first place to fifth place, but it still maintains projects on marine finfish nutrition and genetics. Hawaii has ceased its work with freshwater prawns. More of the projects have elements of biotechnology than previously.

Georgia Sea Grant has moved up to sixth place with increased emphasis on aquaculture. Projects on hard clams and scallops are the main focus of the Georgia program and they are working closely with Louisiana Sea Grant on an algae production system for bivalve culture.

Seventh place is claimed by Maryland Sea Grant which is strong on biotechnology applications for both fish and mollusks. Biotechnology projects include manipulating genes and hormones in striped bass and oysters.

Oregon Sea Grant has slipped back to eighth place in FY 1992 and continues its strong program on disease control and vaccine development in salmonid fish.

North Carolina Sea Grant has also moved into the top-ranked states with projects focused on the hybrid striped bass industry requirements.

The data contained in Table 4 clearly shows that state programs constantly adjust to yearly research needs 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 92

Sea Grant research has led to several hybrid striped bass aquaculture farms in North Carolina, South Carolina, Virginia, and Maryland. The hybrid striped bass market appears to be holding but will depend upon the amount of production and demand over the next few years. More outreach activities are occurring since more farmers are becoming involved.

Grantee Effort in Aquaculture

Grantee	No. of Projects			Funding (K)		
	1988	1989	1992	1988	1989	1992
1. Alaska	3	4	2	114	134	84
2. California	9	6	11	400(3)	291(4)	481(1)
3. S. California	0	1	0	0	40	0
4. Connecticut	3	3	2	118(9	120	95
5. Delaware	3	1	1	47	10	18
6. Florida	2	6	4	45	185	165
7. Georgia	2	3	3	97	133	257(6)
8. Hawaii	10	9	10	529(1)	420(1)	263(5)
9. Illinois	1	2	1	16	66	41
10. Louisiana	3	4	4	87	132	117
11. MN/NH	3	3	7	114	123	304(4)
12. Maryland	8	5	4	300(4)	208(7)	245(7)
13. Woods Hole	2	0	1	80	0	29
14. MIT	0	1	2	0	43	80
15. Michigan	3	1	0	106	16	0
16. Minnesota	4	2	1	102	34	23
17. Miss./Alabama	1	3	2	50	119	58
18. New Jersey	3	2	1	0	49	110
19. New York	4	3	2	149(8)	143	93
20. North Carolina	4	4	5	116	85	200(9)
21. Oregon	4	5	5	209(7)	61(5)	227(8)
22. Puerto Rico	0	0	0	0	0	0
23. Rhode Island	1	2	2	20	75	94
24. South Carolina	4	3	3	221(6)	194(8)	149
25. Texas	10	8	11	427(2)	389(2)	323(3)
26. Virginia	2	3	2	30	186(9)	91
27. Washington	7	6	9	427(2)	387(3)	435(2)
28. Wisconsin	6	4	2	260(5)	210(6)	152

(#) Rank in Terms of Funding

Table 4

Technology developed through Sea Grant research is the basis for a new hard-shell clam farm in South Carolina. The farm, which began production two years ago, will harvest its first crop this year and will be the largest producer of clams on the East Coast. It presently employs 65 people and, in the future, will expand employment opportunities further as production increases.

A researcher at Harbor Branch Foundation in Florida has succeeded in spawning and rearing Nassau grouper for the first time in captivity. Approximately 30, two-year-old grouper were released on reefs in the Virgin Islands to determine the feasibility of stock enhancement for this valuable commercial species.

A new Patent (#5,161,481) was awarded to a University of Connecticut researcher for a "method for increasing crustacean larval production." The method, which uses a crustacean hormone called methyl-farnesoate, results in a 185 percent increase in viable larvae from shrimp broodstock. An industry cooperator is already using this method in a commercial shrimp hatchery.

California Sea Grant researchers have identified the amino acid sequence of the molt inhibiting hormone and the crustacean hyperglycemic hormone in the American lobster. Using this information, they can now proceed with development of hormone antagonists to speedup crustacean molting and growth or develop recombinant DNA techniques to inhibit the gene that produces the inhibitory hormone that controls growth. These approaches could have significant effects on the U.S. shrimp-culture industry.

Other work with crustacean reproduction by Florida Sea Grant has resulted in the isolation of the gene that codes for yolk protein in a commercial shrimp. It is hoped that application of this technology will lead to better quality eggs for use by shrimp farmers.

A Louisiana Sea Grant researcher, working with a private industry cooperator, has developed new biological filters which utilize a floating bead and increase the treatment of ammonia and nitrite by forty-fold. This has major implications for the development of aquaculture recirculating systems.

A Texas Sea Grant researcher has demonstrated the positive effect of beneficial bacteria on marine finfish production when the bacteria are added to hatchery tanks. Manipulation of the microbial community associated with aquaculture hatchery and production facilities offers an entire new area of research.

The National Sea Grant Office worked with the Department of Interior (DOI) again in FY 92 to continue the aquaculture development on Pacific Islands. DOI has provided funds to Hawaii Sea Grant to support giant clam research in Palau. Commercial sales of giant clams are nearing $300,000 per year based on technology developed through the joint DOI-Sea Grant program. 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. Other cooperation with DOI has led to the first harvest of marine shrimp on Guam and to the establishment of a hatchery for both marine shrimp and freshwater prawns to supply the farmers of the area. Success is also reported on the first commercial sponge farm on the island of Pohnpei. Tens of thousands of sponges are now nearing commercial size and initial market surveys are encouraging.

The National Sea Grant Office was also instrumental in developing a network (called Pacific Island Network or PIN) of NOAA representatives for the Pacific islands. The PIN is being funded by the Department of Commerce and DOI with project support from several other federal agencies operating in the Pacific. A full-time extension person was added to the island of Pohnpei and other positions were created on Kosrae, Saipan, and the Marshall Islands. A new PIN coordinator has been hired and is operating out of Hawaii. The network will support aquaculture and other marine resource development projects in the Pacific.

The National Sea Grant Office brought together a team of scientists to attend the meeting of the U.S.-Japan Cooperative Program in Natural Resources (Aquaculture Panel) that was held in Kyoto, Japan. The theme of the meeting was "Aquaculture and the Environment." The next meeting will be held in Alaska, August 1993, and the meeting theme will be "The Effect of Hatchery-produced Aquatic Species on Natural Populations."

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) which were adopted by the National Office 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 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; therefore, work of this type on those animals is low priority.

Environmental Requirements—An inadequate understanding of this aquaculture aspect continues to be manifested by problems of production variability in prawn and shrimp ponds, and by 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.

Recent work with beneficial bacteria in Japan and elsewhere has shown the impact of microbial community structure on aquaculture systems. Work to understand the microbiological interactions and the use of beneficial bacteria to condition aquaculture production systems is high priority.

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, the role of bacteria and other micro-organisms in providing nutrition to pond cultured species is just beginning to be understood. 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.

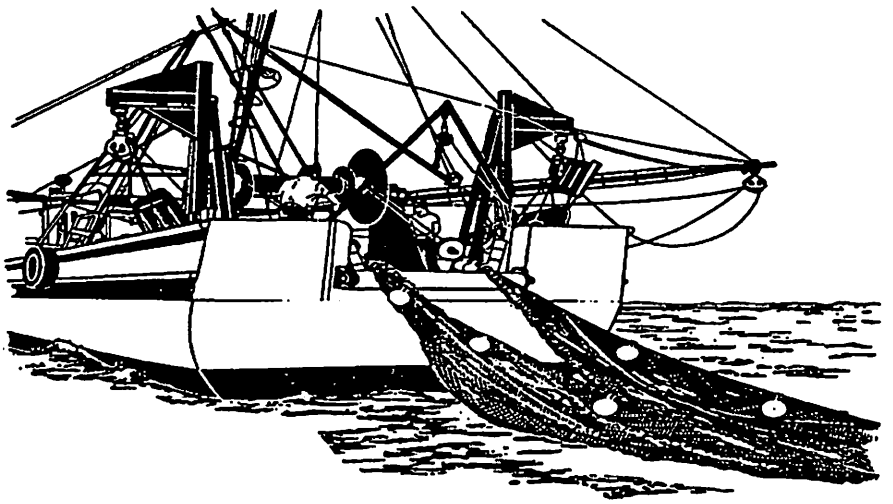
More work is needed to develop technology for the production of marine finfish. Evaluations of live planktonic foods as well as artificial diets should be continued. Environmental manipulation as well as hormonal manipulation of spawning should be compared and improved.

It is becoming apparent that there is a need for more control over the hormonal systems operating in all animal groups being cultured. Endocrinology studies should receive high priority.

As the aquaculture industry comes 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 industry economic guidelines. 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. There is 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, and sea bass might be tested on artificial reef substrates as part of the rapidly expanding U.S. artificial reef system to enhance recruitment and recreational fishing opportunities.



Fisheries

Introduction

Sea Grant's fisheries program focuses on research which supports management, the development of fishing technology, and sampling for management data. The program approach is multidisciplinary and depends on information from and advancements in other Sea Grant research areas such as aquaculture, biotechnology, environmental science, and engineering. Addressing some fisheries issues requires incorporating economics, policy, and social science in order to link biological and anthropologic factors affecting resources allocation and biological productivity. Most fisheries research focuses on identifying and predicting the abundance and distribution of fish populations and on maintaining, restoring, or enhancing stocks of recreational and commercial importance. It also provides information for reaching optimal use of resources.

Sea Grant's fisheries program is the primary source of support for coastal fisheries research, and Sea Grant is the only federal program attempting to set priorities for ameliorating problems in coastal fisheries science and management.

Sea Grant focuses not only on theory but on technological and scientific innovation. It also pursues research on underlying mechanisms and processes. The housing of both Sea Grant and the National Marine Fisheries Service in NOAA, with their connections to state fishery agencies, represents possibly the world's greatest intellectual base capable of addressing the complex problems confronting marine and Great Lakes fisheries.

Program Statistics and Trends

Program Statistics

The fisheries program supported 126, 124, and 127 projects in 1990, 1991, and 1992 respectively (Table 1). The Sea Grant federal funding level during this period was $4.545 M, $4.648 M, and $4.075 M (Figure 1). Matching funds during the period were $3.362 M, $3.229 M, and $3.016 M. Pass through funds received the past three fiscal years were $0.475 M, $1.553 M, and $1.790 M.

On average, 30 new projects were submitted for consideration during each of the National Sea Grant Office (NSGO) biannual competitive reviews. Approximately 90 percent of these projects met scientific standards needed to be considered for funding. Budget restraints did not permit funding all projects, therefore, each projected was evaluated and ranked according to the criteria listed in Table 2 and competed head-to-head with projects similarly ranked in other disciplines.

Twenty-five of the 29 Sea Grant programs support research in fisheries (Table 1). However, historically all programs have supported research in this subject area (Table 1).

Trends

Although the trend in the number of projects funded over the past decade has been downward, the decline observed in FY 1990 represents a substantial drop (Table 1). This decline is more significant in view of the fact that 14 projects are supported by the Coastal Fisheries Ecosystem

Fisheries Level of Effort for Each Institutional Program Fiscal Years 1983-1992

Program	Number of Projects											
	FY83	FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92	AVG*	STDEV*
AK	13	7	8	7	5	10	7	4	7	12	8	3
CA	14	11	21	18	22	8	11	11	8	14	14	5
CT	2	3	2	2	2	2	3	2	0	0	2	1
DE	1	1	5	3	0	0	2	1	3	2	2	1
FL	10	9	8	6	8	9	7	5	5	10	8	2
GA	6	3	4	3	2	4	3	0	2	5	3	2
HI	11	7	6	6	7	7	8	6	4	3	7	2
IL/IN	0	3	3	3	2	3	4	1	2	2	2	1
LA	5	2	2	2	10	5	4	5	6	3	4	2
ME/NH	8	6	9	8	5	3	6	6	6	7	6	2
MD	10	7	7	7	6	12	6	7	6	6	7	2
MIT	2	2	1	1	2	2	4	2	1	2	2	1
WHOI	5	4	5	2	3	2	1	2	4	3	3	1
MI	15	7	7	6	5	6	7	7	4	5	7	3
MN	2	3	5	3	3	4	4	5	5	2	4	1
MS/AL	2	2	2	2	2	2	2	2	3	1	2	0
NC	7	6	5	4	6	6	7	7	8	8	6	1
NJ	6	2	3	7	9	8	5	3	3	2	5	2
NY	8	8	11	8	4	5	8	10	7	6	8	2
OH	2	3	2	4	3	2	1	2	0	0	2	1
OR	10	6	5	3	4	3	4	4	4	3	5	2
PR	2	1	3	4	3	2	1	0	0	0	2	1
RI	4	2	4	3	3	6	4	5	4	2	4	1
SC	4	3	3	2	4	0	1	0	0	1	2	2
USC	1	0	0	0	0	1	1	0	0	0	0	0
TX	8	8	6	5	5	9	9	12	5	5	7	2
VA	7	5	7	6	6	5	6	5	8	4	6	1
WA	14	12	7	8	10	9	12	7	11	11	10	2
WI	12	15	9	9	12	9	4	5	7	7	9	3
CO	0	0	0	0	0	0	0	0	1	1	0	0
	191	148	160	142	153	144	142	126	124	127	146	19

*AVG = mean number of projects, STDEV = standard deviation

Table 1

theme of the Coastal Ocean Program (COP) and another five projects are supported by other components of the COP. The funding level during the past three years has decreased about 20 percent (Figure 1). Again, the decrease is more significant if COP-supported activities are discounted. The COP and other pass-through-supported activities have increased since FY 1989 (Figure 1). The changes observed in the "core" program can be attributed to the competitive review process implemented in FY 1990. The number of submitted fisheries projects did not decline; however, the number of more highly ranked projects in other disciplines increased.

This year, 62 projects or 49 percent conformed to the 1992 *Program Guidance* (Table 3). The level of conformity is consistent with previous years (Table 3). That there is not greater agreement with national priorities reflects the attention individual Sea Grant programs give to local and regional issues and opportunities. Although the level of compliance with the guidance is relatively high, the level of effort among priorities is uneven. Processes influencing recruitment and relating habitat to productivity receive the bulk of attention (Table 3). There is no effort in sampling gear development and only low levels of effort in population modeling and management scheme development.

Progress and Significant Achievements

Coastal Ocean Program:

As predicted in the *National Sea Grant College Program Fiscal Year 1989 Annual Report*, NOAA's Coastal Ocean Program initiated the Coastal Fisheries Ecosystem (CFE) Theme in FY 1991. The CFE focuses on three scientific issues: recruitment variability, compensatory mechanisms, and species interactions. Two multi-study projects were begun in FY 1991. The South Atlantic Bight Recruitment Experiment (SABRE), funded at $1.0 M

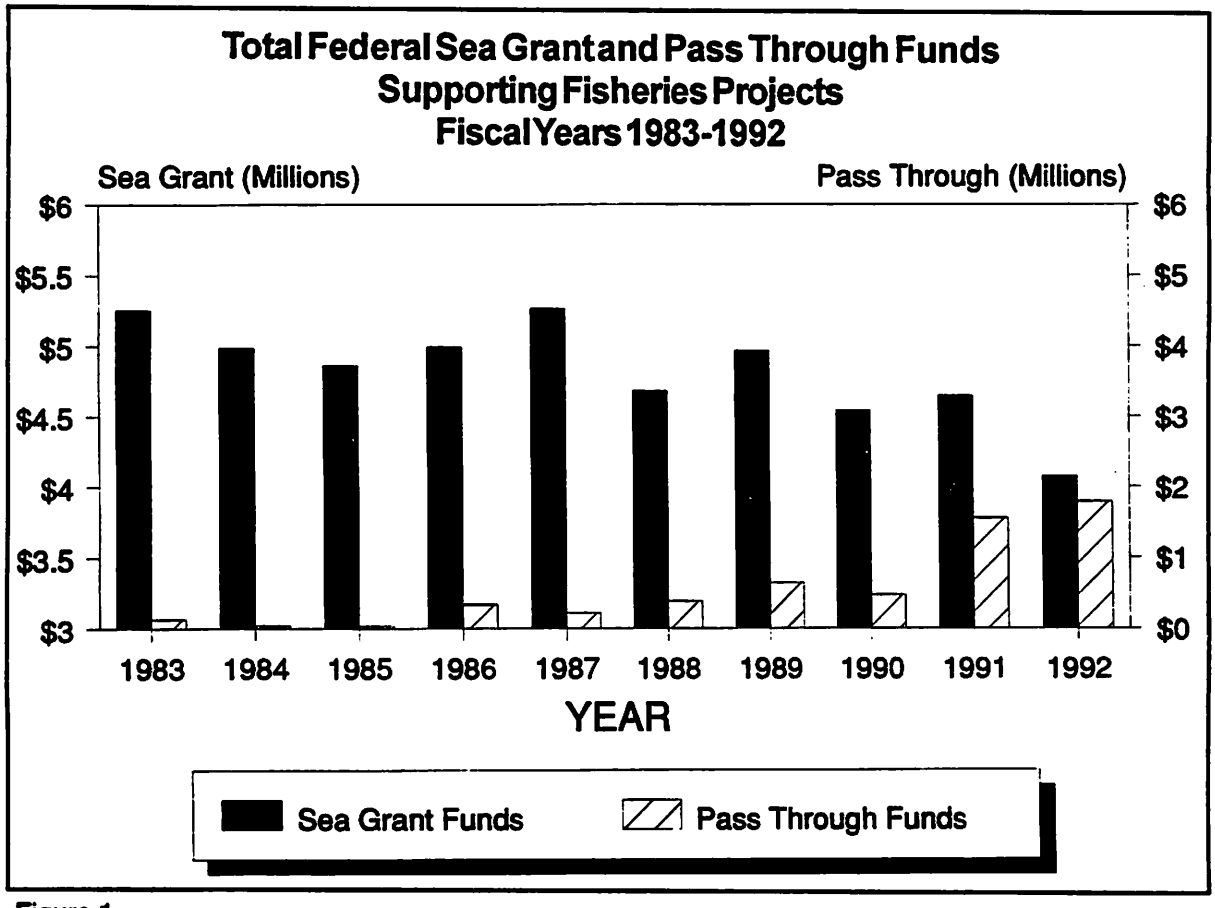


Figure 1

Criteria Used to Evaluate and Rank Research and Education Projects

- Rationale
- Scientific Merit
- User Relationship
- Innovativeness
- Programmatic Rationale
- Relationship to Sea Grant Priorities
- Qualifications and Past Record of Investigators

Table 2

per year, seeks to understand the relationship between variation in environmental factors and the variability in recruitment of "estuarine dependent" fishes of the South Atlantic Bight. Atlantic menhaden life history is examined with respect to offshore spawning, onshore transport, estuarine development, and offshore transport and migration to determine if, when, and where bottlenecks occur to limit recruitment. The second project, Bering Sea Fisheries Oceanography Cooperative Investigation (FOCI), funded at $0.95 M per year, studies the relation between larval walleye pollack transport and recruitment to the central Aleutian Basin pollack fishery. Another project entitled "Predation and the Structure of the Georges Bank Ecosystem" successfully competed for additional Coastal Ocean Program funds that became available in FY 1993. The objective of this project, funded at $450 K in FY 1993, is to examine the interactive effects of predation and exploitation on recruitment and overall productivity of fish populations on Georges Bank. All projects are funded for three years after which they will be reviewed for additional support for up to two more years.

Projects comprising the CFE consist of coordinated studies conducted by scientists from federal and academic laboratories. The CFE set as a funding goal a 60/40 percent split between federal and nonfederal researchers. Whereas funds are passed by the Coastal Ocean Program Office to a "lead" federal laboratory, most grants to academic institutions are made as Sea Grant pass through grants. Although the funding level of CFE projects is high in comparison to Sea Grant efforts, the complexity and scale of these are such that many important ancillary studies cannot be supported. Accordingly, opportunities exist for Sea Grant to take advantage of ship time and other available resources in pursuit of research benefiting both programs.

Blue Crab Program:

For more than 12 years, Sea Grant has supported blue crab research and outreach activities. Much of the research deals with identifying the factors controlling population abundance. Early efforts demonstrated that adults spawn at the mouths of estuaries; spend larval stages in surface waters over the continental shelf; and at the last larval stage, megalopa, enter estuaries where they settle and metamorphose into juveniles. The current research focus is on identifying the mechanisms that facilitate reentry into estuaries and the factors influencing survival of juvenile crabs. In 1989, a group of Sea Grant-supported researchers established an informal group whose aim was to coordinate blue crab recruitment research throughout its range in the United States. Building on their research, the group developed and submitted to the CFE a project proposal entitled "Gulf and Atlantic Recruitment Program" (GARP) which sought to investigate the blue crab recruitment process along the Atlantic and Gulf of Mexico coasts. This proposal was not funded by the CFE, but the investigators were encouraged to seek additional Sea Grant support. After negotiations, it was agreed that the NSGO would support some elements of GARP provided the investigators could obtain local Sea Grant director support and that individual proposals could withstand peer review. Presently, eight projects associated with this effort are being supported at Sea Grant colleges from New York to Louisiana.

Crustacean Recruitment Research:

Progress has been made on a number of fronts in crustacean recruitment research other than blue crab. Research on Dungeness crab in Washington coastal waters suggests a life cycle similar to the blue crab. Adults spawn in nearshore waters, larval stages inhabit offshore surface

waters, and megalopa are transported to nearshore waters and settle out in shallow benthic environments along the coast or in estuaries. The largest number of juveniles per unit area are found in the estuaries, but the largest total number occur in coastal benthic areas. The relative importance of these nursery areas to the fishable population is undetermined. Results from these and associated studies have shown that oyster shell can be used to enhance survival of newly settled juveniles. Accordingly, shell deposition is being used by the Army Corps of Engineers as a means of enhancing the crab fishery.

Studies on the spiny lobster in Florida and the American lobster in New England have demonstrated that the availability of juvenile habitat plays a significant role in regulating population abundance of these species. Early life history research on both lobster species indicates that the abundance of presettlement stage lobsters is significantly higher

Comparison of Projects Funded with National Priorities* Identified in Annual Program Guidance

Annual Guidance	Project Agreement			
	FY89	FY90	FY91	FY92
• Improving prediction of populations; short-term and long-term	4	3	3	5
• Defining processes and mechanisms controlling natural variability in populations	19	20	24	27
• Defining relationships between habitat characteristics and productivity	17	10	13	16
• Restoring and enhancing depleted stocks	16	11	6	6
• Developing new commercial and recreational fisheries	3	4	0	2
• Reducing capture of nontargeted species and life stages and degradation of habitat	2	4	2	2
• Improving nondestructive methods for sampling fish and shellfish at all stages of life	0	0	0	0
• Designing, improving, and evaluating management schemes for efficient and equitable allocation of resources among competing users	5	3	7	4

*Priorities listed are those presented in the draft revised Sea Grant Fisheries strategy document.

Table 3

than the number that eventually recruit to the fisheries. In the case of spiny lobster, the availability of benthic red algae and, to a lesser degree, sea grass is a major component of survival variability. Similarly, the presence and abundance of cobble and boulders is critical to the survival of newly settled and juvenile American lobsters. These juvenile stage/habitat interactions are similar to those described for blue crab, suggesting a generic relationship between juvenile habitat and recruitment success among crustacea.

Finfish Recruitment Research:

Investigations on processes influencing recruitment among finfish species have been less definitive than those for crustaceans. Still, some very interesting results have been obtained during the past three years. Studies on bluefish in the Middle Atlantic Bight and estuarine areas of New York show that spawning occurs in spring off the North Carolina coast and in summer off the Long Island coast. Larvae of spring-spawned bluefish are transported up the coast by the Gulf Stream. Early juvenile stage fish are transported across the continental shelf into estuarine nurseries. Summer-spawned fish remain in continental shelf waters until early juvenile stages and are then transported to the estuaries. Juveniles of spring-spawned fish are significantly larger than those of summer spawn when they enter the estuaries. Under "typical" conditions the larger spring-spawned fish have higher survival rates. However, during those years when northern transport is weak, the summer-spawned fish make up a larger portion of the year-class. Results to date suggest that both spawning populations contribute significantly to each year-class.

For almost a century, fishery scientist have studied freshwater early life history stages of salmon in order to predict or enhance adult stock size. This research has achieved only limited success. During the mid 1980s, Sea Grant researchers turned their attention to the oceanic life-history stages for clues on salmon population control. These studies indicated that Pacific salmon abundance is dependent on oceanic factors encountered during the first year at sea. Some evidence indicated that, for some species, recruitment success is determined during the first few days to weeks after entering the ocean. Related research is focused on testing the hypothesis that long-term (decades or longer) trends in population abundance of the oceanic salmon species (sockeye, chum, and pink) are determined by position of the Subarctic Current.

Great Lakes Fisheries:

Predator/prey interactions between stocked salmonids and their naturally reproducing food species continues to be the focus of many Great Lakes researchers. Studies are underway to estimate whole lake biomass of planktivorous fishes (prey species) in Lakes Ontario and Michigan. Information from these studies is used in the development and testing of trophodynamics models designed to predict the consequences of species interactions.

Research also continues on establishing self-sustaining lake trout populations. Investigations evaluating the lake trout rehabilitation effort in Lake Ontario demonstrated that viable spawn are produced on reefs throughout the lake. Similar investigations in Lake Michigan are presently underway to characterize spawning area which produce fry. The Lake Ontario research showed that no one strain is best suited for the entire lake, but that some strains seem to be better suited for specific spawning sites. The "Ontario strain," the focus of most current stocking efforts, has been shown to not represent the ideal gene pool for restocking the lake.

One of the primary objectives in the clean-up efforts of the Great Lakes large cool water bays (estuaries) is restoration of fish populations. Scientists are presently evaluating the Remedial Action Plan for Green Bay, Lake Michigan, with respect to the fish community of the lower bay. Other researchers have shown that walleye stocked in Saginaw Bay, Lake Huron, are migrating up tributary rivers where they successfully spawn. Larvae produced from this spawn have been sampled along the course of the rivers entering the bay. Within the next few years, it will be possible to determine if this spawn contributes to the walleye population.

Assessment of the impacts of nonindigenous

species on fishery resources is a topic of major importance to the Great Lakes region. The ruffe, a small European perch-like fish, was discovered in the St. Louis Estuary adjacent to Duluth, Minnesota. Research indicates that this species could adversely impact perch and walleye populations in the estuary. *Bythotrephes*, a European predatory cladoceran, established itself in all the Great Lakes during the 1980s. Concern was expressed that this organism could outcompete larval and juvenile fish for food and add a new larval fish predator to the community. Research into these concerns indicates that *Bythotrephes* has little or no significant ecological impact on Great Lakes pelagic ecosystems. Investigations are underway to assess the potential adverse impacts associated with zebra mussel. Topics currently being studied include: physical and chemical (concentration of toxics in feces and pseudofeces); degradation of spawning habitat; and change from a pelagic to a benthic based food web.

Bycatch:

At a commercial fishing industry-sponsored workshop held in Newport, Oregon, during the spring of 1991, industry leaders acknowledged the serious problems caused by bycatch. They recognized that growing public concern about waste could threaten the existence of commercial fishing.

Sea Grant recognized this problem in the mid-1980s with the introduction of the turtle excluder device (TED). Research and outreach activities associated with TEDs have led to the development and evaluation of bycatch reduction devices (BRD), produced to reduce the capture of juvenile finfish during shrimp trawling operations. Similar activities have led to the introduction and testing of juvenile fish excluders in shrimp trawls used in northern New England.

During the past three years, a good deal of research has focused on improving selectivity and evaluating mesh sizes and shapes used in trawls. Silicon intensifier target (SIT) cameras have been deployed on commercial trawls to monitor the behavior of fishes as they are netted. Ethograms are then developed for various species and used to modify fishing practices and gear rigging to reduce bycatch. Studies of the long-term consequences on population dynamics of using various mesh sizes and shapes, showed that the use of larger square mesh in cod ends of trawls reduced bycatch of small nontargeted species and life stages, reduced catch sorting time, and should result in higher population abundance. These findings are being seriously considered in the development of groundfish management regulations being promulgated by fisheries management councils.

Genetics:

Sea Grant has a long history in supporting research in fish and shellfish genetics. From the 1970s to the mid-1980s activities centered on stock separation using electrophoresis technology. The level of effort in this area diminished significantly when, in the mid-1980s, it was determined that Sea Grant could not afford to continue support for such stock separation studies. Emphasis in genetics shifted to the application of stock separation technology to address specific management issues; for example, the lake trout recovery studies described above. Interest in stock separation studies began to increase again in the late 1980s when Sea Grant supported one of the first studies using mitochondrial DNA (mtDNA) for stock separation. Thirty mtDNA stock separation proposals have reached the NSGO over the past three years. Support was provided to examine mtDNA of oysters, stripped bass, American lobster, mahimahi, red drum, snook, red snapper, herring, walleye pollack, cod, haddock, and cobia. Results of these studies are reported in the technical articles listed in Publications section of this report under the heading "Genetics." This past year, it was determined that Sea Grant could only support those projects in which mtDNA technology was needed to address specific management questions such as, evaluating enhancement programs by distinguishing between wild and stocked fishes.

In 1990, the first DNA fingerprinting proposal was submitted to the NSGO. This is a technique in which nuclear DNA is used to distinguish organisms. The technique has the advantage over mtDNA in that genomes from both parents can be studied (mtDNA is contributed only from the mother). The major disadvantage of the technique is information overload and data reduction. Ten additional propos-

als were submitted between 1991 and 1992. Rather than waiting for history to repeat itself, the decision was made to support DNA fingerprinting only when it is needed to resolve management-related issues other than stock identification.

Future Directions and Plans

In 1985, the NSGO issued a strategy for fisheries research which has been the basis for managing the fisheries program. Priorities and objectives identified in the strategy are used by state Sea Grant directors in developing their programs. This past year, that strategy document was updated in accordance with guidance obtained at the Sea Grant fisheries symposium held at the 120th Annual Meeting of the American Fisheries Society. A draft of the revised strategy will be distributed widely for review and comment during the first quarter of 1993. Table 3 lists the research priorities identified in the draft.

Fisheries research supported in the 1980s and early 90s was more fundamental than that of the 60s and 70s. This research and focus has had an influence on the discipline as a whole. The understanding of the factors controlling recruitment variability and research are areas of significant activity among fisheries scientists. These topics and other process-oriented research areas that are now in vogue can be attributed to Sea Grant support. Where Sea Grant has had little impact is in translating this research into management practices or extending information obtained to intended constituencies. Although accounting for the largest expenditure of Sea Grant research funds, fisheries provides the fewest examples of verifiable benefits. During the next four years this situation must change.

Opportunities:

Population and Community Modeling

The activity level in modeling has diminished over the past four years. There is a need for evaluating the assumptions of commonly used population models, and incorporating results of recruitment research into population and community models. Research in multispecies fisheries models is also an area that needs increased effort.

Recruitment Fisheries Oceanography

As stated above, excellent opportunities exist to develop studies in association with or complementary to NOAA's Fisheries Oceanography Cooperative Investigation (FOCI) in the Gulf of Alaska and the Bering Sea, and with the South Atlantic Bight Recruitment Experiment (SABRE) off the Atlantic Coast between North Carolina and central Florida. Additional opportunities exist in developing research that is complementary to the National Science Foundation/NOAA Global Ecosystems Dynamics field study in the area of Georges Bank.

Gear Studies

Research on fishing and sampling gear has been very scarce despite the large number of problems associated with harvesting and sampling. Research that has been pursued on harvesting gear has focused on modifications of traditional devices such as nets and traps. Many opportunities exist for research on novel and innovative approaches to selectively and efficiently harvest fish and shellfish. Research is needed on sampling gear for larval and particularly juvenile stages. Emphasis should be placed on sampling gear that facilitates sample processing and speeds up processing time. In addition, studies are encouraged that investigate the effects of gear on habitat.

Publications

Sea Grant Abstracts, a quarterly publication of the National Sea Grant College Program, lists all publications submitted to the Sea Grant Depository. Only papers appearing in *Sea Grant Abstracts* are considered Sea Grant publications when evaluating previous productivity of an investigator seeking support for a grant. The following is a partial list of technical papers and reports exemplifying the quality of Sea Grant-supported fisheries research. The publications are organized, to the extent possible, according to the progress and achievements described above.

Blue Crab Program:

Epifanio, C.E., Masse, A.K., Garvine, R.W., 1989. Transport of blue crab larvae by surface currents off Delaware Bay, Marine Ecology Progress Series, 54:35-41.

Fitz, H.C., Wiegert, R.G., 1991. Tagging juvenile blue crabs, *Callinectes sapidus*, with mircowire tags: retention, survival, and growth through multiple molts, J. Crustacean Biology, 11(2):229-235.

Goodrich, D.M., Montfrans, J.V., Orth, R.J., 1989. Blue crab megalopal influx to Chesapeake Bay: evidence for a wind-driven mechanism, Estuarine, Coastal, and Shelf Science, 29:247-260.

Montfrans, J.V., Ryers, C.H., Orth, R.J., 1991. Population dynamics of blue crabs *Callinectes sapidus* Rathbun in a lower Chesapeake Bay tidal marsh creek, J. Experimental Marine Biology and Ecology, 153:1-14.

Olmi III, E.J., et al., 1990. Variation in planktonic availability and settlement of blue crab megalopae in the York River, Virginia., Bulletin of Marine Science, 46(1):230-243.

Olmi III, E.J., Lipcius, R.N., 1991. Predation on postlarvae of the blue crab *Callinectes sapidus* Rathbun by sand shrimp *Crangon septemspinosa* Say and grass shrimp *Palaemonetes pugio Holthuis*, Journal of Experimental Marine Biology and Ecology, 151:169-183.

Orth, R.J., Montfrans, J.V., 1990. Utilization of marsh and seagrass habitats by early states of *Callinectes sapidus*: a latitudinal perspective, Bulletin of Marine Sci., 46(1):126-144.

Smith, D.E. and Knappenberger, M., 1989. Blue crab recruitment dynamics in Chesapeake Bay: a review of current knowledge, Report No. VSGCP-T-89-005 (VSG-89-01), 23pp.

Crustacean Recruitment Research:

Gunderson, D.R., Armstrong, D.A., Shi, Y.B., McConnaughey, R.A., 1990. Pattern of estuarine use by juvenile English sole (*Parophrys vetulus*) and Dungeness crab (*Cancer magister*), Estuaries, 13(1):59-71.

Jamieson, G.S., Armstrong, D.A., 1991. Spatial and temporal recruitment patterns of Dungeness crab in the northeast Pacific, Memoirs of the Queensland Museum, 31:365-381.

Kondzela, C.M., 1986. Survival, feeding, and growth of juvenile Dungeness crabs from southeastern Alaska at different temperatures, Report No. AKU-Y-86-002 (SGT 86-01), 80pp.

Little, K.T. and Epifano, C.E., 1991. Mechanisms for the re-invasion of an estuary by two species of brachyuran megalopae, Marine Ecology Progress Series, 68:235-242.

Rooney, P., Cobb, J.S., 1991. Effects of time of day, water temperature, and water velocity on swimming by postlarvae of the American lobster *Homarus americanus*, Canadian J. of Fisheries Aquatic and Sciences, 48(10):1944-1950.

Wahle, R.A., Steneck, R.S., 1991. Recruitment habitats and nursery grounds of the American lobster *Homarus americanus*: a demographic bottleneck?, Marine Ecology Progress Series, 69:231-243.

Finfish Recruitment Research:

Brodeur, R.D. and Pearcy, W.G., 1990. Trophic relations of juvenile Pacific salmon off the Oregon and Washington coast, Fishery Bulletin, 88(4):617-636.

Carr, M.H., 1991. Patterns, mechanisms, and consequences of recruitment of a temperate marine reef fish, Report No. SCU-Y-91-001 (USCSG-TD-01-91), 190pp.

Chiarella, L.A., Conover, D.O., 1990. Spawning season and first-year growth of adult bluefish from the New York Bight., Transactions of the American Fisheries Society, 119:455-462.

Francis, R.C., Pearcy, W.G., Brodeur, R. et al., 1989. Effects of the ocean environment on the survival of Columbia River juvenile salmonids, Report No. WASHU-T-89-008 (WSG-MR 89-8), 20pp.

Freeberg, M.H., Taylor, W.W., Brown, R.W., 1990. Effect of egg and larval survival on year-class strength of lake whitefish in Grand Traverse Bay, Lake Michigan, Transactions of the American Fisheries Society, 119:92-100.

Holt, S.A., Holt, G.J., Arnold, C.R., 1989. Tidal stream transport of larval fishes into non-stratified estuaries, Rapp. P. -v. Reun. Const. int. Explor. Mer, 191:100-104.

Kruse, G.H. and Tyler, A.V., 1989. Exploratory

simulation of English sole recruitment mechanisms. Transactions of the American Fisheries Society, 118:101-118.

McBride, R.S., Conover, D.O., 1991. Recruitment of young-of-the-year bluefish *Pomatomus saltatrix* to the New York Bight: variation in abundance and growth of spring - and summer-spawned cohorts, Marine Ecology Progress Series, 78:205-216.

McGovern, J.C., Wenner, C.A., 1990. Seasonal recruitment of larval and juvenile fishes into impounded and non-impounded marshes, Wetlands, 10(2):203-221.

Miller, T., Crowder, L.B., Binkowski, F.P., 1990. Effects of changes in the zooplankton assemblage on growth of bloater and implications for recruitment success, Transactions of the American Fisheries Society, 119:483-491.

Mulligan, T.J., Bailey, K., Hinckley, S., 1988. The occurrence of larval and juvenile walleye pollock, *Theragra chalcogramma*, in the Eastern Bering Sea with implications for stock structure, Proceedings of the International Symposium on the Biology and Management of Walleye Pollock, pp. 471-489.

Norcross, B.L. and Bodolous, D.A., 1989. Hypothetical northern spawning limit and larval transport of spot, Larval Fish Recruitment and Research in the Americas: Proceedings of the Thirteenth Annual Fish conference, pp. 77-88.

Quinn II, T.J. and Marshall, R.P., 1989. Time series analysis: quantifying variability and correlation in SE Alaska salmon catches and environmental data, Effects of Ocean Variability on Recruitment and an Evaluation of Parameters Used in Stock Assessment Models, 108, pp. 67-80.

Shultz, J.L. et al., 1990. Distribution of fish larvae relative to time and tide in a Gulf of Mexico barrier island pass, Bulletin of Marine Science, 46(3):563-577.

Townsend, D.W., J.J. Graham and Stevenson, D.K., 1986. Dynamics of larval herring (*Clupea harengus L.*) production in tidally mixed waters of the eastern coastal Gulf of Maine, Tidal Mixing and Plankton Dynamics, 17:253-277.

Zastrow, C.E., Houde, E.D., Morin, L.G., 1991. Spawning, fecundity, hatch-date frequency and young-of-the-year growth of bay anchovy *Anchoa mitchilli* in mid-Chesapeake Bay, Marine Ecology Progress Series, 73:161-171.

Great Lakes Fisheries:

Cochran, P.A. and Kitchell, J.F., 1989. A model of feeding by parasitic lampreys, Canadian Jour. of Fisheries and Aquatic Sci., 46(11):1845-1852.

Hewett, S.W. and Stewart, D.J., 1989. Zooplanktivory by alewives in Lake Michigan: ontogenetic, seasonal and historical patterns, Transactions of the American Fisheries Society, 118:581-596.

Hill, D.K. and Magnuson, J.J., 1990. Potential effects of global climate warming on the growth and prey consumption of Great Lakes fish, Transactions of the American Fisherie Society, 119:265-275.

Kitchell, J.F., 1990. The scope for mortality caused by sea lamprey, Transactions of the American Fisheries Society, 119:642-648.

Kocik, J.F., Taylor, W.W., Wagner, W.C., 1991. Abundance, size, and recruitment of pink salmon (Oncorhynchus gorbuscha) in selected Michigan tributaries of the upper Great Lakes, 1984-88. J. Great Lakes Research, 17(2):203-213.

Magnuson, J.J., Meisner, J.D. and Hill, D.K., 1990. Potential changes in the thermal habit of Great Lakes fish after global climate warming, Transactions of the American Fisheries Society, 119:254-264.

Makarewicz, J.C. and Jones, H.D., 1990. Occurrence of *Bythotrephes cederstroemi* in Lake Ontario offshore waters, *Jour. of Great Lakes Research*, 16(1):143-147.

Parrish, D.L., Margraf, F.J., 1990. Interaction between white perch (Morone americana) and yellow perch (*Perca flavescens*) in Lake Erie as determined from feeding and growth, *Canadian Journal of Fisheries and Aquatic Sciences*, 47(9):1779-1787.

Stone, J.N. and Cohen, Y., 1990. Changes in species interactions of the Lake Superior fisheries system after the control of sea lamprey as indicated by time series model, Canadian Journal of Fisheries and Aquatic Sciences, 47(2):251-261.

Habitat Relationships:

Armstrong, D.A., Dumbauld, B., Doty, Daniel, 1989. Oyster culture and crab habitat: conflicts over use of the insecticide Sevin in coastal estuaries, Northwest Environmental Journal, 5:185-187.

Egerton, F.N., 1989. Missed opportunities: U.S. fishery biologists and productivity of fish in Green Bay, Saginaw Bay and western Lake Erie, Environmental Review, 13(2):33-63.

Martin, T.H., Wright, R.A., and Crowder, L.B., 1989. Non-additive impact of blue crabs and spot on their prey assemblages, Ecology, 70(6):1935-1942.

Pearcy, W.G., Wilson, C.D., Chung, A.W. and Chapman, J.W., 1989. Residence times, distribution, and production of juvenile chum salmon, *Oncorhynchus keta*, in Netarts Bay, Oregon, Fishery Bulletin, 87(3):553-568.

Peterson, C.H., 1990. On the role of ecological experimentation in resource management: managing fisheries through mechanistic understanding of predator feeding behaviour, Behavioral Mechanisms of Food Selection, G20:821-846.

Pohle, D.G., Bricelj, V.M., Esquivel, Z.G., 1991. The eelgrass canopy: an above-bottom refuge from benthic predators for juvenile bay scallops Argopecten irradians, Marine Ecology Progress Series, 74:47-59.

Rogers, C.W., Gunderson, D.R., and Armstrong, D.A., 1988. Utilization of a Washington estuary by juvenile English sole, *Parophrys vetulus*, Fishery Bulletin, 86(4):823-831.

Bycatch:

Bahen, J, Weaver, M., 1990. Reducing shrimp loss through net modification in TEDs, NCU-G-90-002 (UNC-SG-BP-90-1), 4pp.

Bergh, M.O. et al., 1990. Statistical design of comparative fishing experiments, Fisheries Research, 9:143-163.

DeAlteris, J.T. (ed.), 1991. Proceedings of the Fisheries Conservation Engineering Workshop, Narragansett, Rhode Island, April 4-5.

Dewees, C.M., Ueber, E., 1990. Effects of different fishery management schemes on bycatch, joint catch, and discards, Summary of a National Workshop, San Francisco, CA, Jan. 29-31, 1990.

Goudey, C.A., 1990. TUGOS utilization and selective gear development, Report No. MIT-T-90-005 (MITSG 90-20), 30pp.

Graham, Gary, 1990. Solving problems with TEDS, Report No. TAMU-G-90-001, 4pp.

Helser, T.E., Condrey, R.E., Geaghan, J.P., 1991. A new method of estimating gillnet selectivity, with an example for spotted seatrout, *Cynocion nebulosus*, Canadian Journal of Fisheries and Aquatic Sciences, 48(3):487-492.

Pikitch, E.K., Bergh, M.O., Erickson, D.L., Wallace, J.R., 1990. Final report on the results of the 1988 west coast groundfish mesh size study, Report No. WASHU-Q-90-001 (WSG-MR-90-02), 103 pp.

Pikitch, E.K., 1991. Technologies interactions in the U.S. West Coast groundfish trawl fishery and their implications for management, ICES Marine Science Symposium, 193:253-263.

Genetics:

Chapman, R.W., 1987. Changes in the population structure of male striped bass, *Morone saxatilis*, spawning in the three areas of the Chesapeake Bay from 1984 to 1986. Fishery Bulletin, 85(1):167-170.

Chapman, R.W., Brown, B.L., 1989. Two methods to detect DNA fragments produced by restriction enzymes, Analytical Biochemistry, 177:199-202.

Chapman, R.W., 1989. Spatial and temporal variation of mitochondrial DNA haplotype frequencies in the striped bass (*Morone saxatilis*) 1982 year class, Copeia, (2):344-348.

Chapman, R.W., 1989. Mitochondrial and nuclear gene dynamics of introduced populations of *Lepomis machrochirus*, Genetics, 123:399-404.

Fields, R.D., Johnson, K.R., Thorgaard, 1989. DNA fingerprints in rainbow trout detected by hybridization with DNA of bacteriophage M13, Transactions of the American Fisheries Society, 118:78-81.

Gharrett, A.J. and Seeb, J.E., 1990. Practical and theoretical guidelines for genetically marking fish populations, American Fisheries Society Symposium, 7:407-417.

Gharrett, A.J., Smoker, W.W., 1991. Two generations of hybrids between even-and odd-year pink salmon (*Oncorhynchus gorbuscha*): a test for outbreeding depression?, Canadian Journal of Fisheries and Aquatic Sciences, 48(9):1744-1749.

Gold, J.R., Richardson, L.R., 1991. Genetic studies in marine fishes. IV. An analysis of population structure in the red drum (*Sciaenops ocellatus*) using mitochondrial DNA, Fisheries Research, 12:213-241.

Gold, J.R., Richardson, L.R., 1990. Restriction site heteroplasmy in the mitochondrial DNA of the marine fish *Scianeops ocellaus* (L.), Animal Genetics, 21:313-316.

Littlewood, D.T.J., Fong, D., Ford, S.E., 1991. Small subunit rRNA gene sequence of *Crassostrea virginica* (Gmelin) and a comparison with similar sequences from other bivalve molluscs, *Nucleic Acids Research*, 19(21):6048.

Marsden, J.E., Krueger, C.C. and May, B., 1989. Identification of parental origins of naturally produced lake trout in Lake Ontario: application of mixed-stock analysis to a second generation, North American Journal of Fisheries Management, 9:257-268.

Artificial Reef Research:

Brock, R.E., Buckley, R.M., and Grace, R.A., 1985. An artificial reef enhancement program for nearshore Hawaiian waters, Artificial Reefs: Marine and Freshwater Applications, Chapter 11, pp. 317-336.

Brock, R.E., and Norris, J.E., 1989. An analysis of the efficacy of four artificial reef designs in tropical waters, Bulletin of Marine Science, 44(2):934-941.

Brock, R.E., 1985. Preliminary study of the feeding habits of pelagic fish around Hawaiian fish aggregation devices or can fish aggregation devices enhance local fisheries productivity?, Bulletin of Marine Science, 37(1):40-49.

New Techniques and Methodology:

Cailliet, G.M., 1990. Elasmobranch age determination and verification: an updated review, Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of the Fisheries, pp. 157-165.

Conover, D.O. and Present, T.M.C., 1990. Countergradient variation in growth rate: compensation for length of the growing season among Atlantic silvesides from different latitudes, Oecologia, 83:316-324.

Conover, David O., 1990. The relation between capacity for growth and length of growing season: evidence for and implications of countergradient variation, Transactions of the American Fisheries Society, 119:416-430.

Dewess, C.M., 1989. Assessment of the implementation of individual transferable quotas in New Zealand's inshore fishery. North American Journal of Fisheries Management, 9:131-139.

Feller, R.J., Hentschel, B.T. and Ferguson, R.B., 1990. Immunoelectrophoretic assay of mixed species meals: an example using penaeid shrimp, Trophic Relationships in the Marine Environment, pp. 588-596.

Hakanson, J.L., 1989. Condition of larval anchovy (*Engraulis mordax*) in the Southern California Bight, as measured through lipid analysis. Marine Biology, 102(2):153-159.

Hentschel, B.T., Feller, R.J., 1990. Quantitative immunoassay of the proventricular contents of white shrimp *Penaeus setiferus Linnaeus*: a laboratory study, Jour. of Experimental Marine Biology and Ecology, 139:85-99.

Hill, K.T., Calilliet, G.M. and Radtke, R.L., 1989. A comparative analysis of growth zones in four calcified structures of Pacific blue marlin, Makaira nigricans, Fishery Bulletin, 87:829-843.

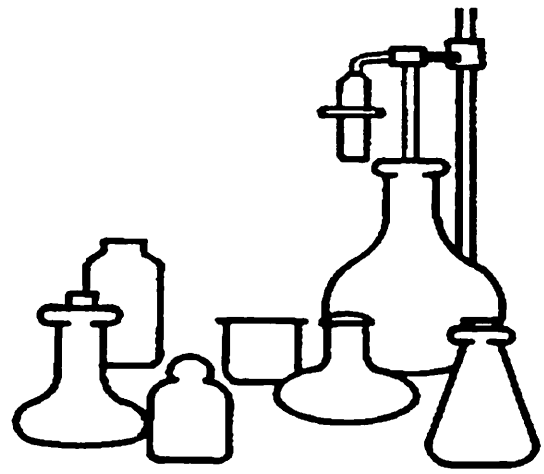
Lam, C.F., Whitaker, J.D. and Lee, F.S., 1990. Model for white shrimp landings for the central coast of South Carolina, North American Journal of Fisheries Management, 9:12-22.

Mangel, M., Smith, P.E., 1990. Presence/absence sampling for fisheries management. Canadian Jour. of Fisheries and Aquatic Sciences, 47(10):1875-1887.

Purcell, J.E. et al., 1991. Differential ingestion and digestion of bivalve larvae by the scyphozoan *Chrysaora quinquecirrha* and the ctenophore *Mnemiopsis leidyi*, Biological Bulletin, 180:103-111.

Quinn II, T.J., Fagen, R. and Zheng, J., 1990. Threshold management policies for exploited

populations, Canadian Jour. of Fisheries and Aquatic Sci, 47(10):2016-2029.
Quinn II, T.J., Collie, J.S., 1990. Alternative population models for eastern Bering Sea pollock, Proceedings of the Symposium on Application Stock Assessment Techniques to Gadids, pp. 243-257.
Secor, D.H. and Dean, J.M., 1989. Somatic growth effects on the otolith-fish size relationship in young pond-reared striped bass, *Morone saxatilis*, Canadian Jour. of Fisheries & Aquatic Sci., 46(1):113-121.
Smith, C.L., 1990. Resource scarcity and inequality in the distribution of catch, North American J. of Fisheries Management, 10:269-278.
Wilson, J.A., et al., 1991. Management of multispecies fisheries with chaotic population dynamics, ICES Marine Science Symposium, 193:287-300.
Wilson, J.A., et al., 1991. Chaotic dynamics in a multiple species fishery: a model of community predation, Ecological Modelling, 58:303-322.
Yudin, K.G. and Cailliet, G.M., 1990. Age and growth of the gray smoothhound, *Mustelus californicus*, and the brown smoothhound, *M. henlei*, sharks from central California, Copeia, (1):191-204.



Marine Biotechnology

Introduction

Biotechnology may be defined as the application of scientific and engineering principles to provide goods and services through mediation of biological agents. This broad definition encompasses more than DNA technology. Exclusive of agriculture, application of biotechnology in sewage treatment and water purification now comprises the largest sector in volume. Production of beer and spirits, cheese and other dairy products, baker's yeast, organic acids, and antibiotics follow in order of decreasing value. These traditional applications of biotechnology, which are based primarily on use of terrestrial organisms, are enormously important to the economy as well as human health and nutrition.

While biotechnology is not new, developments in modern molecular biology indicate that it is still in its emerging phase. Some authorities expect high technology, especially biotechnology, to be a primary basis of America's economic development and strength in the 21st century. Oceanic organisms harbor a major portion of the Earth's genetic resources, yet the large majority of marine organisms are not known well enough for their gene pool and biological processes to be accessible to those who develop and practice biotechnology in industry and academe. However, exploratory research shows the rich potential for exploiting the biochemical capabilities of marine organisms to provide models for new classes of pharmaceuticals, polymers, other chemical products, and new industrial processes as well as vaccines, diagnostic and analytical reagents, and genetically altered organisms for aquaculture.

In addition to aquacultural research on animal and algal food species, Sea Grant sponsors a research program directed to advancing science in support of other types of marine biotechnology. This research encompasses both traditional approaches and modern molecular methods. The program also sponsors development of DNA and other molecular methods for delineation of fishery stocks and aquacultural strains. In FY 1992, the program encompassed 63 projects with $2,808,208 in federal funds and $1,754,878 in matching funds. Other federal programs provided $244,712 of the federal funds.

This level of support is inadequate for a unique program with broad bounds. The program, which can be considered in the four categories shown in Table 1, can afford only a few projects on most issues relating to marine biotechnology. Thus, it is primarily one of research forays along several avenues, many of which are providing a basis for greater investment. Table 1 compares funding by category in FY 1991 and 1992. The increase in funding for molecular biology results primarily from including projects directed to resource management and environmental issues. Such projects were not included in the accounting for FY 1991. Table 2 shows funding for marine biotechnology research in state and regional Sea Grant programs.

Sea Grant researchers have been effective over the past three years in advancing science in support of marine biotechnology. This report provides examples of results. Names in parentheses after each example identify a corresponding paper or papers in the appendix. The appendix lists over 200 reports and books

Funding for Sea Grant Projects in Marine Biotechnology in FY 1991 and 1992
(in thousands of dollars)

Category	FY 91 No. of Projects	Funding Federal	Funding Match	FY 92 No. of Projects	Funding Federal[1]	Funding Match
Natural Products: Biochemistry/ Bioactivity	16	794	561	11	608	353
Molecular Biology	21	840	614	28	1,342[2]	831[2]
Biochemical Engineering/ Industrial Chemicals	11	311	326	11	472	306
Microbiology/ Phycology	5	244	120	13	386	265
General	3	54	195	-	-	-
Totals	56	2,244	1,815	63	2,808	1,755

[1] Includes $244,712 that other federal agencies provided to Sea Grant.
[2] Includes research in molecular biology directed to resource management and environmental issues; such research is not included in the accounting for FY 1991.

Table 1

published during 1990, 1991, and 1992.

A companion report—*Projects '92*—has a section listing of all projects in marine biotechnology that were funded in FY 1992. The listing provides principal investigators and their institutional affiliations. The funding levels shown are not comparable because some are for more or less than a one-year period and some do not include funding for the students and postdoctoral associates assigned to the projects.

Examples of Recent Advancements

Resource Management and Environmental Issues

Biologists showed that two alleles for malate dehydrogenase can be used as genetic markers in pink salmon to determine origins of exploited fish populations. (Lane et al.)

Analysis of mitochondrial DNA from red drum of the southeastern Atlantic coast and the northern Gulf of Mexico showed that the population is only weakly subdivided. (Gold and Richardson)

Extensive polymorphism at the adenosine deaminase locus indicated this locus my be useful in genetic marking of hatchery-produced stocks. (Bohlmeyer and Gold)

Two biologists recommended caution in using transgenic fish and that biologists and resource managers should develop integrated approaches to assessing ecological risks associated with such use. (Kapuscinski and Hallerman)

Biologists offered practical and theoretical guidelines for intentional genetic marking of fish populations. (Gharrett and Seeb)

The Restriction Enzyme Analysis Package, a computer program, alleviated difficulties inherent in manipulating data from restriction enzyme analyses. (McElroy et al.)

Biologically derived lipid structures (liposomes)

delay the dilution of species-specific amino acid mixtures from prey of yellowfish tuna. This allows the tuna to detect the prey beyond visual range. (Williams et al.)

Biologists developed putative DNA probes for distinguishing larvae of *Crassostrea virginica* from larvae of four other mollusks that can occur in the same environmental samples. (Littlewood et al.)

Biologists demonstrated an immunochemical method for detecting predation by larval fish on a ciliate without digestion-resistant hard parts. (Ohman et al.)

A biologist discussed the possible shift in role of hatcheries from stock enhancement to genetic conservation. (McNeil)

Oligonucleotide probes provided a method to quantify eubacterial cell densities in dilute communities of small bacterioplankton. (Hicks et al.)

Foreign organic substances modulated the synthesis of RNA and DNA in oyster cell cultures; the result suggests that such modulation could be used as a basis for a technique to investigate effects, on invertebrates, of pollutants in aquatic environments. (Sami et al.)

Aquaculture of Food Species

Molecular biologists developed two fish expression vectors that will be useful for genetic engineering of fish; they have been used with growth-enhancing genes in transgenic fish. (Liu et al.; Liu et al.) The

State and Regional Funding for Research in Support of Marine Biotechnology FY 1992
(in dollars)

Program	Funding Federal[1]	Funding Match	No. Projects
California Sea Grant	635,696	370,290	12
Delaware Sea Grant	132,252	154,910	5
Hawaii Sea Grant	147,339	167,424	5
Louisiana Sea Grant	53,807	43,067	2
UM/UNH Sea Grant	330,717	190,885	7
Maryland Sea Grant	136,204	48,503	3
MIT Sea Grant	59,334	35,507	1
Minnesota Sea Grant	102,570	33,708	3
Mississippi-Alabama Sea Grant	131,324	70,956	4
New Jersey Sea Grant	42,869	60,805	1
New York Sea Grant	139,460	79,090	2
North Carolina Sea Grant	9,591	12,390	1
Oregon Sea Grant	276,456	91,600	6
South Carolina Sea Grant	130,058	67,379	2
Texas Sea Grant	118,464	134,361	4
Virginia Sea Grant	72,207	54,120	1
Washington Sea Grant	211,200	95,299	3
Wisconsin Sea Grant	78,660	44,581	1
Totals	2,808,208	1,754,878	63

[1] Includes $244,712 that other federal agencies provided to Sea Grant.

Table2

avian Rous sarcoma virus also promoted gene expression in transgenic fish. (Hallerman et al.)

Molecular biologists transferred, expressed, and demonstrated the inheritance of trout and human growth hormone genes in carp and loach. (Chen et al.)

Bovine or salmon growth hormone microinjected into pike eggs under the control of the Rous sarcoma virus promoted growth to higher weight. (Gross et al.)

Biologists described the role allozyme analysis is likely to play in measuring the number and parental source of chromosome sets in manipulated progeny as the genomic manipulation of stocks becomes used more widely in fish culture and fisheries management. (Seeb and Miller)

Virologists developed a method for the concentration of infectious pancreatic necrosis virus from water in salmon hatcheries. It will be used in detecting and controlling spread of the virus. (Maheshkumar et al.)

A new staphylococcal co-agglutination assay detected and identified infectious hematopoietic necrosis virus in cell cultures and tissue samples of fish in less than 15 minutes. (Bootland and Leong)

Microbiologists demonstrated that a large genomic segment of the infectious pancreatic necrosis virus can be abundantly expressed in *Escherichia coli*. Administration of the resulting bacterial lysate protected fish from infection. (Manning and Leong; Manning et al.)

The glycoprotein from a single isolate of infectious hematopoietic necrosis virus (IHNV), a pathogen of young salmon and trout, induced a protective immune response in vivo to the five types of IHNV. Corresponding fusion proteins synthesized in a bacterium protected fry of rainbow trout from infection. (Engelking et al.; Xu et al.; Koener and Leong; Leong and Munn)

Scientists grew the virus, which causes infectious hypodermal and hematopoietic necrosis in penaeid shrimp, in an established fish cell line. This is the first successful growth of the penaeid virus in a fish cell line and promises to provide a convenient system for use in detecting the virus. (Loh et al.)

An aquacultural scientist reviewed the known hosts, geographical range, and diagnostic procedures for viral diseases of concern to shrimp culturists in the Americas. (Lightner and Redman)

RNA analysis showed that *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease in salmonids, is singularly different in form from its closest relatives and deserves classification as a separate genus. (Gutenberger et al.) Animal pathologists developed an enzyme-linked immunosorbent assay for diagnosis of the disease. (Hsu et al.)

Biotechnologists developed a novel method for manipulation of reproductive cycles in fish through controlled release of gonadotropic releasing hormones. (Langer and Zohar)

Studies of molting hormones in lobsters produced criteria for predicting molting. (Chang and Cheng)

Microbiologists developed an identification scheme predicated on detection, in shellfish, of lipopolysaccharide antigens of serovars of the human pathogen *Vibrio vulnificus*. (Siebeling and Martin)

Industrial Materials and Processes

New technology provided a means of producing intercalation complexes of chitin and organic compounds; it offers new avenues for applying chitin in films, filaments, dispersions, slow release drugs, and other biomedical products. (Austin and Albisetti)

An engineering procedure that uses inorganic polybasic acids to remove impurities provided pure, colorless chitosan having a controlled molecular weight. (Allan and Muvundamina)

Chitosan formed uniform and adherent coatings on wood pulp fibers and glass fibers both of which readily formed paper. (Allan et al.)

Scientists developed and patented a new method and an improved method of waste-water treatment that employ chemical enhancement. One of the methods employs the marine biopolymer chitosan. Chitosan proved to be too expensive a reagent except in processes where the resulting sludge can be converted to, or used as, a by-product. (Murcott; Murcott and Harleman)

Experiments showed that DNA fragments excised from a low melting point agarose gel can be digested with restriction enzymes, ligated or introduced into a bacterial host. The new "in-gel" manipulation technique allows bypassing of the slow and yield-reducing steps of fragment purification or electroelution. (Szumanski et al.)

Phycologists developed molecular probes for the gelling sequences of commercially important algal polysaccharides, the kappa and iota carrageenans. (Zablackis et al.)

Two brown algae yielded the enzyme vanadium bromoperoxidase which catalyzes the oxidation of bromine. The enzyme showed it ability also to catalyze the oxidation of chloride and the chloride-assisted conversion of hydrogen peroxide to water and molecular oxygen. (Soedjak and Butler) Phosphate inactivated the enzyme. (Butler et al.)

Polymer chemists advanced the science relating to use of water-soluble copolymers to reduce drag in turbulent flow and reviewed predictive theories on the effects of polymer structure. (McCormick et al.; Morgan and McCormick)

A 25-chapter book provided information on the discovery and commercialization of surface reactive peptides and polymers. (Wheeler and Sikes)

A molecular biologist discussed the development and potential applications of synthetic analogues of antifreeze proteins from fishes. (Caceci)

Halophyte and Algal Biotechnology

A tribute highlighted the career of the late Boudewijn H. Brinkhuis, a distinguished researcher in phycology. (Yarish)

A scientist demonstrated regeneration of plantlets from the aseptic cells of a number of seagrasses and marine coastal plants. (Ellender)

Molecular biologists developed a rapid and simple method for the simultaneous isolation of RNA and DNA from red algae. The presence of phycocolloids makes standard isolation procedures unwieldy. (Roell and Morse)

A scientist determined the physical organization of chloroplast DNA from an economically important red alga and showed that it carries several genes not found in higher plant chloroplasts. (Shivji)

Comparison of plastid genomes of two red algae and two green plants showed differences in gene organization but overall similarities in architecture, gene content, and gene sequences. (Shivji et al.)

Significantly greater variation in secondary structure of chloroplast RNA among algal classes than in seed plant taxa suggested non-equivalence in taxonomic rank among the two phylogenetic groups. (Delaney and Cattolico)

In efforts to develop management strategies and reseeding techniques for the commercial alga *Ascophyllum nodosum* phycologists developed a predictive model for gamete release in this species. (Bacon and Vadas)

A survey estimated the size, character, economic value, and future direction of the macroalgal industry in Maine. (Crawford)

Botanists determined growth response and ion content of seashore mallow grown in salinities from 85 to 255 mol/m^3 NaCl. Seashore mallow is a potential grain crop for seawater-based agriculture. (Blits and Gallagher)

Phycologists better defined the range of environmental conditions under which three seaweeds can be cultivated commercially for carrageenan polymers. (Glenn and Doty)

Natural Products: Chemistry and Biological Activity

Industrial, academic, and governmental scientists examined prospects for marine pharmacology in the 1990s. (Jacobs and de Carvalho)

Scientists showed the enzyme 15-lipoxygenase to occur along with 12-lipoxygenase in fish gills. These enzymes catalyzed the synthesis of 8,15-diHETE, one member of a family of regulators of biological function in mammalian tissues. (German and Berger; German and Creveling)

Biochemists summarized efforts to survey and chemotaxonomically describe algal species producing eicosanoid natural products. They provided evidence for widespread 12-lipoxygenase activity in red algae - a metabolic process previously known only in

animals. (Gerwick et al.)

For the first time, the plant kingdom yielded the mammalian pre-hormone, insulin release enhancer hepoxilin B_3. (Moghaddam et al.)

From red algae came a series of novel eicosanoids and other hydroxylated fatty acids that are expected to have a variety of uses in investigating biochemical processes in mammals. (Jiang and Gerwick; Moghaddam and Gerwick; Nagle and Gerwick) Biochemists determined the mechanisms of formation of dihydroxy fatty acids in one alga. (Hamberg et al.)

Biochemists showed that aqueous extracts of a coralline red alga catalyzes the oxidation of arachidonic acid to a previously unreported w6 eicosapentaenoic acid containing a conjugated tetraene. (Burgess et al.)

Diets rich in n-3 polyunsaturated fatty acids enhanced production of tumor necrosis factor in mice. (Hardardottir and Kinsella)

Nutritionists showed that degree of saturation in dietary fat in rats affected glucose transport, oxidation and conversion to fatty acids, but not insulin binding. (Pan and Berdanier)

Dietary fish oil in mice modulated eicosanoid metabolism and altered composition of fatty acids in tissue phospholipids 2.5 to 5 times more effectively than linolenic acid. (Whelan et al.)

Diets containing Chinook salmon or sablefish (both high in n-3 fatty acids) increased LDL-cholesterol in human males as compared to diets containing Dover sole (low in n-3 fatty acids). The results suggest that consumption of fish with moderate amounts of n-3 fatty acids may cause a deleterious rise in LDL-cholesterol. (Gerhard et al.)

Mice on diets containing increasing amounts of fish oil produced four additional leukotrienes in response to inflammatory stimulus than those on control diets. (Whelan et al.)

A survey determined the fatty acid composition of eight species of Lake Superior fishes. (Wang et al.)

Nutritionists demonstrated that accurate dietary recommendations require better information about seasonal variation in lipid content of finfish. (Wander and Patton) Others reviewed possible mechanisms of actions and dietary implications of n-3 polyunsaturated fatty acids. (Kinsella et al.) A book clarified numerous issues surrounding the consumption of fish oil. (Lees and Karel)

A scientist summarized the effects of dietary polyunsaturated fatty acids on membrane composition, membrane-associated enzyme and receptor functions, signal transduction, and eicosanoid generation. (Kinsella)

A brown alga provided the first example of a new class of diterpene having a novel tricarbocyclic skeleton. (Trimuratulu et al.) Another brown alga yielded 11 new diterpenes. (Rao et al.)

Chemists isolated from an octocoral, a sea whip, four new diterpenoid arabinose glycosides that inhibit inflammation with potencies equivalent to pharmaceutical standards. (Shin and Fenical) Two new anti-inflammatory bromophenols came from a Caribbean red alga. (Idler et al.)

Pharmacologists demonstrated that the anti-inflammatory sponge compound scalaradial inactivates phospholipase A_2 in a two-step process. (De Carvalho and Jacobs)

The marine natural product manoalide inactivated secreted phospholipase A^2 isolated from patients with arthritis. (Jacobson et al.)

A Caribbean sponge yielded two new antimicrobial pyridines. (Stierle and Faulkner) A novel compound from another Caribbean sponge proved to be the first natural product that incorporates a six-membered perlactone. (Kushlan and Faulkner)

A red alga yielded a substance, 3-(hydroxyacetyl)indole, that regulates plant growth. For example, it stimulates root growth in lettuce seedlings. (Bernart and Gerwick)

Chemists isolated molluskan alarm pheromones from a Fijian sponge and hypotensive agents from a Caribbean sponge. (Carroll and Scheuer; Lemke et al.)

Bioactive microalgal metabolites mediated ecological interactions in suspension-feeding invertebrates. (Ward and Targett)

Chemists described structures and anti-parasitic properties of new anthelmintic components of two Fijian sponges. (Alvi et al.; Horton et al.)

A sponge from Palau yielded two novel compounds that inhibit protease enzymes in the human immunodeficiency virus (HIV). Such inhibitors are of interest as models for drugs to prevent replication of the virus. (Potts et al.)

Fijian sponges yielded novel amino acids and amino alcohols in complex mixtures of bioactive constituents. (Jimenez et al.; Jimenez and Crews)

Because of the significant antitumor activities and remarkable structural features associated with polycyclic aromatic alkaloids from sessile invertebrates, marine scientists examined two tropical tunicates for alkaloids and found two novel octacyclic compounds and a quinolizidine. (Faulkner and He; Faulkner and Kong) Novel alkaloids also appeared in sponges. (Faulkner and Bobzin) (Jimenez et al.) (Akee et al.)

Chemical ecologists isolated five toxic pentacyclic polyaromatic alkaloids from both a mollusk and a tunicate on which it feeds. (Carroll and Scheuer)

Biochemists demonstrated that the marine natural product, okadaic acid, represents a new class of tumor promoters. This suggests it will be a useful tool for research on the mechanism of carcinogenicity. (Fujiki et al.; Nishiwaki et al.)

Ascidians (tunicates) and sponges yielded a variety of novel cytotoxic alkaloids, diterpenoids, and triterpenoids. Cytotoxicity is one guide to potential antitumor compounds. (Schmitz et al.; Gunasekera and Schmitz; DeGuzman and Schmitz)

Pharmacologists undertook structure/activity studies to further define the features of the octocorallian neurotoxin, lophotoxin, which are responsible for its biological activity. (Abramson et al.)

Plant pathologists cloned and sequenced disease resistance response genes in peas that are activated by the biopolymer chitosan. The genes appear to encode low molecular weight proteins with a high content of cysteine residues. (Chiang and Hadwiger)

Microbiology, Biofouling and Biocorrosion

Oceanographers further explored the relationships among hydrocarbon seepage, carbonate rock production and chemosynthetic communities of organisms. (Brooks et al.)

Scientists adapted a fluorometric DNA assay for the rapid enumeration of bacteria adherent to surfaces and potentially involved in biofouling. They also described a method for rapid screening of the effects of antifoulants on marine bacteria. (Shea and Williamson)

Comparison of the adhesion properties of a fouling bacterium with a mutant strain deficient in production of exopolysaccharide provided evidence for exopolymers' important role in cell aggregation and adhesion to surfaces. (Shea et al.)

Engineers determined the effects of marine bacteria on calcareous deposition on cathodically-protected surfaces. (Dexter and Lin)

Biological experiments supported the hypothesis that passive surface chemical properties of gorgonian corals play a role in preventing biofouling overgrowth. (Vrolijk et al.)

A review article discussed ecological processes involved in microbial corrosion. (Ford and Mitchell)

Opportunities for the Future

The results of Sea Grant's investment in marine biotechnology show that academic research can advance fundamental science while also providing the technical basis for new research and resource management tools and for new commercial products and processes. This research has been limited to only a few of the many current and potential lines of research in support of marine biotechnology and indicates that broader and heavier investment would benefit U.S. science and technology.

In 1992, the Federal Coordinating Council on Science, Engineering and Technology issued a report on "Biotechnology for the 21st Century" as a basis for the presidential initiative in biotechnology—one of five presidential initiatives in science education and technology. The report included marine biotechnology as a major topic and showed that the federal invest-

ment in this field is only $44 million per year—about one percent of the total federal investment in biotechnology. Listed below are a few examples of research directions that offer opportunities for advancing basic science, providing research tools, and laying foundations for new industrial products and processes.

- Developing the technology for cell culture of algae, invertebrates and microorganisms and defining associated physiology and nutrition;
- Defining biochemical engineering parameters for bioreaction, photo-bioreaction, fermentation, and immobilized biocatalyst reaction with marine microorganisms and cells of higher organisms;
- Developing new approaches to biological control or detoxification of industrial effluents and wastes;
- Exploiting microalgae for energy-rich substances, such as molecular hydrogen;
- Studying organelle functioning and associated biochemistry for application in biosensors;
- Molecular genetics of marine plants, animals, and microorganisms as a basis for their genetic engineering;
- Defining nutritional and environmental controls on secondary metabolism in marine organisms;
- Determining the structures and natural function of bioactive metabolites in cellular processes;
- Defining the properties of secondary metabolites in a spectrum of biological assays and determining their sites and mechanisms of action;
- Defining pharmacophores through molecular structure, synthesis, and computer modelling;
- Identifying secondary metabolites from and defining the biochemistry of marine microorganisms and other little known marine organisms;
- Investigating the bioactivity of aqueous extracts and macromolecules;
- Elucidating biochemical pathways and identifying associated enzymes;
- Exploring the biochemical and physical properties of enzymes and biopolymers;
- Cloning and expressing genes encoding for useful enzymes and polymers; and
- Cloning and expressing gene clusters encoding for biosynthesis of secondary metabolites.

The last few years have produced remarkable advancements in defining the secondary metabolism and products of marine organisms which synthesize a vast array of novel bioactive substances. Most of these new compounds have been investigated as models for pharmaceutical or agricultural substances in only a few systems. Work on the biological properties of these substances has fallen behind advancements in chemistry. Thus, there are broad opportunities and needs for research that will advance the understanding of natural function of bioactive metabolites and their potential as models for commercial products.

Common to most areas of biotechnological research is the need to meld chemical and biological sciences and often engineering science as well. Yet many projects are conducted from the point of view of a single academic discipline. It is the kind of disconnect that is encouraged by disciplinary organization in academic institutions. It causes angst among some philosophers of science and technology because adherence to disciplinary bounds often causes important problems and opportunities to be addressed obliquely and ineffectively.

Appendix Marine Biotechnology Publications: 1990-1992

Resource Management and Environmental Issues

Bohlmeyer, D.A., Gold, J.R., 1990. Extensive polymorphism at adenosine deaminase in the marine fish *Sciaenops ocellatus* (L.), Animal Genetics 21:211-213.

Bohlmeyer, D.A., Gold, J.R., 1991. Genetic studies in marine fishes. II. A protein electrophoretic analysis of population structure in the red drum, *Sciaenops ocellatus*, Marine Biology 108:197-206.

Choi, K.S. et al., 1991. A polyclonal antibody developed from Perkinsus marinus hypnospores fails to cross react with other life stages of *P. marinus* in oyster (*Crassostrea virginica*) tissues., Jour. of Shellfish Research 10(2):411-415.

Cottrell, M.T. and Suttle, C.A., 1991. Wide-spread

occurrence and clonal variation in viruses which cause lysis of a cosmopolitan, eukaryotic marine phytoplankter, *Micromonas pusilla,* Mar. Ecol. Prog. 78:1-9.

Gharrett, A.J. and Seeb, J.E., 1990. Practical and theoretical guidelines for genetically marking fish populations. American Fisheries Society Symposium 7:407-417.

Gold, J.R. and Richardson, Linda R., 1991, Genetic studies in marine fishes. IV. An analysis of population structure in the red drum (*Sciaenops ocellatus*) using mitochondrial DNA, Fisheries Research 12:213-241.

Gold, J.R., Richardson, L.R., 1990. Restriction site heteroplasmy in the mitochondrial DNA of the marine fish *Sciaenops ocellatus* (L.), Animal Genetics 21:313-316.

Hallerman, E.M. and Kapuscinski, A.R., 1990. Transgenic fish and public policy: patenting of transgenic fish, Fisheries 15(1):21-24.

Hallerman, E.M. and Kapuscinski, A.R., 1990. Transgenic fish and public policy: regulatory concerns, Fisheries 15(1):12-20.

Hicks, R., Amann, R. and Stahl, D.A., 1992. Dual staining of natural bacterioplankton with 4',6-diamidino-2-phenylindole and fluorescent oligonucleotide probes targeting kingdom-level 16S rRNA sequences, Appl. Environ. Microbiol. 58: 2158-2163.

Kapuscinski, A.R. and Hallerman, E.M., 1990. Implications of introduction of transgenic fish into natural ecosystems, Can. J. Fish. Aquat. Sci. 48:99-107.

Kapuscinski, A.R. and Hallerman, E.M., 1990. Transgenic fish and public policy: Anticipating environmental impacts of transgenic fish, Fisheries 15(1):2-11.

Lane, S. et al, 1990. Genetic marking of an Alaska pink salmon population, with an evaluation of the mark and the marking process. American Fisheries Society Symposium 7:395-406.

Littlewood, D.T.J., Ford, S.E., and Fong, D., 1991. Small subunit rRNA gene sequence of *Crassostrea virginica* (Gmelin) and a comparison with similar sequences from other bivalve molluscs, Nucleic Acids Research 19 (21):6048.

McElroy, D., Moran, P., Bermingham, E., and Kornfield, I., 1992. REAP: An integrated environment for the manipulation and phylogenetic analysis of restriction data, J. Heredity 83(2):157-158.

McGauley, K., 1991, An application of polymerase chain reaction: Examination of yellowtail rockfish (*Sebastes flavidus*) mitochondrial DNA, Thesis Abstract, California Sea Grant College Program.

McNeil, W.J., 1991. American strategies and problems., Sea ranching scientific experiences and challenges, Proceedings from the symposium and workshop, pp. 78-79.

Moav, B., Liu, Z., Groll, Y., and Hackett, P.B., 1992. Selection of promoters for gene transfer into fish, Molecular Marine Biology and Biotechnology, 1(4/5), 338-345.

Mulligan, T.J., Chapman, R.W., Brown, B.L., 1992. Mitochondrial DNA analysis of walleye pollock, Theragra chalcogramma, from the eastern Bering Sea and Shelikof Strait, Gulf of Alaska, Canadian J. Fisheries & Aquatic Sci., 49(2):319-326.

Ohman, M.D., Theilacker, G.H., and Kaupp, S.E., 1991. Immunochemical detection of predation on ciliate protists by larvae of the northern anchovy (*Engraulis mordax*), Biol. Bull. 181:500-504.

Sami, S., Faisal, M., Ahmed, I.I., 1992, *In vitro* cultures of oysters *Crassostrea virginica* cells: Stimulation by mitogens, in New Perspectives in the Chesapeake System: A Research and Management Partnership, Report No. VSG-92-137R, Virginia Sea Grant College Program, pp. 403-407.

Schulte, B.A., deNys, R., Bakus, G.J., Crews, P., Eid, C., Naylor, S. and Manes, L.V., 1991. A modified allomone collecting apparatus, J. Chem. Ecol. 17(7):1327-32.

Seeb, L.W., Seeb, J.E., and Gharrett, A.J., 1991. Genetic marking of fish populations, in Electrophoretic and Isoelectric Focusing Techniques in Fisheries Management, Report No. WSG-TA 90-14, Washington Sea Grant College Program, pp. 223-239.

Seeb, L.W. et al., 1990. Evaluation of adult returns of genetically marked chum salmon, with suggested future applications, Amer. Fish. Soc. Symposium, 7:418-425.

Shields, B.A., Kapuscinski, A.R., Guise, K.S., 1992. Mitochondrial DNA variation in four Minnesota populations of lake whitefish: utility as species and population markers, Transactions of the American Fisheries Society, 121:21-25.

Suttle, C.A. and Chen, F., 1992. Mechanisms and rates of decay of marine viruses in seawater, Appl. Environ. Microbiol. 58(11):3721-29.

Williams, J.D., Holland, K.N., Jameson, D.M. and Bruening, R.C., 1992. Amino acid profiles and liposomes: Their role as chemosensory information carriers in the marine environment, J. Chem. Ecol. 18(11):2107-15.

Molecular Techniques in Aquaculture of Food Species

Bartholomew, J.L., Arkoosh, M.R., Rohovec, J.S., 1991. Demonstration of the specificity of the salmonid humoral response to Renibacterium salmoninarum with a monoclonal antibody against salmonid immunoglobulin, J. Aquatic Animal Health, 3:254-259.

Bootland, L.M., Leong, J.A.C., 1992. Staphylococcal coagglutination, a rapid method of identifying infectious hematopoietic necrosis virus, Appl. and Environ. Microbiol. 58(1):6-13.

Bowser, P.R., Hsu, H.M., Schachte Jr., J.H., 1991. Development and evaluation of a monoclonal-antibody-based enzyme-linked immunosorbent assay for the diagnosis of *Renibacterium salmoninarum* infection, Journal of Aquatic Animal Health 3:168-175.

Chen, T.T., Lin, C.M., Zhu, Z., Gonzalez-Villasenor, L.I., Dunham, R.A., and Powers, D.A., 1990. Gene transfer, expression and inheritance of rainbow trout and human growth hormone genes in carp and loach, in Transgenic Models in Medicine and Agriculture, Wiley-Liss, Inc., pp. 127-139.

Cheng, J.H. and Chang, E.S., 1991. Variations in urinary output of the lobster, J. Exp. Zool. 260: 288-294.

Chien, M.S., Gilbert, T.S., Huang, C., Landolt, M.L., O"Hara, P.J., and Winton, J.R., 1992. Molecular cloning and sequence analysis of the gene coding for the 57-kDa major soluable antigen of the salmonid fish pathogen *Renibacterium salmoninarum*, FEMS Microbiology Letters 96:259-266.

Duncan, R., Mason, C.L., Nagys, E., Leong, J., and Dobos, P., 1991. Sequence analysis of infectious pancreatic necrosis virus genome segment B and its encoded VP1 protein: A putative RNA-dependent RNA polymerase lacking the GLY-ASP-ASP motif, Virology, 181: 541-552.

Dunham, R.A., and Powers, D.A., 1990, Gene transfer, expression and inheritance of rainbow trout and human growth hormone genes in carp and loach, in Transgenic Models in Medicine and Agriculture, Wiley-Liss, Inc., pp 127-139.

Engelking, H.M., Harry, J., and Leong, J.C., 1991, Comparison of representative necrosis virus by serological neutralization and cross-protection assays, Appl. Environ. Microbiol., 57:1372-1378.

Gross, M.L., Schneider, J.F., Moav, N., Moav, B., Alvarez, C., Myster, S.B., Liu, Z., Hallerman, E.M., Hackett, P.B., Guise, K.S., Faras, A.J., and Kapuscinski, A.R., 1992. Molecular analysis and growth evaluation of northern pike (*Esox lucius*) microinjected with growth hormone genes, Aquaculture, 103:253-273.

Gutenberger, S.K. et al, 1991. A phylogenetic comparison, of the 16s rRNA sequence of the fish pathogen, *Renibacterium salmoniarum* to Gram-positive bacteria, FEMS Microbiology Letters 77:151-156.

Hallerman, Eric M., Schneider, J.F., Gross, M., Liu, Z., Yoon, S.J., He L., Hackett P.B., Faras, A.J., Kapuscinski, A.R., and Guise, K.S., 1990. Gene expression promoted by the RSV long terminal repeat element in transgenic goldfish, Animal Biotechnology 1(1):79-94.

He, Ling et al., 1992. Characterization of *AluI* repeats of zebrafish (Brachydanio rerio), Molecular Marine Biology and Biotechnology, 1(2):125-135.

Hsu, H.M., Schachte, J.H., Bowser, P.R., 1991. Development and evaluation of a monoclonal-antibody-based enzyme-linked immunosorbent assay for the diagnosis of Renibacterium salmoninarum infection, J. Aquatic Animal Health 3:168-175.

Koener, J.F. and Leong, J.C., 1990, Expression of the glycoprotein gene from a fish rhabdovirus by using baculovirus vectors, J. Virol. 64:428-430.

Langer, R., and Zohar, Y., 1992, Development of a novel technology for the manipulation of fish reproductive cycles; controlled release of gonadotropin releasing hormones, Report No. MITSG 92-1, MIT Sea Grant College Program.

Lannan, C.N., Ewing, S.A., Fryer, J.L., 1991. A fluorescent antibody test for detection of the rickettsia causing disease in Chilean salmonids, J.

Aquatic Animal Health, 3(4):229-234.
Leong, J.C., Barrie, R., Engelking, H.M., Feyereisen-Koener, J., Gilmore, R., Harry, J., Kurath, G., Manning, D.S., Mason, C.L., Oberg, L., and Wirkkula, J., 1990. Recombinant viral vaccines in aquaculture, in Genetics in Aquaculture, Proceedings of the sixteenth U.S.-Japan meeting on aquaculture, R.S. Sryjcek, ed., pp. 27-32.
Leong, J.C., and Munn, C.B., 1991. Potential uses of recombinant DNA in the development of fish vaccines, Bull. Eur. Ass. Fish Pathol. 11(1):30-40.
Lightner, D.V., 1990. Viruses section: Introductory remarks, in Pathology in Marine Science, Perkins, F.O. and Cheng, T.C. (eds.), Academic Press, pp. 3-6.
Lightner, D.V. and Redman, R.M., 1992. Penaid virus diseases of the shrimp culture industry of the Americas, in Developments in Aquaculture and Fisheries Science, 23. Marine Shrimp Culture: Principals and Practices, Fast, A.W. and Lester, L.J. (eds.), Elsevier Science Pub. Co., pp. 569-588.
Liu, Z., Moav, B., Faras, A.J., Guise, K.S., Kapuscinski, A.R., and Hackett, P.B., 1990, Development of expression vectors for transgenic fish, Biotechnology 8:1268-1272.
Liu, Zhanjiang et al, 1990. Functional analysis of elements affecting expression of the B-actin gene of carp, Molecular and Cellular Biology 10(7):3432-3440.
Lu, Y., Loh, P.C., and Brock, J.A., 1990. Growth of the penaeid shrimp virus infectious hypodermal and hematopoietic necrosis virus in a fish cell line, J. Virol. Methods 28(3): 273-280.
Maheshkumar, S. et al. 1991. Method for the concentration of infectious pancreatic necrosis virus from hatchery water, J. Virological Methods 31:211-218.
Manning, D.S. and Leong, J.C., 1990, Expression in *Escherichia coli* of the large genomic segment of infectious pancreatic necrosis virus, Virology 179:16-25.
Manning, D.S., Mason, C.L., and Leong, J.C., 1990. Cell-free translational analysis of the processing of infectious pancreatic necrosis virus polyprotein, Virology 179:9-15.
Moav, B., Liu, Z., Groll, Y., and Hackett, P.B., 1992. Selection of promoters for gene transfer into fish, Molecular Marine Biology and Biotechnology 1(4/5),338-345.
Munn, C.B., and Leong, J.A., 1991, Potential uses of recombinant DNA in the development of fish vaccines, Bulletin of the European Association of Fish Pathologists, 11(1):30-40.
Oberg, L.A., et al., 1991. Bacterially expressed nucleoprotein of infectious hematopoietic necrosis virus augments protective immunity induced by the glycoprotein vaccine in fish, J. Virol. 65(8):4486-4489.
Seeb, J.E., and Miller, G.D., 1991. Integration of allozyme analyses and genomic manipulations for fish culture and management, in Electrophoretic and Isoelectric Focusing Techniques in Fisheries Management, pp. 265-279.
Siebeling, R.J., Martin, S.J., 1991. Identification of *Vibrio vulnificus* O serovars with antilipopolysaccharide monoclonal antibody, J. Clinical Microbiology 29(8):1684-1688.
Xu, L., Mourich, D.V., Engelking, H.M., Ristow, S., Arnzen, J. and Leong, J.C., 1991, Epitope mapping and characterization of the infectious hematopoietic necrosis virus glycoprotein, using fusion proteins synthesized in *Escherichia coli*, J. Virol. 65:1611-1615, ORESU-R-91-002.
Yoon, S.J., Hallerman, E.M., Gross, M.L. et al., 1990. Transfer of the gene for neomycin resistance into goldfish, *Carassius auratus*, Aquaculture 85:21-33.
Zhang, P., Hayat, M., Joyce, C., Gonzalez-Villasenor, L.I., Lin, C.M., Dunham, R.A., Chen, T.T., and Powers, D.A., 1990, Gene transfer, expression and inheritance of pRSV-rainbow trout-GH cDNA in the common carp, *Cyprinus carpio* (Linnaeus), Molecular Reproduction and Development 25:3-13.

Industrial Materials and Processes

Albisetti, C.J., and Castle, J.E., 1990. Dispersions of chitin and product therefrom, Report No. DELU-R-90-003, Delaware Sea Grant College Program.
Allan, G.G. and Muvundamina, M., 1991. Materials synthesis based on biological processes, Mat. Res. Soc. Sym. Proc. 218:265-273.
Allan, G.G. and Muvundamina, M., 1991. Processability of composite materials containing chitosan, in Materials Research Society Symposium Proceedings, Volume 218: Materials Synthe-

sis Based on Biological Processes, M. Alper et al. (eds.), pp. 225-232.

Allan, G.G. et al., 1990. Chitosan-coated fibers for use in papermaking. in Materials Research Society Symposium Proceedings, Volume 197: Materials Interactions Relevant to the Pulp, Paper, and Woods Industries, D.F. Caulfield et al., (eds.), pp. 239-243.

Allan, G.G., Muvundamina, M., 1991. Decolorization of chitosan, in Materials Research Society Symposium Proceedings, Volume 218: Materials Synthesis Based on Biological Processes, M. Alper et al., (eds.) pp. 265-273.

Attaway, D.H., 1991. Marine Organisms: their future in providing goods and services, in Bioactive Compounds from Marine Organisms, Thompson, M.-F., Sarojini, R. and Nagabhushanami, R., eds., Oxford & IBH Pub. Co., pp. 399-403.

Austin, P.R. and Albisetti, C.J., 1990. New intercalation complexes of chitin and selected organic compounds, Report No. DEL-SG-08-90, Delaware Sea Grant College Program, 13pp.

Butler, A., Soedjak, H.S., Everett, R.R., 1991. The novel non-heme vanadium bromoperoxidase from marine algae: phosphate inactivation, J. Industrial Microbiology, 8:37-44.

Butler, A., 1992. Vanadium bromoperoxidase, In *Bioinorganic catalysis*, J. Reedijk (ed.), Marcel Dekker Pub. Co., pp. 425-445.

Caceci, Thomas, 1991. Applying the Fishes' Antifreeze Solution, Natural Science November:290-297.

Chiang, C.C., Hadwiger, L.A., 1990. Cloning and characterization of a disease resistance response gene in pea inducible by *Fusarium solani*, Molecular Plant-Microbe Interactions, 3(2):78-85.

Chiang, C.C., Hadwiger, 1991. *Fusarium solani*-induced expression of a pea gene family encoding high cysteine content, Molecular Plant-Microbe Interactions 4(4):324-331.

Cooney, C.L., 1991. Biosensors for marine and other environments, Report No. MIT-W-91-002 (MITSG-91-8), MIT Sea Grant College Program, 27pp.

Crowe, J.H., Carpenter, J.F., Crowe, L.M., and Anchordoguy, T.J., 1990, Are freezing and dehydration similar stress vectors? A comparison of modes of interaction of stabilizing solutes with biomolecules, Cryobiology 27:219-231.

Daniels, C.H., Hadwiger, L.A., 1990. Effects of heat shock on the expression of disease resistance response genes in pea, Pisum Newsletter 22:12-14.

Delaney, T.P., Cattolico, R.A., 1991. Sequence and secondary structure of chloroplast 16S rRNA from the chromophyte alga Olisthodiscus luteus, as inferred from the gene sequence, Nucleic Acids Research, 19(22):6328.

Eighmy, T.T., Arwa, J., de Rome, L., Brown, M., Cimini, R.A., Sundberg, D.C. and Weisman, G.R., 1992. Controlled release antifouling coatings. II. The effects of controlled release of 2,4-dinitrophenolate and benzoate on marine biofilm development and metabolic activity. Biofouling 6:147-63.

Hurter, P.N. and Hatton, T.A., 1992. Solubilization of polycyclic aromatic hydrocarbons by poly(ethylene oxide-propylene oxide) block copolymer micelles: Effects of polymer structure, Langmuir 8:1291-1299.

McCormick, C.L. et al, 1990. Water soluble copolymers. 31. Effects of molecular parameters, solvation, and polymer associations on drag reduction performance, Macromolecules 23(8):2132-2139.

Morgan, S.E. and McCormick, C.L., 1990. Water-soluble copolymers XXXII: macromolecular drag reduction. A review of predictive theories and the effects of polymer structure, Progressive Polymer Sci. 15:507-549.

Murcott, S., 1991. Towards a patent for a new wastewater treatment process: Chemically enhanced primary wastewater treatment and the use of chitosan in chemically enhanced primary wastewater treatment, Report No. MITSG 92-11, MIT Sea Grant College Program.

Murcott, S., Harleman, D.R.F., Parsons, R.M., 1991. Chitosan, metal salt, and polyacrylamide jar tests at the Gloucester Water Pollution Control Facility, Report No. MITSG 92-12, MIT Sea Grant College Program, 28pp.

Nelson, J.R., Guarda, S. Cowell, L.E. and Heffernan, P.B. 1992. Evaluation of microalgal clones for mass culture in a subtropical greenhouse bivalve hatchery: growth rates and biochemical composition at 30° C., Aquaculture, 106:357-377.

Plonski, B.A., Luong, H.V. and Brown, E.J., 1990. Arsenic sorption by chitosan and chitin deacetylase production by *Mucor ruoxii*, Biorecovery 1:239-253.

Shivji, M.S., Li, N., CAttolico, R.A., 1992. Structure and organization of rhodophyte and chromophyte plastid genomes: implications for the ancestry of plastids, Molecular General Genetics, 232:65-73.

Soedjak, H.S. and Butler, A., 1990. Chlorination catalyzed by vanadium bromoperoxidase, Inorganic Chemistry, 29:5015-5017.

Szumanski, M.B.W., Toth, T.E., and Caceci, T., 1990. Ethanol precipitation to concentrate DNA excised from agarose gel, BioTechniques 9(6):708 & 710.

Weisman, G.R., Sundberg, D.C., Cimini, R.A., Brown, M., Beno, B.R. and Eighmy, T.T., 1992. Controlled release of 2,4-dinitrophenolate and benzoate into seawater, Biofouling 6:123-46.

Wheeler, A.P., Sikes, C.S., 1991. Surface Reactive Peptides and Polymers: Discovery and Commercialization, American Chemical Society, 416pp.

Zablackis, E. et al, 1991. Differential localization of carrageenan gelling sequences in *Kappaphycus alvarezii* var. *tambalang* (Rhodophyta) with FITC-conjugated carrageenan oligosaccharides, J. Phycology 27:241-248.

Halopyte and Algal Technology

Bacon, L.C., Vadas, R.L., 1991. A model for gamete release in *Ascophyllum nodosum* (Phaeophyta), J. Phycology 27:166-173.

Blits, K.C. and Gallagher, J.L., 1990. Salinity tolerance of *Kosteletzkya virginica* I. Shoot growth, ion and water relations, Plant, Cell and Environment 13::409-418.

Blits, K.C. and Gallagher, J.L., 1990. Effect of NaCl on lipid content of plasma membranes isolated from roots and cell suspension cultures of the dicot halophyte *Kosteletzkya virginica* (L) Presl., *Plant Cell Reports* 9:156-159.

Blits, K.C. and Gallagher, J.L., 1991. Morphological and physiological responses to increased salinity in marsh and dune ecotypes of *Sporobolus virginicus* (L.) Kunth, Oecologia 87:330-335.

Crawford, S., 1991. The macroalgae industry in Maine, Report No. MEU-T-91-001 (TR-MSG-91-1), Maine/New Hampshire Sea Grant College Program, 28pp.

Delaney, T.P. and Cattolico, R.A., 1991. Sequence and secondary structure of chloroplast 16S rRNA from the chromophyte alga *Olisthodiscus luteus*, as inferred from the gene sequence, Nucleic Acids Research, 19(22):6328.

Ellender, R.D., 1990, Initiation of callus cultures and plantlet regeneration from seagrasses and marine coastal plants, Report No. MASGP-90-020, Mississippi-Alabama Sea Grant Consortium, 108pp.

Glenn, E.P. and Doty, M.S., 1990. Growth of the seaweeds *Kappaphycus alvarezii, K. striatum* and *Eucheuma denticulatum* as affected by environment in Hawaii, Aquaculture 84:245-255.

Hand, C., Uhlinger, K.R., 1992. The culture, sexual and asexual reproduction, and growth of the sea anemone Nematostella vectensis, Biological Bulletin, 182:169-176.

Jartsfer, A.G., Sylvia, D.M., 1992. The production and use of aeroponically grown inocula of VAM fungi in the native plant nursery, Report No. FLSGP-T-92-002 (SGEB-22), Florida Sea Grant College Program, 11pp.

Kelley, S.K. et al., 1990. Identification of a tyrosinase from a periphytic marine bacterium, FEMS Microbiology Letters, 67:275-280.

Li, N., Hedberg, M.F., and Cattolico, R.A., 1991. Chloroplast DNA heterogeneity in *Monodus* sp. (Eustigmatophyta), Current Genetics, 20:157-159.

Mayber, A.P. et al., 1992. Seeds of Kosteletzkya virginica (Malvaceae): their structure, germination, and salt tolerance. 1. Seed structure and germination, Amer. J. Botany, 79(3):249-256.

Pillai, M.C., Baldwin, J.D. and Cherr, G.N., 1992. Early development in an algal gametophyte: Role of the cytoskeleton in germination and nuclear translocation, Protoplasma 170:34-45.

Poljakoff-Mayber, A., Somers, G.F., Werker, E., and Gallagher, J.L., 1992, Seeds of *Kosteletzkya virginica* (Malvaceae):Their structure, germination, and salt tolerance. 1. Seed structure and germination, American Journal of Botany 79(3):249-256.

Roell, M.K. and Morse, D.E., 1991. Fractionation of nuclear, chloroplast, and mitochondrial DNA from *Polysiphonia boldII* (Rhodophyta) using a rapid simple method for the simultaneous isolation of RNA and DNA, J. Phycol. 27:299-305.

Shivji, M.S. et al., 1991. Organization of the chloroplast genome in the red alga *Porphyra yezoenis*, Current Genetics 19:49-54.

Shivji, M.S., Rogers, S.O. and Stanhope, M.J., 1992. Rapid isolation of high molecular weight DNA from marine macroalgae, Marine Ecology Progress Series, 84:197-203.

Shivji, M.S., 1992. Structure and organization of rhodophyte and chromophyte plastid genomes: implications for the ancestry of plastids, Mole. Gen. Gen. 232:65-73.

Soedjak, H.S., Everett, R.R. and Butler, A., 1991. The novel non-heme vanadium bromoperoxidase from marine algae: phosphate inactivation, Journal of Industrial Microbiology 8:37-44.

Soedjak, H.S., and Butler, A., 1990. Characterization of vanadium bromoperoxidase from *Macrocystis and Fucus*: reactivity of vanadium bromoperoxidase toward acyl and alkyl peroxides and bromination of amines, Biochemistry 29(34):7974-7981.

Straub, P.F., Decker, D.M. and Gallagher, J.L., 1992. Characterization of tissue culture initiation and plant regeneration in *Sporololus virginicus* (Gramineae), Am. J. Bot. 79(10):1119-25.

Szumanski, M.B.W., Toth, T.E., and Caceci, T., 1990, Ethanol precipitation to concentrate DNA excised from agarose, Biotechniques 9(6):708 & 710.

Wells, M.L., Mayer, L.M., Guillard, R.L., 1991. A chemical method for estimating the availability of iron to phytoplankton in seawater, Marine Chemistry, 33:23-40.0

Wijte, A.H.B.M., and Gallagher, J.L., 1991. The importance of dead and young live shoots of *Spartina alterniflora* (Poaceae) in a mid-latitude salt marsh for overwintering and recoverability of underground reserves, Bot. Gaz. 152(4):509-513.

Yarish, Charles, 1990. In memoriam: Boudewijn H. Brinkhuis (1946-1989), Phycologia 29(3):385-387.

Zablackis, E., Vreeland, V., Doboszewski, B., and Laetsch, W.M., 1991. Differential localization of carrageenan gelling sequences in *Kappaphycus alvarezii* var. *Tambalang* (Rhodophyta) with FITC-conjugated carrageenan oligosaccharides, J. Phycol. 27, 141-248.

Natural Products Chemistry and Biological Activity

Abramson, S.N., et al., 1991. Structure/activity and molecular modeling studies of the lophotoxin family of irreversible nicotinic receptor antagonists, J. Med. Chem. 34:1798-1804.

Abramson, S.N., J.A. Trishchman, D.M. Tapiolas, E.E. Harold, W. Fenical, and P. Taylor, 1991. Structure/activity and molecular modeling studies of the lophotoxin family of irreversible nicotinic receptor antagonists, J. Med. Chem. 34(6): 1798-1804.

Adamczeski, M., Quinoa, E., and Crews, P., 1990. Novel sponge-derived amino acids. 11. The entire absolute stereochemistry of the bengamides, J. Org. Chem. 55(1):240-242.

Akee, R.K. et al., 1990. Two imidazole alkaloids from a sponge, J. Org. Chem. 55(6):1944-1946.

Alvi, K.A. and Crews, P., 1991. Structures and total synthesis of 2-aminoimidazoles from a *Notodoris* nudibranch, J. Nat. Prod. 54(6):1509-15.

Alvi, K.A., L. Tenenbaum, and P. Crews. 1991. Anthelmintic polyfunctional nitrogen-containing terpenoids from marine sponges, J. Nat. Prod. 54(1):71-78.

Berdanier, C.D., Johnson, B., Hartle, D.K., Crowell, W., 1992. Life span is shortened in BHE/cdb rats fed a diet containing 9% menhaden oil and 1% corn oil, J. Nutr. 122:1309-1317.

Bernart, M. and Gerwick, 1990. W.H., 3-(Hydroxyacetyl)indole, A plant growth regulator from the Oregon red alga *Prionitis lanceolata*, Phytochemistry 29:3697-3698.

Bernart, M.W. et al., 1992. Laurencione, a heterocycle from the red alga Laurencia spectabilis, Phytochemistry, 31(4):1273-1276.

Bobzin, S.C. and D.J. Faulkner, 1992. Chemistry and chemical ecology of the Bahamian sponge *Aplysilla glacialis*, J. Chem. Eco. 18(3):309-332.

Bobzin, S.C., and D.J. Faulkner, 1991. Diterpenes from the marine sponge *Chelonaplysilla* sp., J. Nat. Prod. 54(1):225-232.

Bobzin, S.C., and D.J. Faulkner, 1991. Aromatic alkaloids from the marine sponge *Chelonaplysilla* sp., J. Org. Chem. 56(14):4403-4407.

Bobzin, S.C. and Faulkner, D.J. 1991. Diterpenes from the ponapeian marine sponge *Chelonaplysilla sp.*, J. Nat. Prod. 54: 225-232.

Boyle, J.L., Lindsay, R.C., Stuiber, D.A., 1992. Contributions of bromophenols to marine-associated flavors of fish and seafoods, JAFPT 1(3/4):43-63.

Brooks, J.M. et al, 1990. Salt, seeps and symbiosis in

the Gulf of Mexico. A preliminary report of deepwater discoveries using DSV Alvin, EOS 71(45):1772-1773.

Broughton, K.S., Whelan, J., Hardardottir, I., Kinsella, J.E., 1990. Effect of increasing the dietary (n-3) to (n-6) polyunsaturated fatty acid ratio on murine liver and peritoneal cell fatty acids and eicosanoid formation, Lipids 4:3064.

Burgess, J.R., R. de la Rosa, R.S. Jacobs, and A. Butler. 1991. A new eicosapentaenoic acid formed from arachidonic acid in the coralline red algae *Bossiella orbigniana*, Lipids 26(2): 162-165.

Carney, J.R., Yoshida, W.Y., and Scheuer, P.J., 1992. Kiheisterones, new cytotoxic steroids from a Maui sponge, J. Org. Chem. 57:6637-40.

Carney, J.R., Pham, A.T., Yoshida, W.Y. and Scheuer, P.J., 1992. Napalilactone, a new halogenated norsesquiterpenoid from the soft coral *Lemnalia africara*, Tetrahedr. Lettrs. 33(47):7115-18.

Carroll, A.R. and Scheuer, P.J., 1990. Kuanoniamines A, B, C, and D: pentacyclic alkaloids from a tunicate and its prosobranch mollusk predator *Chelynotus semperi*, J. Org. Chem. 55(14):4426-4431.

Carroll, A.R. and Scheuer, P.J., 1990. Four beta-alkylpyridines from a sponge, Tetrahedron 46(19):6637-6644.

Chang, E.S., Chens, J.H., 1991. Ecysteroid treatment delays ecdysis in the lobster, *Homarus americanus*, Biol. Bull., 181:169-174.

Chiang, C.C. and Hadwiger, L.A., 1991. Fusarium solani-induced expression of a pea gene family encoding high cysteine content, Molecular Plant-Microbe Interactions, 4(4):324-331.

Chiang, C.C. and Hadwiger, L.A., 1990. Cloning and characterization of a disease resistance response gene in pea inducible by *Fusarium solani*, Molecular Plant-Microbe Interactions 3(2):78-85.

Coleman, M.T.D. and Faulkner, D.J., New diterpenoic acid glycerides from the Antarctic nudibranch *Austrodoris kerguelensis*, Tetrahedron, 47:9743-9750.

Crews, P., C. Jimenez, and M. O'Neil-Johnson. 1991. Using spectroscopic and database strategies to unravel structures of polycyclic bioactive marine sponge sesterterpenes, Tetrahedron 47(22): 3585-3600.

Daniels, Catherine H., 1990. Effects of heat shock on the expression of disease resistance response genes in pea, Pisum Newsletter 22:12-14.

DeCarvalho, M.S., and R.S. Jacobs. 1991. Two-step inactivation of bee venom phospholipase A_2 by scalaradial, Biochem. Pharmacol. 42(8): 1621-1626.

DeGuzman, F.S. and Schmitz, F.J., 1991. Naurol A and B, novel triterpone alcohols from a Pacific sponge, J. Org. Chem. 56(1):55-58.

DeGuzman, F.S. and Schmitz, F.J., 1990. Peroxy aliphatic esters from the sponge *Plakortis lita*, J. Nat. Prod. 53(4):926-931.

Fahy, E., B. Potts, D.J. Faulkner, and K. Smith. 1991. 6-Bromotryptamine derivatives from the Gulf of California tunicate *Didemnum candidum*, J. Nat. Prod. 54(2):564-569.

Faulkner, D.J., 1992. Biomedical uses for natural marine chemicals, Oceanus 35(1):29-35.

Faulkner, D.J., Kong, F., 1991. Pictamine, a quinolizidine alkaloid from the tunicate *Clavelina picta*, Tetrahedron Letters 32(30):3667-3668.

Faulkner, D.J., He, H., 1991. Eudistones A and B: two novel octacyclic alkaloids from a Seychelles tunicate, *Eudistoma* sp., J. Org. Chem. 56(18):5369-5371.

Faulkner, D.J. and Salva, J., 1990. A new brominated diphenyl ether from a Philippine *Dysidea* species, J. Nat. Prod. 53(3):757-760.

Faulkner, D.J., Bobzin, S.C., 1991. Aromatic alkaloids from the marine sponge *Chelonaplysilla* sp., J. Org. Chem. 56(14):4403-4407.

Fujiki, H. et al, 1990. A new pathway of tumor promotion by the okadaic acid class compounds, in The Biology and Medicine of Signal Transduction, Nishizuka, Y. et al. (eds.), Raven Press, New York, pp. 340-344.

Gerhard, G.T. et al., 1991. Comparison of three species of dietary fish: effects on serum concentrations of low-density-lipoprotein cholesterol and apolipoprotein in normotriglyceridemic subjects, Amer. J. of Clin. Nutr., 54:334-339.

German, J.B. and Berger, R., 1990. Formation of 8, 15-dihydroxyeicosatertraenoic acid via 15-and 12-lipoxygenases in fish gill, Lipids 25(12):849-853.

German, J.B. and Creveling, R.K, 1990. Identification and characterization of a 15-lipoxygenase from

fish gills, J. Agricultural and Food Chem. 38:2144-2147.

Gerwick, W.H. et al, 1990. Eicosanoids from the Rhodophyta: new metabolism in the algae, Hydrobiologia 204/205:621-628.

Gerwick, W.H., Jiang, Z.D., Agarwal, S.K., and Farmer, B.T., 1992. Total structure of hormothamnin A, a toxic cyclic undecapeptide from the tropical marine cyanobacterium *Hormothamnion enteromorphoides*, Tetrahedron 48(12):2313-2324.

Gerwick, W.H., Moghaddam, M., and Hamberg, M., 1991. Oxylipin metabolism in the red alga *Gracilariopsis lemaneiformis*: Mechanism of formation of vicinal dihydroxy fatty acids, Archives of Biochemistry and Biophysics 290(2):436-444.

Gleason, F.K., 1990. The natural herbicide, cyanobacterin, specifically disrupts thylakoid membrane structure in Euglena gracilis strain Z, Microbiology Letters 68:77-82.

Grace, K.J.S., Medina, M., Jacobs, R.S., and Wilson, L., 1992. Selection inhibition of cytokinesis in sea urchin embryos by the marine natural product pseudopterolide, Molecular Pharmacology 41:631-638.

Gulavita, N.K., Scheuer, P.J., deSilva, E.D., 1992. Antimicrobial constituents of a sponge-nudibranch pair from Sri Lanka, Bioactive Compounds of Marine Organisms, M.-F. Thompson et al. (eds.), Oxford & IBH Pub. Co., 229-233.

Gunasekera S.P. and Schmitz, F.J., 1990. New spongian diterpenoids from a Great Barrier Reef sponge, *Spongia sp.*, J. Org. Chem. 56(3):1250-3.

Guzman, F.S.D. and Schmitz, F.J., 1990. Peroxy aliphatic esters from the sponge *Plakortis lita*, J. Nat. Prod. 53(4):926-931.

Hamann, M.T. and Scheuer, P.J. 1991. Cyanopuupehenol, an antiviral metabolite of a sponge of the order Verongida, Tetrahedron Letters 32(41):5671-5672.

Hamberg, M., Gerwick, W.H., and Asen, P., 1992. Linoleic acid metabolism in the red alga *Lithothamnion corallioides*: Biosynthesis of H(C)-hydroxy-9(Z), 12(Z)- octadecadienoci acid, Lipids 27(7):487-93.

Hamberg, M., Moghaddam, M., Gerwick, W.H., 1991. Oxylipin metabolism in the red alga *Gracilariopsis lemaneiformis:* mechanism of formation of vicinal dihydroxy fatty acids, Archives of Biochemistry & Biophysics 290(2):436-444.

Hardardottir, I., Kinsella, J.E., 1991. Tumor necrosis factor production by murine resident peritoneal macrophages is enhanced by dietary n-3 polyunsaturated fatty acids, Biochemica et Biophysica Acta 1095:187-195.

Hardardottir, I. and Kinsella, J.E., 1992. Increasing the dietary (n-3) to (n-6) polyunsaturated fatty acid ratio increases tumor necrosis factor production by murine resident peritoneal macrophages without an effect on elicited peritoneal macrophages, J. Nutr. 122:1942-1951.

Hardardottir, I. Whelan, J. and Kinsella, J.E., 1992. Kinetics of tumour necrosis factor and prostaglandin production by murine resident peritoneal macrophages as affected by dietary n-3 polyunsaturated fatty acids, Immunology 76:572-577.

He, H., and Faulkner, D.J. 1992. A new imidazole alkaloid from the marine sponge *Leucetta microrhaphis*, J. Org. Chem. 57:2176-8.

He, H., and Faulkner, D.J. 1991. Eudistones A and B: two novel octacyclic alkaloids from a Seychelles tunicate, *Eudistoma sp.*, J. Org. Chem. 56(18):5369-5371.

He, H., Faulkner, D.J., 1991. New chlorinated diterpenes from the gorgonian *Junceella gemmacea*, Tetrahedron 47(20/21):3271-3280.

Hines, G.A. et al, 1990. Sex steroid extraction from echinoderm tissues, J. Liquid Chromatography 13(12):2489-2498.

Horton, P., Inman, W.D., and Crews, P., 1990. Enantiomeric relationships and anthelmintic activity of dysinin derivatives from dysidea marine sponges, J. Nat. Prod. 53(1):143-151.

Idler, D.D., Wiemer, D.F., Fenical, W., 1991. Vidalols A and B, new anti-inflammatory bromophenols from the Caribbean marine red alga *Vidalia obtusaloba*, Experientia 47:851-853.

Jacobs, R.S., De Carvalho, M. (eds.), 1990. Marine pharmacology: prospects for the 1990s, California Sea Grant College Program, 81pp.

Jacobson, P.B., Marshall, L.A., Sung, A., and Jacobs, R.S., 1990. Inactivation of human synovial fluid phospholipase A_2 by the marine natural product, manoalide, Biochemical Pharmacology

39(10):1557-1564.

Jacobson, P.B. and Jacobs, R.S., 1992. Fuscoside: An anti-inflammatory marine natural product which selectively inhibits 5-lipoxygenase. Part II: Biochemical studies in the human netrophil, J. Pharmacol. Exp. Therap. 262(2)874-882.

Jiang, Z.D. and Gerwick, W.H., 1991. An aldehyde-containing galactolipid from the red alga *Gracilariopsis lemaneiformis*, Lipids 26:960-63.

James, D.M. Kunze, H.B., and Faulkner, D.J. 1991. Two new brominated tyrosine derivatives from the sponge *Druinella (Psammaplysilla) purpurea*, J. Nat. Prod. 54(4):1137-1140.

Jiang, Z.D. and Gerwick, W.H., 1991. Eicosanoids and other hydroxylated fatty acids from the marine alga *Gracilariopsis lemaneiformis*, Phytochemistry 30(4):1187-1190.

Jiang, Z.D. and Gerwick, W.H., 1991. Novel pyrroles From the Oregon red alga *Gracilariopsis Lemaneiformis*, J. Nat. Prod. 54(2):403-407.

Jiang, Z.D. and Gerwick, W.H., 1990. Galactolipids from the temperate red marine alga *Gracilariopsis lemaneiformis*, Phytochemistry 29(5):1433-1440.

Jimenez, C., and Crews, P., 1990. Novel marine sponge derived amino acids 10. Xestoaminols from *Xestospongia sp.*, J. Nat. Prod. 53(4):978-982.

Jimenez, C., and P. Crews. 1991. Novel marine sponge derived amino acids 13. Additional psammaplin derivatives from *Psammaplysilla purpurea*, Tetrahedron 47(12/13):2097-2102.

Jimenez, C., E. Quinoa, M.Adamczeski, L.M. Hunter, and P. Crews. 1991. Novel sponge-derived amino acids. 12. Tryptophan-derived pigments and accompanying sesterterpenes from *Fascaplysinopis reticulata*, J. Org. Chem. 56(10): 3403-3410.

Jimenez, C., E. Quinoa, and P. Crews. 1991. Novel marine sponge alkaloids 3. Carbolinium salts from *Fascaplysinopsis reticulata*, Tetrahedr. Lett. 32(16): 1843-1846.

Jimenez, C., and Crews P., 1990. Novel marine sponge amino acids, 10. Xestoaminols from *Xestospongia* sp., J. Nat. Prod. 53(4):978-982.

Jimenez, C. et al, 1991. Novel sponge-derived amino acids. 12. Tryptophan-derived pigments and accompanying sesterterpenes from *Fascaplysinopis reticulata*, J. Org. Chem. 56:3403-3410.

Jimenez, C., Johnson, M.O., Crews, P., 1991. Using spectroscopic and database strategies to unravel structures of polycyclic bioactive marine sponge sesterterpenes, Tetrahedron 47(22):3585-3600.

Kinsella, J.E., Lokesh, B., and Stone, R.A., 1990. Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular disease: possible mechanisms, Amer. J. Clinical Nutrition 52:1-28.

Kinsella, J.E., 1990. Lipids, membrane receptors, and enzymes: effect of dietary fatty acids, J. Parenteral and Enteral Nutr., 14(5):200s-217s.

Kong, F., and D.J. Faulkner. 1991. Pictamine, a quinolizidine alkaloid from the tunicate *Clavelina picta*, Tetrahedr. Lett. 32(30):3667-3668.

Kubo, I., Ochi, M., Shibata, K., Hanke, F.J., Nakatsu, T., Tan, K.S., Taniguchi, M., Kamikawa, T. Yamagiwa, Y., Arizuka, M., and Wood, W.F. 1990. Effect of a marine algal constituent on the growth of lettuce and rice seedlings, J. Nat. Prod. 53(1)50-56.

Kubo, I., Himejima, M., Tsujimoto, K., Muroi, H., and Ichikawa, N. 1992. Antibacterial activity of crinitol and its potentiation, J. Nat. Prod. 55(6):780-785.

Kushlan, D.M., and Faulkner, D.J., A novel perlactone from the Caribbean sponge *Plakortis angulospiculatus*, J. Nat. Prod. 54(5): 1451-1454.

Lakshmi, V., Gunasekera, S.P., Schmitz, F.J., Ji, X., and van der Helm, D., 1990. Acid-catalyzed rearrangement of arenerol, J. Org. Chem. 55(15):4709-11.

Lees, R.S. and Karel, M. (eds.), 1990. Omega-3 fatty acids in health and disease, Proceedings of the 15th annual MIT Sea Grant lecture and seminar, Marcel Dekker, Inc., 240pp.

Lemke, T.L., Sanduja, R., Mroue, M.M., Iyer, S., Alam, M., Hossain, M.B., and van der Helm, D., 1990. Isolation, synthesis, and evaluation of a series of indenecarbazates as hypotensive agents, J. Pharmaceutical Sci. 79(12):1126.

Lokesh, B., LiCari. J., and Kinsella, J.E., 1992. Effect of dietary triglycerides on liver fatty acids and prostaglandin synthesis by mouse peritoneal cells, J. Parenter. Enter. Nutit. 16(4):316-21.

Moghaddam, M.F. and Gerwick, W.H., 1990. 12-Lipoxygenase activity in the red marine alga *Gracilariopsis lemaneiformis*, Phytochemistry

29(8):2457-2459.

Moghaddam, M.F., Gerwick, W.H. and Ballantine, D.L., 1990. Discovery of the mammalian insulin release modulator, hepoxilin B_3 from the tropical red algae *Platysiphonia miniata* and *Cottoniella filamentosa*, J. Biol. Chem. 265(11):6126-6130.

Moghaddam, M.F., Gerwick, W.H., 1991. Cell-free biosynthesis and source of hydroxyl groups in (12R,13S)-dihydroxy-(5Z,8Z,10E,14Z)-eicosatetraenoic acid, a novel eicosanoid from the marine alga *Gracilariopsis lemaneiformis*, J. Nat. Prod. 54(6):1619-1624.

Morse, A.N.C., 1991. GABA-mimetic peptides from marine algae and cyanobacteria as potential diagnostic and therapeutic agents, Bioactive Compounds from Marine Organisms: with Emphasis on the Indian Ocean, et al. (eds.), pp. 167-172.

Nagle, D.G., McClatchey, W.C., and Gerwick, W.H., 1992. New glycosphingolipids from the marine sponge *Halichondria panicea*, J. Nat. Prod. 55(7):1013-1017.

Nagle, D.G., and Gerwick, W.H., 1990. Isolation and structure of constanolactones A and B, new cyclopropoyl hydroxy-eicosanoids from the temperate red alga *Constantinea simplex*, Tetrahedron Letters 31(21):2995-2998.

Nishiwaki, S. et al, 1990. Structure-activity relationship within a series of okadaic acid derivatives, Carcinogenesis 11(10):1837-1841.

Pan, J.S., Berdanier, C.D., 1991. Dietary fat saturation affects glucose metabolism without affecting insulin receptor number and affinity and adipocytes from BHE rats, J. Nutr. 121:1811-1819.

Pan, J.S., Berdanier, C.D., 1991. Dietary fat saturation affects hepatocyte insulin binding and glucose metabolism in BHE rats, J. Nutr. 121:1820-1826.

Pan, J.S., Berdanier, C.D., 1991. Dietary fat saturation affects glucose metabolism without affecting insulin receptor number and affinity in adipocytes from BHE rats, J. Nutr. 121:1811-1819.

Pham, A.T., Ichiba, T., Yoshida, W.Y., Scheuer, P.J., Uchida, T., Tanaka, J. and Higa, T. 1991. Two marine sesquiterpene thiocyanates, Tetrahedron Letters 32(37):4843-4846.

Pham, A.T. et al., 1992. Haumanamide, a nitrogenous spongian derivative from a Spongia sp. Tetrahedron Letters, 33(9):1147-1148.

Pordesimo, E.O. and Schmitz, F.J., 1990 New bastadins from the sponge *Ianthella basta*. J. Org. Chem. 55:4704-4709.

Potts, B.C.M., Capon, R.J., and Faulkner, D.J. 1992. Luffalactone and (4E,6E)-dehydromanoalide from the sponge *Luffariella variabilis*, J. Org. Chem., 57:2965-7.

Potts, B., and D.J.Faulkner. 1991. Didemnaketals A and B, HIV-1 protease inhibitors form the ascidian *Didemnum* sp., J. Am. Chem. Soc. 113(16):6321-6322.

Potts, B.C.M., Faulkner, D.J., DeCarvalho, M.S., and Jacobs, R.S. 1992. Chemical mechanism of inactivation of bee venom phospholipase A_2 by the marine natural products manoalide, luffariellolide, and scalaradial, J. Amer. Chem. Soc. 114:5093-100.

Proteau, P.J. and Gerwick, W.H., 1992. Cymathere ethers A and B: bicyclic oxylipins from the marine brown alga *Cymathere triplicata*, Tetrahedron Letters, 33(31):4393-4396.

Rao, C.B., G. Trimurtulu, D.V. Rao, S.C. Bobzin, D.M. Kushlan, and D.J. Faulkner. 1991. Diterpenes from the brown alga *Dictyota divaricata* of the Indian Ocean, Phytochemistry 30(6):1971-1976.

Rodriguez, A.D., Yoshida, W.Y., and Scheuer, P.J., 1990. Poplohuanone A and B. Two new sesquiterpenoid aminoquinones from a Pacific sponge, *Dysidea* sp., Tetrahedron 46(24):8025-8030.

Rogers, G.A., S.M. Parsons, D.C. Anderson, L.M. Nilsson, B.A. Bahr, W.D. Kornreich, R. Kaufman, R.S. Jacobs, and B. Kirtman. 1989. Synthesis, in vitro acetylcholine-storage-blocking activities, and biological properties of derivatives and analogues of trans-2-(4-phenylpiperridino) cyclohexanol (vesamicol), J. Med. Chem. 32:1217-1230.

Roussis, V. et al, 1990. New antiinflammatory pseudopterosins from the marine octocoral *Pseudopterogorgia elisabethae*, J. Org. Chem. 55(16):4916-4922.

Salva, J. and D.J. Faulkner, 1990. A new brominated diphenyl ether from a Philippine *Dysidea* species, J. Nat. Prod. 53(3):757-760.

Salva, J. and Faulkner, D.J., 1990. Metabolites of the sponge *Strongylophora durissima* from Maricaban

Island, Philippines, J. Org. Chem. 55(6):1941-1943.

Schmitz, F.J., DeGuzman, F.S., Hossain, M.B., and Helm, D.V.D., Cytotoxic aromatic alkaloids from the ascidian *Amphicarpa meridiana* and *Leptoclinides* sp.: Meridine and 11-Hydroxyascididemin, J. Org. Chem. 56(2):804-808.

Schmitz, F.J.,DeGuzman, F.S., Choi, Y.H., Hossain, M.B., Rizvi, S.K., and Helm, D.V.D, 1990. Biologically active compounds from marine organisms, Pure & Appl. Chem. 62(7):1393-1396.

Sea Grant Working Committee, 1991. Marine resource development: Pharmacology and bio-organic chemistry, California Sea Grant College Program, 10pp.

Shin J. and Fenical, W. 1991. New Diterpenoids from the Caribbean gorgonian *Eunicea calyculata*. Photochemical interconversion of the cembrene and cubitene skeletons, J. Org. Chem., 56pp.

Shin, J. and Fenical, W. 1991. Fuscosides A-D: Antiinflammatory diterpenoid glycosides of new structural classes from the Caribbean gorgonian *Eunicea fusca*, J. Org. Chem. 56(9):3153-8.

Soedjak, H.S., R.R. Everett, and A. Butler. 1991. The novel non-heme vanadium bromoperoxidase from marine algae: Phosphate inactivation, J. Ind. Microbiol 8:37-44.

Stierle, D.B., and Faulkner, D.J., 1991. Two new pyrroloquinoline alkaloids from the sponge *Damiria* sp., J. Nat. Prod. 54(4):1131-1133.

Stierle, D.B, and Faulkner, D.J., 1991. Antimicrobial n-methylpyridinium salts related to the xestamines from the Caribbean sponge *Calyx podatypa*, J. Nat. Prod. 54(4):1134-1136.

Sullivan, B.W., Faulkner, D.J., Rao, C.B., Rao, D.V., and Raju, V.S.N., 1991. New Alkaloids from an Indian Species of *Zoanthus*, in Bioact. Compd. Mat. Org., Indo-U.S. Symp., Thompson, M-F. et al., eds., Balkema, Rotterdam, pp. 219-24.

Surette, M.E., Whelan, J., Broughton, K.S., and Kinsella, J.E., 1992. Evidence for mechanisms of the hypotriglyceridemic effect of n-3 polyunsaturated fatty acids, Biochimica et Biophysica Acta 1126:199-205.

Surette, M.E., Whelan, J., Lu, G.P., Broughton, K.S., and Kinsella, J.E., 1992. Dependence of dietary cholesterol for n-3 polyunsaturated fatty acid-induced changes in plasma cholesterol in the Syrian hamster, J. Lipid Research 33:263-71.

Tius, M.A. and Reddy, N.K., 1991. Cembrane synthesis. An advanced intermediate for crassin acetate, Tetrahedron Letters 32(30):3605-3608.

Trimurtulu, G., Kushlan, D.M., Faulkner, D.J., and Rao, C.B. 1992. Divarinone, a novel diterpene from the brown alga *Dictyota divaricata* of the Indian Ocean, Tetrahedron Letters 33(6):729-732.

Venhateswarlu, Y., and D.J. Faulkner. 1991. Smenochromenes, unusual macrocyclic sesquiterpene hydroquinone derivatives from a Seychelles sponge of the genus *Smenospongia*, J. Org. Chem. 56(22):6271-6274.

Wander, R.C. and Patton, B.D., 1991. Lipids and fatty acids of three species of northeast Pacific finfish harvested in summer, J. Food Comp. and Anal. 4:128-135.

Wang, Y.J., Miller, L.A., Perren, M., and Addis, P.B., 1990. Omega-3 fatty acids in Lake Superior fish, J. Food Sci. 55(1):71-73 & 76.

Ward, J.E., Targett, N.M., 1991. Bioactive microalgal metabolites: mediation of subtle ecological interactions in phytophagous suspension-feeding marine invertebrates, Bioorg. Mar. Chem. 4:91-118.

Whelan, J., Broughton, K.S., and Kinsella, J.E., 1991. The comparative effects of dietary a-linolenic acid and fish oil on 4- and 5-series leukotriene formation in-vivo, Lipids 26(2):119-126, 1991.

Whelan, J., Broughton, K.S., and Kinsella, J.E., 1991. In vivo formation of leukotriene E_5 by murine peritoneal cells, Prostaglandins 41(1):29-42.

Wiemer, D.F.,D.D. Idler, and W. Fenical. 1991. Vidalols A and B, new anti-inflammatory bromophenols from the Caribbean marine red alga *Vidalia obtusaloba*, Experientia 47:851-853.

Biofouling and Biocorrosion

Abu, G.O., et al., 1991. Properties of an extracellular adhesive polymer from the marine bacterium, *Shewanella colwelliana*, Biofouling, 3:69-84.

Dexter, S.C., Lin, S.H., 1991. Effect of marine bacteria on calcareous deposition, Materials Performance 30(4):16-21.

Ford, T., and Mitchell, R., 1990. The ecology of microbial corrosion, Advances in Microbial Ecology 11:231-262.

LaBlare, M.P. and Wiener, R.M., 1990. Interactions between *Shewanella colwelliana*, oyster larvae, and hydrophobic organophosphate pesticides, Applied and Environmental Microbiology 56(12):3817-3821.

Nunley, J.W., Shea, C., Smith-Somerville, H.E., 1991, Variable expression of gliding and swimming motility in *Deleya marina*, Can. J. Microbiol 37:808-814.

Rice, S.A., Johnson, B.R., and Estevez, E.D., 1990. Wood-boring marine and estuarine animals in Florida. Report No. FLSGP-R-90-005, Florida Sea Grant College Program, 28pp.

Samuelsson, M.-O. and Kirchman, D.L., 1990, Degradation of adsorbed protein by attached bacteria in relationship to surface hydrophobicity, Appl. Environ. Microbiol. 56(12):3643-3648.

Shea, Catherine and Williamson, J. Chad, 1991, A fluorometric microtiter assay for the rapid enumeration of adherent bacteria, BioTechniques 10(2):77.

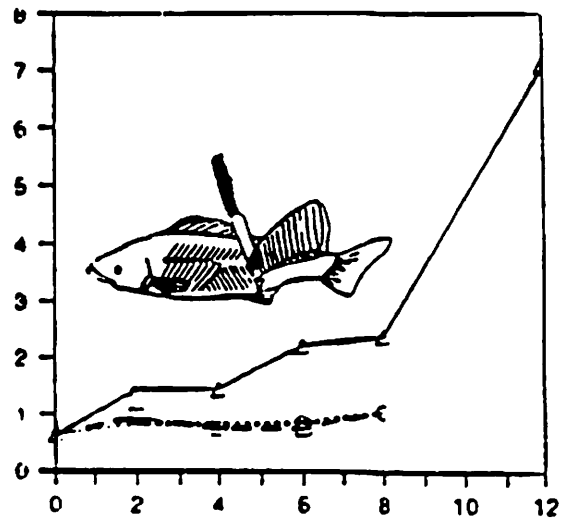
Shea, Catherine and Wiliamson, J.C., 1990. Rapid analysis of bacterial adhesion in a microplate assay, BioTechniques 8(6):610-611.

Shea, Catherine, 1991. Comparison of the adhesion properties of *Deleya marina* and the exopolysaccharide-defective mutant strain DMR, Applied and Environmental Microbiology 57(11):3107-3113.

Shea, C., Nunley, J.W. and Smith-Somerville, H.E., 1991. Variable expression of gliding and swimming motility in *Deleya marina*, Can. J. Microbiol., 37:808-814.

Sledjeski, D.D., Weiner, R.M., 1991. Hyphomonas spp., Shewanella spp., and other marine bacteria lack heterogeneous (ladderlike) lipopolysaccharides, Applied and Environmental Microbiology, 57(7):2094-2096.

Vrolijk, N.H., Targett, N.M., Baier, R.E. and Meyer, A.E., 1990. Surface characterization of two gorgonian coral species: implications for a natural antifouling defense, Biofouling 2:39-54.



Seafood Science and Technology

Introduction

University research in seafood science and technology aids the seafood industry through improvement of technology and products, development of new products and by-products, and through development of techniques and processes for assuring seafood safety and high quality. The research is important in order to develop skilled personnel for employment. It also contributes to expanding domestic and foreign markets for U.S. seafood because expansion depends largely on product quality, safety, appearance, and regional acceptance, and on innovation and efficiency in production.

Although foreign fishing in the U.S. zone of extended economic jurisdiction has declined sharply over the past few years to only 5,349 metric tons in 1991, imports of edible fishery products still stood at 1.4 million metric tons valued at $5.7 billion. Total exports of edible fishery products stood at $3.0 billion. Obviously, this large deficit in trade deserves attention. Seafood science plays a role in reducing it. It can play a larger role and also can aid in providing safe and nutritious food to consumers increasingly concerned about effects of diet on health.

Research, education, and outreach in seafood technology comprise an important component of the National Sea Grant College Program. This component trains students for productive careers and serves a sector of marine industry made up primarily of small processing companies without research capability. Of the approximately 1,300 companies engaged in processing seafood fewer than 30 percent have gross revenues exceeding $2 million. Many of the problems and opportunities of the industry are of interest to academic scientists and amenable to their research methods.

Sea Grant's research in seafood technology is closely aligned with the needs of industry because of close linkages with it through advisory service programs. In fact, a number of advisory specialists in Sea Grant extension programs serve as investigators in research projects. Some also have formal teaching responsibilities at the universities where they are employed. Research and demonstration projects conducted by advisory personnel with funding through extension programs complement the work conducted in formal research projects.

Sea Grant's research in seafood science complements related research of the National Marine Fisheries Service in its laboratories in Charleston, South Carolina; Gloucester, Massachusetts; Pascagoula, Mississippi; and Seattle, Washington as well as in extramural projects supported with Saltonstall-Kennedy (S-K) funds. Some of the S-K research and service is conducted by scientists, advisory specialists, and educators as an adjunct to or extension of their Sea Grant work. Developmental projects of the National Coastal Resources Research and Development Institute often are closely aligned with Sea Grant research in seafood technology or are extensions of it.

During FY 1992, Sea Grant sponsored 39 research projects in the four categories shown in Table 1 with $1,400,000 in federal funds and $857,000 in nonfederal matching funds. Table 2

Seafood Science and Technology
Federal Funding for Projects
in Fiscal Years 1991-1992
(in dollars)

Category	1991 No. Projects	Funding Federal	Funding Match	1992 No. Projects	Funding Federal*	Funding Match
Engineering and Waste Treatment	1	44,729	22,831	1	47,108	14,607
Product Development/ By-Product Recovery	5	196,708	126,227	6	276,571	185,145
Microbiological, Nutritional, Organoleptic Quality	20	708,602	335,092	26	946,309	494,573
Handling/ Processing	9	238,918	191,608	6	130,263	162,989
Total	35	1,188,957	675,758	39	1,400,251	857,314

*Includes $174,935 that other federal agencies provided to Sea Grant.

Table 1

shows the number of projects and funding for research in seafood technology in state and regional Sea Grant programs.

Contamination or potential contamination of seafood with the bacterium *Listeria monocytogenes* was the most alarming safety issue to face the seafood industry recently. *Listeria* was unknown to most food microbiologists until 1985 when it was found in certain soft cheeses. Because the organism can cause severe illness or death, regulatory agencies established the most conservative standard possible—"zero tolerance" in ready-to-eat foods. Sea Grant researchers and advisory specialists in the Southeast, especially in Virginia, have been working to develop new ways to control *Listeria* and to heighten awareness about the nature and control of this pathogen. Working with crab processors, the National Fisheries Institute, and the Virginia Department of Health, they initiated research and educational efforts that began with monitoring for the presence of *Listeria* in processing plants. With support from the Virginia Seafood Council, the researchers conducted workshops that included instruction on the design and implementation of a cleaning and sanitation program to control *Listeria* and demonstrations of appropriate plant cleaning procedures and equipment. These efforts quickly extended beyond Virginia. At the annual conference of the National Blue Crab Industry Association and the Shellfish Institute of North America in early 1992, Sea Grant personnel from several states conducted a session for the seafood industry on "Coping with *Listeria* in the 90s." Sea Grant acted as an essential link between regulators and processors in practical application of standards for *Listeria*.

Examples of other activities and advancements are given below by category. The name or names after each example is the key to a corresponding

publication in the appendix which is a listing, in five categories, of recent Sea Grant publications dealing with seafood technology. The intent was to include papers, reports, and bulletins appearing since the last report in this series which was issued in early 1990. A section of a companion report —*Projects '92* — provides a listing of all Sea Grant seafood science and technology research projects funded in FY 1992. That listing gives levels of funding and names of the projects' principal investigators with their institutional affiliations.

Examples of Advancements and Activities

Engineering and Waste Treatment

An international conference examined a wide range of possibilities for making value-added products and profits from seafood wastes. (Keller)

A technologist reviewed seafood waste management alternatives, including dry cleanup, water conservation, water recycling, and by-product recovery and provided case histories that illustrate practical approaches for industry. (Gates)

A report described current technologies for increasing the value of fish processing wastes and decreasing the pollution caused by them. It suggests which technologies might be adopted by a processor of finfish, what it might cost, and how to proceed. (Goldhor and Regenstein)

Studies in a herring roe and oyster cannery showed that requirements relating to oxygen content of effluent could be easily achieved by simple settling. Wastewater from oyster canning met guidelines without treatment. (Grassiano et al.)

Engineers defined environmental regulatory requirements applying to seafood processors in Louisiana and developed recommendations for treatment of nontoxic biodegradable wastes. (Zachritz and Malone)

A food technologist reviewed technology and data relating to recovery of chitin and chitosan from shellfish processing and applying them in waste management, beverage clarification, and production of packaging films and diet supplements. (Knorr)

A compilation of processing costs and revenue

Seafood Science and Technology
Number of Projects and Funding
in State and Regional Sea Grant Programs
Fiscal Year 1992
(in dollars)

Institution	No. Projects	Funding Federal*	Funding Match
Alaska Sea Grant	3	105,102	48,279
California Sea Grant	5	71,890	68,666
Florida Sea Grant	1	24,012	12,064
Georgia Sea Grant	2	62,359	84,443
Hawaii Sea Grant	1	21,929	15,498
Louisiana Sea Grant	3	99,088	67,659
Maryland Sea Grant	1	93,126	0
ME/NH Sea Grant	1	50,000	7,519
MS/AL Sea Grant	2	61,796	47,980
MIT Sea Grant	1	50,010	27,070
Michigan Sea Grant	1	33,465	17,841
New York Sea Grant	1	50,541	40,974
N. Carolina Sea Grant	2	8,206	54,368
Oregon Sea Grant	3	132,956	96,300
Texas A&M Sea Grant	3	148,790	59,136
Virginia Sea Grant	1	44,966	24,314
Washington Sea Grant	3	109,838	39,448
Wisconsin Sea Grant	3	148,837	84,707
Woods Hole Sea Grant	2	83,340	61,048
Total	39	1,400,251	857,314

*Includes $174,935 that other federal agencies provided.

Table 2

data from a pilot project showed the business potential for turning fishery wastes into saleable compost. (Frederick)

Demonstration projects presented Great Lakes fishing resorts with composting as an alternative for disposing of fish wastes. (Halbach and Baker)

Product Development and By-Product Recovery

Experiments defined techniques and conditions for mechanical recovery of high quality minced meat from picking-room wastes of blue crabs. (Gates and Parker)

Filleted menhaden packed in oil or broth showed potential as a canned product for human consumption. (Johnson et al.)

As compared to a soybean meal diet, a fish meal diet lowered milk fat and increased production of milk per unit of dry matter ingested. (Bruce and Herlugson)

Freeze-dried wash water from clam processing replaced clam meat in clam dip without any significant changes in overall acceptability, taste, odor, texture or appearance. (Reddy et al.)

A manual specified standard methods for measuring and specifying the properties of surimi. (Lanier et al.)

A food engineer discussed the use of rheology in studying gels, made from food proteins, and in determining their quality. (Hamann) Another described interactions of muscle and non-muscle proteins that determine the rheological properties of heat-set gels. (Lanier)

Commercially available dried beef plasma hydrolysate and egg white solids inhibited gel weakening in surimi. (Hamann et al.)

Experiments demonstrated the effects of salt and sucrose on thermal denaturation and aggregation of proteins leached from fish muscle. (Park and Lanier)

Pre-rigor fish provided surimi with significantly higher protein yield, less cook loss, and enhanced gel-forming ability than fish in rigor mortis. (Park et al.)

Measurements with a simple muscle tension measuring device provided monitoring of rigor mortis development just as reliably as most published methods that involve complex equipment or procedures. (Korhonen et al.)

Food technologists reviewed use of carbohydrates as cryoprotectants in production of surimi, discussed mechanisms of protection, and addressed future directions in cryoprotection. (MacDonald and Lanier)

Food engineers developed a system for measuring thermal conductivity of surimi and selected a model for predicting its temperature dependent properties. They also demonstrated the great potential of differential scanning calorimetry for measuring and modeling thermal properties of frozen food. (Wang and Kolbe)

Microbial, Nutritional, and Organoleptic Quality

Microbiologists showed that microorganisms common in production plants are a potential source of contamination of surimi and discussed procedures that will minimize microbial loads. (Himelbloom et al.; Jong)

Environmental temperatures or salinity affected the concentrations of 16 elements in oysters. (Ward and Flick)

Direct titration of chloride with silver nitrate provided an easier and quicker method for determining salt in oysters than the standard AOAC procedure. (Hackney et al.)

Nutritionists compiled a comprehensive nutrient and nomenclature handbook for selected fishes of the southeastern United States. (Sullivan and Otwell)

Studies of non-enzymatic oxidation of lipids in mackerel muscle suggests that metals such as iron that are normally present catalyze the process. (Decker and Hultin; Decker and Hultin) Chloride ion also stimulated oxidation of some lipid fractions. (Osinchak et al.)

Although haeme iron is a catalyst of oxidation, bleeding of salmon prior to frozen storage did not reduce the rate at which rancidity developed. (Porter

and Kennish) Surface blanching of lake herring fillets decreased the rate of lipid oxidation. (Wang and Addis)

Chitosan powder provided the basis for a new fluorescence sensor to monitor lipid oxidation. (Weist and Karel)

Magnetic resonance imaging provided a new method for noninvasive measurement of lipid and water in food. (Winkler et al.)

A review summarized and compared the role of lipids in providing texture, flavor, and color in avian, aquatic, and mammalian muscle. (German)

Microbiologists used the polymerase chain reaction for a new procedure to detect the human pathogen *Vibrio vulnificus* in raw oysters in less than eight hours. (Brauns et al.)

In a bulletin for processors, seafood technologists described the symptoms associated with, characteristics and control of most human pathogens associated with seafood in the Pacific Northwest. (Lee and Hilderbrand)

Studies of thermal death times for the human pathogen *Listeria monocytogenes* indicated that parameters used to commercially pasteurize crab meat are adequate to inactivate the bacterium. (Harrison and Huang) Levels of the bacterium on inoculated fish and shrimp did not increase over a period of three months in frozen storage or during 21 days of chilled storage regardless of the type of packaging. (Harrison et al.)

A computer program predicted and calculated the meat yield from blue crabs as a function of biological and processing variables. (Hong et al.)

Studies of soft-shell clams in Chesapeake Bay showed their levels of bacteria to be safe for consumption. (Chai et al.)

Sensory evaluation of previously frozen albacore tuna suggested that processing at sea may improve flesh appearance, but would not significantly change other properties. During a period of 33 days chilled storage albacore tuna dressed, bled, or left round did not differ in several chemical indices of quality. (Price et al.; Price et al.)

Studies of iced rockfish during the first several days postharvest suggested that enzymatic solubilization of collagen is responsible for undesirable softening of flesh. (Kim and Haard) A new method provided quantitative measures of collagen cross-linking in fish muscle. (Bracho and Haard)

A seafood technologist reviewed the chemical basis of the quality of seafood flavors and aromas and described the kind of deteriorative processes that must be suppressed to maintain high quality. (Lindsay)

Nine-carbon volatile alcohols and aldehydes proved to be responsible for the more pronounced aromas of salmon in spawning condition; they add to the distinct and desirable plant-like aromas from the eight-carbon alcohols and aldehydes normally present. (Josephson et al.)

Several volatile bromophenols that occur naturally in marine food chains imparted flavor notes reminiscent of marine fish and seafood to shrimp, fresh water fish, and vegetable oil matrices. (Boyle et al.)

Carotenoids appeared to be precursors of a single compound that provides a distinct cooked salmon-loaf aroma. (Josephson et al.)

Carbon dioxide atmospheres and sorbate dips each retarded deterioration (as indicated by hypoxanthine formation) of fresh fish in refrigerated storage. (Boyle et al.)

Rainbow trout diets enriched in linolenic acid increased the concentration of this acid in the flesh, but affected the relative concentration of the n-3 fatty acids, EPA and DHA to only a small degree. (Sowizral et al.)

Diets rich in n-3 polyunsaturated fatty acids enhanced production of tumor necrosis factor in mice. (Hardardottir and Kinsella)

Nutritionists showed that degree of saturation in dietary fat in rats affected glucose transport, oxidation and conversion to fatty acids, but not insulin binding. (Pan and Berdanier)

In the hamster, consumption of n-3 fatty acids increased low density lipoprotein (LDL) cholesterol

levels and decreased high density lipoprotein (HDL) cholesterol levels; changes in LDL-cholesterol but not HDL-cholesterol depended on content of dietary cholesterol. Ingestion of modest amounts of n-3 fatty acids decreased levels of triglyceride in plasma. (Surette et al.; Surette et al.)

Diets containing Chinook salmon or sablefish (both high in n-3 fatty acids) increased LDL-cholesterol in human males as compared to diets containing Dover sole (low in n-3 fatty acids). The results suggest that consumption of fish with moderate amounts of n-3 fatty acids may cause a deleterious rise in LDL-cholesterol. (Gerhard et al.)

A diet containing 9 percent menhaden oil and 1 percent corn oil shortened the life of rats bred to develop noninsulin-dependent diabetes mellitus and lipemia without obesity. (Berdanier et al.)

Dietary fish oil modulated eicosanoid metabolism and altered composition of fatty acids in tissue phospholipids two and one-half to five times more effectively than linolenic acid. (Whelan et al.)

A survey determined the fatty acid composition of eight species of Lake Superior fishes. (Wang et al.)

Nutritionists demonstrated that accurate dietary recommendations require better information about seasonal variation in lipid content of finfish. (Wander and Patton) Others reviewed possible mechanisms of actions and dietary implications of n-3 polyunsaturated fatty acids. (Kinsella et al.) A book clarified numerous issues surrounding the consumption of fish oil. (Lees and Karel)

A scientist summarized the effects of dietary polyunsaturated fatty acids on membrane composition, membrane-associated enzyme and receptor functions, signal transduction, and eicosanoid generation. (Kinsella)

A microbiologist reviewed the ecology of estuarine bacteria capable of causing human disease. (Grimes)

Virologists developed a high efficiency procedure for plating hepatitis A virus in monkey kidney cells. (Nadala and Loh)

Biochemical studies showed that excretions and/or secretions from larval anisakid worms are vital for the establishment of the parasite in its hosts which include fishes and humans. (Sakanari)

Levels of paralytic shellfish toxins in the viscera of the purple hinge rock scallop could not be used to determine safety of adductor muscles for consumption. (Beitler)

Diets of either a low-toxicity or high-toxicity strain of the dinoflagellate *Alexandrium fundyense* caused accumulation of saxitoxin in the northern quahog and showed the potential of this species to act as a vector of poisoning in humans. (Bricelj et al.)

A new method using centrifugation provided quantitative extraction of dinoflagellate cysts from marine sediments. (Schwinghamer et al.)

Physiological adaptations by the dinoflagellate *Alexandrium fundyense* to nitrogen and phosphorus limitation produced dramatic changes in relative abundance of toxins; this finding is at odds with the paradigm that total concentration of toxins, but not relative abundance of each toxin, varies with growth conditions. (Anderson et al.)

A new chemical method permitted determination of twelve PCBs in fish samples at parts-per-trillion levels. (Hong and Bush) Total concentration of PCBs but not fish length provided good estimates of toxicity of fish flesh. (Williams et al.)

A study of PCBs in fish and mussels indicated that accurate determination of the PCB congeners that elicit aryl hydrocarbon hydroxylase activity in animals is important in assessing risk of consumption. (Hong et al.)

Over a period of 10 years levels of DDT in serum of 115 eaters of Great Lake fishes declined significantly while PCB levels declined only slightly. (Hovinga et al.)

Fat trimming proved effective in reducing levels of PCB and mirex in brown trout from Lake Ontario. The correlations between weight, length, and age of fish and the levels of fat content reinforced the value of recommendations to avoid larger and older fish in order to minimize ingestion of fat-soluble contaminants. (Voiland et al.)

Comparison of fresh and 40-year-old pasteurized blue crab meat showed that neither harbored herbicides although the 40-year-old sample contained very low levels of DDT decomposition products. (Reddy et al.)

Handling and Processing

A primer for shippers and cargo handlers provided practical information on how to ship fresh fish by air. (Crapo and Paust)

A new manual with color photographs described causes of poor quality salmon and how to avoid them. (Doyle)

Because the fishing season for halibut is only four or five days, fishers want to avoid on-board processing. Experiments showed no significant differences in quality between dressed and round halibut held at 32°F. Quickly reducing the internal temperature of halibut is a primary key to high quality. (Crapo et al.)

Vacuum packaging and treatment with a water soluble antioxidant provided long-term quality protection of fatty mackerel during frozen storage. Low-fat hake fared better without vacuum or antioxidants. (Santos and Regenstein)

Studies of an interactive model for determining minimum freezing times for fish products in commercial operations showed that it provides a rough prediction of freezing times. Researchers will improve it through cooperative efforts with users. (Kolbe)

An engineer designed a monitor, assembled from commercially available hardware and instrumentation, that allows small processors and laboratories to track and analyze performance data during various kinds of freezing and storage of food. (Kolbe and Schnekenburger)

Use of seawater refrigerated mechanically for flooded tanks on fishing vessels consumed energy at roughly half the rate required for seawater chilled with ice brought from shore. (Kolbe)

A new technique for quickly freezing Dungeness crab with liquid nitrogen achieved preservation of texture and flavor closely approximating that of fresh crab. (Berstein et al.)

A workshop, involving industrial, academic, and governmental participants, addressed a spectrum of issues affecting post-harvest quality of the abundant Pacific whiting. (Sylvia and Morrissey)

A mathematical model predicted lag phase in growth of *Clostridium botulinum* toxicity in fresh fish stored under modified atmospheres. (Baker and Genigeorgis)

The second edition of a text for home study provided current information on the many aspects of managing and operating commercial seafood departments. (Arnold and Gall)

A bulletin offered suggestions for low-cost or no-cost methods to improve or maintain energy efficiency in fish processing plants and provided general principles of energy conservation. (Barkston et al.)

Engineering and economic scientists summarized economic and technical considerations for brine freezing of shrimp. (Bankston et al.)

Soaking Dungeness crab in 10% polyphosphate for one to two hours improved meat yield, quality, and stability in frozen storage. (Crapo and Crawford)

Alkali refining and clay bleaching removed many odiferous compounds in menhaden oils; steam deodorization eliminated most volatiles. (Lin et al.)

Seafood scientists predicted non-traditional methods of preserving seafood such as hypobaric storage, enzyme treatment, and pasteurization will be used more extensively in the future. (Flick et al.)

An evaluation of handling practices for scallop meat on fishing vessels showed that scallops held on deck should be immersed in 1:2 ice:seawater in insulated totes. (DuPaul et al.)

Analyses indicate that although benefits are not obvious, Mid-Atlantic fishers should consider implementing ship-board procedures for quality control in order to maintain their share of the market. (Fisher)

Opportunities and Needs for the Future

The National Sea Grant College Program's investment in seafood science and technology pays off well with fundamental advancements in food science, results important in improving practice and efficiency in seafood processing, and training of competent new professionals for the work force. The research, education, and service in this field also help the U.S. seafood industry improve its position in international commerce. In this regard, there are special opportunities in improving surimi technology especially for abundant species that don't now lend themselves easily to this application.

Seafood is still a significant contributor to food-borne illness and accounts for about 10 percent of all outbreaks of reported food-borne illness. Thus, issues relating to microbial quality of seafood, especially, are still important. Some areas of concern, relating to research and extension, are (a) the need for better tests to measure and control microbiological contamination in shellfish-growing waters and in shellfish stock, (b) the need for reliable measure or better indicator of viral contamination in shellfish, (c) the need to create greater public awareness of potential health risks associated with consuming raw or undercooked molluskan shellfish, (d) the need for more consumer education about seafood handling and preparation, and (e) the need for more research to better understand chemical contamination in seafood and its implications for human health.

Natural toxins such as ciguatoxin, scombrotoxin, paralytic shellfish poison, and diarrhetic shellfish poison, continue to be principal contributors to seafood-borne illness. The source and distribution of the ciguatoxins remains poorly defined and no quick and reliable methods for their routine detection have been adopted. Problems relating to these toxins need research attention from a number of directions including food science, medical science, and ecological science.

More recent and perhaps much more serious is the natural toxin, domoic acid, that causes amnesiac shellfish poison (ASP.) Domoic acid is an insidious, neuroexcitatory, non-protein amino acid. ASP was characterized for the first time in late 1987 after isolation from Canadian blue mussels. In 1991, it appeared in shellfish off the West Coast. ASP and the biological oceanography of *Nitschia*, the genus of diatom that elaborates it, are topics of importance for research.

Organoleptic quality and efficiency in production of seafood as well as new product types will be issues of increasing importance in the competition to sell products in both domestic and foreign markets.

Seafood processors across the United States are facing serious and urgent problems in meeting requirements of county, state, and national regulations for protection of the environment from solid, liquid, and air-borne wastes. These regulations are not uniform nor are they uniformly enforced across jurisdictions. And they are changing. Penalties for violation of these regulations can be severe. Heavy fines can be levied against companies—heavy fines and jail terms against individuals. Companies across the nation are having to close when faced with associated costs. Rapidly rising costs for treating water and sewage are accruing to governmental entities. Because they transfer these costs to industry, disposal and treatment of processing wastes in public facilities is no longer feasible for many commercial operations. Some governmental jurisdictions no longer accept seafood wastes for disposal in landfills. Thus, research to address issues relating to effluent and waste management is of high priority. Research on by-product recovery, water conservation, and biological processing and associated demonstration projects are potential avenues for addressing this issue.

Appendix
Seafood Science and Technology Publications: 1990-1992

Engineering and Waste Treatment

Cato, J.C. (ed.), 1992. Composting and using by-products from blue crab and calico scallop processing plants in Florida, Report No. FLSGP-O-92-001 (SGR-107), Florida Sea Grant College Program, 67pp.

Frederick, L., 1991. Turning fishery wastes into saleable compost, Biocycle 32(9):70-71.

Gates, K., 1992. Waste reduction, water conservation, and recovery of seafood by-products, MTS

Journal 25(1):44-51.
Goldhor, S.H., Regenstein, J.M., 1991. Improving the profitability of finfish processing waste, Report No. NYSGI-T-91-001, New York Sea Grant College Program, 101pp.
Grassiano, J.W., Boardman, G.D. and Flick, G.J., 1990. Wastewater treatment alternatives for a seafood and vegetable cannery, Report No. VSGCP-T-90-003(VSG-90-05), Virginia Sea Grant College Program, 175pp.
Halbach, T.R., Baker, D.R., 1991. Composting fish waste: An alternative for Minnesota resorts, Report No. MINNU-H-91-001, Minnesota Sea Grant College Program, 16pp.
Hart, K., Green, D., 1992. The 1991 seafood environmental summit proceedings, Report No. UNC-SG-92-06, North Carolina Sea Grant Program, 132pp.
Keller, Sue, 1990. Making profit$ out of seafood wastes, Report No. 90-07, Alaska Sea Grant College Program, 239pp.
Knorr, Dietrich, 1991. Recovery and utilization of chitin and chitosan in food processing waste management, Food Technology, 45:114-122.
Zachritz, W.H. and Malone, R.F., 1991. Wastewater treatment: Options for Louisiana seafood processors, Report No. LSU-T-91-001, Louisiana Sea Grant College Program, 76pp.

Product Development and By-Product Recovery

Albisetti, C.J. and Castle, J.E., 1990. Dispersions of chitin and product therefrom, Report No. DELU-R-90-003, Delaware Sea Grant College Program, 98pp.
Anonymous, 1991. A manual for standard methods for measuring and specifying the properties of surimi. Report No. NCU-H-91-002 (UNC-SG-91-01), North Carolina Sea Grant College Program, 68pp.
Bruce, L.B. and Herlugson, M.L., 1991. Milk fat content and production performance of Holstein dairy cows fed fish meal, Asian-Australasian Journal of Animal Science 4(1):25-29.
Chang-Lee, M.V., Lampila, L.E., and Crawford, D.L., 1990. Yield and composition of surimi from Pacific whiting (*Merluccius productus*) and the effect of various protein additives on gel strength, J. Food Sci. 55(1):83-86.
Gates, K.W., Parker, A.H., 1992. Recovery of minced meat from blue crab picking plant by-products, Report No. GAUS-T-92-001, Georgia Sea Grant College Program, 54pp.
Gates, K.W., Parker, A.H., 1992. Characterization of minced meat extracted from blue crab picking plant by-products, J. Food Sci. 57(2):267-270 & 290.
German, J.B., McCarthy, M.J., Winkler, M., 1991. Noninvasive measurement of lipid and water in food using magnetic resonance imaging, J. Food Sci. 56(3):811-815.
Hamann, D.D. et al, 1990. Inhibition of modori (gel weakening) in surimi by plasma hydrolysate and egg white, J. Food Sci., 55(3):665-669 & 794.
Hamann, D.D., 1990. Rheology: A tool for understanding thermally-induced protein gelatin in interactions of food proteins, Parris, N. and Barford, R. (eds.), American Chemical Society, pp 212-227.
Hamann, D.D., Purkayastha, S. and Lanier, T.C., 1990. Applications of thermal scanning theology to the study of food gels, in Thermal Analyis of Foods, Harwalkar, V.R. and Ma, C.Y. (eds.), Elsevier Applied Science, pp. 306-332.
Huang, T-s, Chen, J.S., Marshall, M.R. and Wei, C-i., 1990. Quantification of shrimp in shrimp-surimi mixtures using urea gel isolelectic focusing, J. Food Sci. 55(5):1206-09.
Johnson, J.M., Flick, G.J., Long, K.A., Phillips, J.A., 1990. Menhaden (*Brevoortia tyrannus*): thermally processed for a potential food resource, Report No. VSG-90-109R, Virginia Sea Grant College Program, 79pp.
Korhonen, R.W., Lanier, T.C., and Giesbrecht, F., 1990. An evaluation of simple methods for following rigor development in fish, J. Food Sci. 55(2):346-348 & 368.
Knorr, D., Beaumont, M.D., Caster, C.S., Dornenburg, H., Gross, B., Pandya, Y., Romagnoli, L.G., 1990. Plant tissue culture for the production of naturally derived food ingredients, Food Technology, 45:71-79.
Lanier, T.C., 1991. Interactions of muscle and nonmuscle proteins affecting heat-set gel rheology, ACS Sym. Ser. 454:268-84.
Lanier, T.C., Hart, K., Martin, R.E. (eds.), 1991. A manual of standard methods for measuring and

specifying the properties of surimi, Report No. UNC-SG-91-01, North Carolina Sea Grant College Program, 64pp.

Lee, J.S., Hilderbrand Jr., K.S., 1992. Hazard analysis and critical control point applications to the seafood industry, Report No. ORESU-H-92-001, Oregon Sea Grant College Program, 28pp.

Lee, J.S., 1992. Microbiological considerations in surimi manufacturing, in Surimi Technology, Marcel Dekker, Inc., pp. 113-121.

MacDonald, G.A., Lanier, T., 1990. Carbohydrates as cryoprotectants for meats and surimi, Food Technology 45(3):150, 152-154, 156, 158-159.

Meyers, S.P. et al., 1990. An integrated approach to recovery and utilization of Louisiana crawfish processing wastes, Int'l. Fish By-Prod. Conf. Proceedings, pp. 161-171.

Park, J.W., Korhonen, R.W., and Lanier T.C., 1990. Effects of rigor mortis on gel-forming properties of surimi and unwashed mince prepared from tilapia, J. Food Sci. 55(2):353-355 & 360.

Park, J.W., Lanier, T.C., 1990. Effects of salt and sucrose addition on thermal denaturation and aggregation of water-leached fish muscle, J. Food Biochem. 14(5):395-404.

Reddy, N.R., Flick, G.J., Dupuy, H.P., Boardman, G.D., 1990. Characterization and utilization of dehydrated wash waters from clam processing plants as flavoring agents, J. Food Sci. 54(1):55-59 & 182.

Regenstein, J.M., Goldhor, S.H., 1991. Improving the profitability of finfish processing waste: options for fish processors with an emphasis on mechanical deboning (mincing), hydrolysis (liquid fertilizer production), and composting, Report No. NYSGI-T-91-001, New York Sea Grant College Program, 48pp.

Shiau, C.Y. and Chai, T., 1990. Characterization of oyster shucking liquid wastes and their utilization as oysters soup, J. Food Sci. 55(2):374-378.

Wang, D.Q. and Kolbe, E., 1990. Thermal conductivity of surimi-measurement and modeling, J. Food Sci. 55(5):1217-1221 & 1254.

Wang, D.Q. and Kolbe, E., 1991. Thermal properties of surimi analyzed using DSC. J. Food Sci. 56(2):302-308.

Wei, C-i., An, H., Chen, J-s., and Marshall, M.R., 1990. Use of modified urea gel isoelectric focusing method for species identification of raw or boiled white, pink, and rock shrimp, J.Food Biochem. 14:91-102

Microbial, Nutritional, and Organoleptic Quality

An, H., Klein, P.A., Kao, K-j., Marshall, M.R., Otwell, W.S., and Wei, C-i., 1990. Development of monoclonal antibody for rock shrimp identification using enzyme-linked immunosorbent assay, J. Agri. Food Chem. 38:2094-2100.

Anderson, D.M., Kulis, D.M., Sullivan, J.J., and Hall, S., 1990. Toxic composition variations in one isolate of the dinoflagellate *Alexandrium fundyense*, Toxicon 28(8):885-893.

Anderson, D.M., 1990. Toxin variability in Alexandrium species, in Toxic Marine Phytoplankton, E. Graneli et al. (eds.), Elsevier Sci. Pub. Co., pp. 41-51.

Anderson, J.G. and Anderson, J.L., 1991. Seafood quality: Issues for consumer researchers, Journal of Consumer Affairs 25(1):144-163.

Anonymous, 1991. Moisture/protein levels in sea scallops, Report No. VSGCP-G-91-004. Virginia Sea Grant College Program, 1pp.

Anonymous, 1991. Consumo de pescado del Lago Michigan, Report No. WISCU-G-91-002 (WOS-SG-91-158), Wisconsin Sea Grant College Program, 2pp.

Arganosa, G.C. and Flick, G.J., 1992. Off-flavors in fish and shellfish, in Off-flavors in Foods and Beverages, Charalambus, G. (ed.), Elsevier Sci. Pub., pp. 103-126.

Baker, D.A. et al., 1990. Growth and toxigenesis of *C. botulinum* type E in fishes packaged under modified atmospheres, International J. of Food Microbiology 10:269-290.

Beitler, M.K., 1991. Toxicity of adductor muscles from the purple hinge rock scallop (*Crassadoma gigantea*) along the Pacific coast of North American, Toxicon 29(7):889-894.

Berdanier, C.D., Johnson, B., Hartle, D.K., Crowell, W., 1992. Life span is shortened in BHE/cdb rats fed a diet containing 9% menhaden oil and 1% corn oil, J. Nutr. 122:1309-1317.

Beristain, M., 1991. Pathogens, Report No. NYSGI-G-91-001, New York Sea Grant College Program, 4pp.

Beristain, M. and Gall, K., 1990. Long Island Sound

study: seafood issues, Report No. NYEXT-G-90-001, New York Sea Grant College Program, 4pp.

Binder, B.J. and Anderson, D.M., 1990. Biochemical composition and metabolic activity of *Scrippsiella trochoidea* (Dinophycease) resting cysts, J. of Phycology 26:289-298.

Boyle, J.L., Lindsay, R.C., Stuiber, D.A., 1991. Adenine nucleotide degradation in modified atmosphere chill-stored fresh fish, J. Food Sci. 56(5):1267-1270.

Boyle, J.L., Lindsay, R.C., and Stuiber, D.A., 1991. Contributions of bromophenols to marine-associated flavors of fish and seafood, JAFPT 1(3/4):43-63.

Bracho, G.E. and Haard, N.F., 1990. Determination of collagen crosslinks in rockfish skeletal muscle, J. Food Biochem. 14:435-451.

Brauns, L.A., Hudson, M.C., Oliver, J.D., 1991. Use of the polymerase chain reaction in detection of culturable and nonculturable *Vibrio vulnificus* cells, Appl. Environ. Microbiol. 9:33-47.

Bricelj, V.M., Lee, J.H., Cembella, A.D. and Anderson, D.M., 1990. Uptake of *Alexandrium fundyense* by *Mytilus edulis* and *Mercenaria mercenaria* under controlled conditions, in Toxic Marine Phytoplankton, Elsevier Sci. Pub. Co., pp. 269-274.

Bricelj, V.M, Lee, J.H., Cembella, A.D. and Anderson, D.M., 1990. Uptake kinetics of paralytic shellfish toxins from the dinoflagellate *Alexandrium fundyense* in the mussel *Mytilus edulis*, Mar. Ecol. Prog. Ser. 63:177-188.

Bricelj, V.M., Lee. J.H. and Cembella, A.D., 1991. Influence of dinoflagellate cell toxicity on uptake and loss of paralytic shellfish toxins in the northern quahog *Mercenaria mercenaria*, Mar. Ecol. Prog. Ser. 74:33-46.

Broughton, K.S. et al, 1990. Effect of increasing the dietary (n-3) to (n-6) polyunsaturated fatty acid ratio on murine liver and peritoneal cell fatty acids and eicosanoid formation, J. Nutr. 12:155-164.

Bucknavage, M.W. et al, 1990. Thermal inactivation of *Clostridium botulinum* type E spores in oyster homogenates at minimal processing temperatures, J. Food Sci. 55(2):372-373 & 429.

Bunce, O.R., Abou El-Elz, S.H., and Berdanier, C.D., 1992. Long-term feeding of corn oil, beef tallow, or menhaden oil and eicosanoid levels in BHE/cdb rats, Nutrition 8(6):421-25.

Cepeda Jr., R. et al., 1990. An immunological method for measuring collagen degradation in the muscle of fish, in Advances in Fisheries Technology and Biotechnology for Increased Profitability, pp. 488-506.

Chai, T.J. et al, 1990. Microbial studies of Chesapeake Bay soft-shell clams (*Mya arenaria*), J. Food Protection 53(12):1052-1057.

Clair, M.B. et al, 1991. Dioxin: sources, health risks, alternatives, Report No. NCU-G-91-002 (UNC-SG-FS-91-01), North Carolina Sea Grant College Program, 4pp.

Crapo, C.A., Crawford, D.L., 1991. Influence of polyphosphate soak and cooking procedures on yield and quality of Dungeness crab meat, J. Food Sci. 56(3):657-659 & 664.

Croset, M., Kinsella, J.E., 1989. Changes in phospholipid fatty acid composition of mouse cardiac organelles after feeding graded amounts of docosahexaenoate in presence of high levels of linoleate, Ann. Nutr. Metab 33:125-142.

Decker, E.A., Hultin, H.O., 1990. Factors influencing catalysis of lipid oxidation by the soluble fraction of mackerel muscle, J. Food Sci. 55(4):947-953.

Decker, E.A., Hultin, H.O., 1990. Nonenzymic catalysts of lipid oxidation in mackerel ordinary muscle, J. Food Sci., 55(4):951-953.

Dupuy, H.P., Flick, G.J., St. Angelo, A.J., Sumrell, G., 1990. Analysis for trace amounts of geosmin in water and fish, JOCS 63(7):905-908.

Flick, G.J., Hong, G.P. and Knobl, G.M., 1992. Lipid oxidation of seafood during storage, in Lipid Oxidation in Food, St. Angelo, A.J. (ed.), American Chemical Society, pp. 183-207.

Franks, P.J.S., Anderson, D.M., 1992. Toxic phytoplankton blooms in the southwestern Gulf of Maine: Testing hypotheses of physical control using historical data, Marine Biology 112:165-174.

Gall, Ken, 1990. Seafood and health: Nutrient composition., Report No. NYEXT-G-90-007, New York Sea Grant College Program, 4pp.

Gerhard, G.T. et al., 1991. Comparison of three species of dietary fish: effects on serum concentrations of low-density-lipoprotein cholesterol

and apolipoprotein in normotriglyceridemic subjects, Am. J. Clin. Nutr., 54:334–339.

German, J.B. and Berger, R., 1990. Formation of 8, 15–dihdroxyeicosatetraenoic acid via 15– and 12–lipoxygenases in fish gill, Lipids 25(12):849–853.

German, J.B. and Creveling, R.K., 1990. Identification and characterization of a 15–lipoxygenase from fish gills, J. Agri. Food. Chem. 38:2144–2147.

German, J.B., 1990. Muscle lipids, J. Muscle Foods 1:339–361.

German, J.B., Hu, M.L., 1990. Oxidant stress inhibits the endogenous production of lipoxygenase metabolites in rat lungs and fish gills, Free Radical Biology & Medicine, 8:441–448.

German, J.B., Zhang, H. and Berger, R., 1992. Role of lipoxygenases in lipid oxidation in foods, in Lipid Oxidation in Food, A. St. Angelo, (ed.), American Chemical Society, Chap. 5.

Grimes, D.J., 1991. Ecology of estuarine bacteria capable of causing human disease: A review, Estuaries 14(4):345–360.

Haard, Norman F., 1992. Biochemical reactions in fish muscle during frozen storage, in Seafood Science and Technologists, Blackwell Scientific Publishing, 176–209.

Hackney, C.R., Sanders, L., Rippen, T., Reily, L., 1990. Improved method for determination of salt in oysters by direct titration of chloride ion, J. Food Sci. 53(1):288–289.

Hardardottir, I., Kinsella, J.E., 1991. Tumor necrosis factor production by murine resident peritoneal macrophages is enhanced by dietary n–3 polyunsaturated fatty acids, Biochemica et Biophysica Acta 1095:187–195.

Hardardottir, I. and Kinsella, J.E., 1992. Increasing the dietary (n–3) to (n–6) polyunsaturated fatty acid ratio increases tumor necrosis factor production by murine residnet peritoneal macrophages without an effect on elicited peritoneal macrophages, J. Nutr. 122:1942–1951.

Hardardottir, I. Whelan, J. and Kinsella, J.E., 1992. Kinetics of tumour necrosis factor and prostaglandin production by murine residnet peritoneal macrophages as affected by dietary n–3 polyunsaturated fatty acids, Immunology 76:572–577.

Harrison, M.A., et al., 1991. Fate of *Listeria monocytogenes* on packaged, refrigerated, and frozen seafood, J. Food Protection, 54(7):524–527.

Harrison, M.A., Huang, Y.W., 1990. Thermal death times for *Listeria monocytogenes* (Scott A) in crab meat, J. Food Protection, 53(10):878–880.

Hegen, A.R., 1990. Seafood–the healthy choice, Report No. TAMU–G–90–002 (TAMU–SG–90–505), Texas Sea Grant College Program, 7pp.

Heil, T.P. and Lindsay, R.C., 1990. Environmental and industrial factors relating to flavor tainting of fish in the upper Wisconsin River, Environmental Science and Health B25(4):527–552.

Hicks, Doris, 1991. Seafood is good for you, Report No. DELU–G–91–004, Delaware Sea Grant College Program, 2pp.

Himelbloom, B.H., Brown, E.K., and Lee, J.S., 1991. Microorganisms isolated from surimi processing operations, J. Food Sci. 56(2):299–301.

Holland, K.N., Brill, R.W., Chang, R.K.C., Sibert, J.R., Fournier, D.A., 1992. Physiological and behavioral thermoregulation in bigeye tuna (*Thunnus obesus*), Nature 358:410–412.

Hong, C.S., and Bush, B., 1990. Determination of mono– and non–ortho coplanar PCBs in fish, Chemosphere 21(1–2):173–181.

Hong, C.S., Bush, B., Xiao, J., 1992. Coplanar PCBs in fish and mussels from marine and estuarine waters of New York State, Ecotoxicology and Environmental Safety 23:118–131.

Hovinga, M.E., Sowers, M.F., Humphrey, H.E.B., 1992. Historical changes in serum PCB and DDT levels in an environmentally–exposed cohort, Arch. Environ. Contam. Toxicol. 22:362–366.

Iwamoto, R.N., Myers, J.M., and Hershberger, W.K., 1990. Heritability and genetic correlations for flesh coloration in pen–reared coho salmon, Aquaculture 86:181–190.

Jeanneret, D. and Brainard, M., 1991. PCBs: Their history and our health., Report No. OHSU–G–91–004, Ohio Sea Grant College Program, 2pp.

Josephson, D.B., Lindsay, R.C., Stuiber, D.A., 1991. Influence of maturity on the volatile aroma compounds from fresh pacific and Great Lakes salmon, J. Food Sci. 56(6):1576–1579 & 1585.

Josephson, D.B., Lindsay, R.C., Stuiber, D.A., 1991.

Volatile carotenoid-related oxidation compounds contributing to cooked salmon flavor, Food Sci. & Tech. 24(5):424-432.

Kelleher, S.D., Silva, L.A., Hultin, H.O. and Wilhelm, K.A., 1992. Inhibition of lipid oxidation during processing of washed, minced Atlantic mackerel, J. Food Sci. 57(5)1103-08 & 1119.

Kim, K. and Haard, N.F., 1991. Degradation of proteoglycans in the skeletal muscle of Pacific rockfish (*Sebastes* sp.) during ice storage, J. Muscle Food 3:103-121.

Kinsella, J.E., Broughton, K.S., and Whelan, J.W., 1990. Dietary unsaturated fatty acids: interactions and possible needs in relation to eicosanoid synthesis, J. Nutr. Biochem. 1:123-141.

Kinsella, J.E., 1990. Lipids, Membrane receptors and enzymes: effects of dietary fatty acids, J. Parenteral and Enteral Nutrition, 14(5):200S-217S.

Kinsella, J.E., Lokesh, B., and Stone, R.A., 1990. Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular disease: Possible mechanisms, Am. J. Clinical Nutrition 52:1-28.

Kinsella, J.E., 1990. Sources of omega-3 fatty acids in human diets, in Omega-3 Fatty Acids in Health and Diseases, Marcel Dekker, Inc., pp. 157-200.

Knuth, B.A., 1990. Risk communication: A new dimension in sport-fisheries management, North American Journal of Fisheries Management 10:374:381.

Kvitek, R.G. and Beitler, M.K., 1991. Relative insensitivity of butter clam neurons to saxitoxin: a pre-adaptation for sequestering paralytic shellfish poisoning toxins as a chemical defense, Marine Ecology Progress Series 69:47-54.

Lee, J.S. and Hilderbrand, K.S., 1992. Hazard & Critical Point Applications to the Seafood Industry. Report No. ORESU-H-92-001, Oregon Sea Grant College Program, 25pp.

Lee, R.S. and Karel, M., 1990. Omega-3 fatty acids in health and disease, Proceedings of the 15th annual MIT Sea Grant lecture and seminar, Marcel Dekker, Inc., 240pp.

Lindsay, R.C., 1991. Chemical basis of the quality of seafood flavors and aromas, MTS Journal 25(1):16-22.

Lirdwitayaprasit, T. et al., 1990. J. Phycology 26:299-306.

Lokesh, B.R., Sayers, T.J., and Kinsella, J.E., 1990. Interleukin-1 and tumor necrosis factor synthesis by mouse peritoneal macrophages is enhanced by dietary w-3 polyunsaturated fatty acids, Immunology Letters 23:281-286.

Martin, J.L., White, A.W., Sullivan, J.J., 1990. Anatomical distribution of paralytic shellfish in soft-shell clams, Toxic Marine Phytoplankton, pp. 379-384.

Michigan Sea Grant, 1991. Are Great Lakes fish safe to eat?, Report No. MICHU-G-91-001 (MICHU-SG-91-700), Michigan Sea Grant College Program, 2pp.

Miller, L.A., Addis, P.B., Wang, Y.J., 1991. Effect of heat inactivation of lipoxygenase on lipid oxidation in lake herring (*Coregonus artedii*), J. Amer. Oil Chemists Soc. 68(10):752-757.

Nadala Jr., E.C.B. and Loh, P.C., 1990. A nitrocellulose-enzyme immunoassay method for the detection of hepatitis A virus, J. Virological Methods 28:155-164.

Nadala Jr., E.C.B. and Loh, P.C., 1990. Immunofluorescence and immunoperoxidase assays for the titration of infectious hepatitis A virus (HAV), J. Virological Methods 28:117-124.

Nadala Jr., E.C.B. and Loh, P.C., 1991. Production of high efficiency of plating hepatitis A virus in primary African green monkey kidney cells, Proc. Soc. Exp. Biol. Med. 199(4):400-403.

Nakamura, Yasuo, et al., 1990. Encystment of *Chattonella antiqua* in laboratory cultures, Journal of the Oceanographical Society of Japan 46(2):35-43.

Newell, Carter, 1990. Guide to mussel quality control, Report No. MEU-H-90-001, Maine/ New Hampshire Sea Grant College Program.

Osinchak, J.E., Hultin, H.O., Zajicek, O.T., Delleher, S.D., Huang, C.H., 1992. Effect of NaCl on catalysis of lipid oxidation by the soluble fraction of fish muscle, Free Radical Biology Medicine, 12:35-41.

Pan, J.S., Berdanier, C.D., 1991. Dietary fat saturation affects glucose metabolism without affecting insulin receptor number and affinity and adipocytes from BHE rats, J. Nutr. 121:1811-1819.

Pan, J.S., Berdanier, C.D., 1991. Dietary fat saturation affects hepatocyte insulin binding and glucose metabolism in BHE rats, J. Nutr., 121:1820-1826.

Pedrosa-Menabrito, A. and Regensteing, J.M., 1990. Shelf-like extension of fresh fish-a review. Part III-fish quality and methods of assessment, J. Food Qual. 13:209-223.

Peters, J.B., King, T.L., 1991. Parasites. Report No. WASHU-G-91-006 (WSG-AS 91-07), Washington Sea Grant College Program, 2pp.

Porter, P.J., Kennish, J.M., Kramer, D.E., 1992. The effects of exsanguination of sockeye salmon on the changes in lipid composition during frozen storage, in Seafood Science & Technology, Blackwell Scientific Pubs., pp. 76-83.

Price, R.J., 1990. Seafood Safety, Report No. CUIMR-G-90-002, California Sea Grant College Program. 45pp.

Price, R.J., 1990. Contaminants in fish., Report No. CUIMR-G-90-012 (UCSGEP 90-14), California Sea Grant College Program, 2pp.

Price, R.J., Tom, P.D., 1990. Contaminants in fish, Report No. CUIMR-G-91-002 (UCSGEP 91-3), California Sea Grant College Program, 2pp.

Price, R.J. and Price, D.W., 1990. Paralytic shellfish poisoning, Report No. CUIMR-G-90-001 (UCSGEP 90-4), California Sea Grant College Program, 2pp.

Price, R.J. and Tom, R.D., 1990. Parasites in marine fishes, Report No. CUIMR-G-90-005 (UCSGEP 90-7), California Sea Grant College Program, 2pp.

Price, R.J., 1990. Seafood that glows in the dark, Report No. CUIMR-G-90-006 (UCSGEP 90-8), California Sea Grant College Program, 1pp.

Price, R.J., 1990. Consumer tips for handling seafood safely, Report No. CUIMR-G-90-008 (UCSGEP 90-10), California Sea Grant College Program, 2pp.

Price, R.J., 1991. Mercury in seafood, CUIMR-G-91-008(UCSGEP 91-10), California Sea Grant College Program, 2pp.

Price, R.J., Melvin, E.F., Bell, J.W., 1992. Postmortem changes in blast, brine and brine-coil frozen albacore, J. Aquatic Food Prod. Tech, Vol. 1(1):67-84.

Price, R.J., Melvin, E.F., Bell, J.W., 1991. Postmortem changes in chilled round, bled and dressed albacore, J. Food Sci. 56(2):318-321.

Price, R.J., 1992. Sanitizers for food plants, Report No. UCSGEP 92-9, California Sea Grant College Program, 4pp.

Price, R.J., Hansgen, K.H. and Langlois, G.W., 1992. Toxinas marinas naturalos, Report No. UCSGEP 92-11, California Sea Grant College Program, 2pp.

Price, R.J. and Jan, P.D., 1992. Environmental conditions for pathogenic bacterial growth, Report No. UCSGEP 92-10, California Sea Grant College Program, 4pp.

Reddy, N.R. et al, 1991. Composition and pesticide and herbicide residue analysis of fresh and 40-year-old pasteurized blue crab (*Callinectes sapidus*) meat, J. Food Protection 54(4):298-301.

Sakanari, J.A, 1990. Anisakis-from the platter to the microfuge, Parasitology Today 6(10):323-327.

Schwinghamer, P., Anderson, D.M., Kulis, D.M., 1991. Separation and concentration of living dinoflagellate resting cysts from marine sediments via density-gradient centrifugation, Limnology and Oceanography, 36(3):588-592.

Siebeling, R.J., Martin, S.J., 1991. Identification of *Vibrio vulnificus* O serovars with antilipopolysaccharide monoclonal antibody, J. Clin. Microbiology 29(8):1684-1688.

Simonson, J.G., Siebeling, R.J., 1991. Detection of *Vibrio cholerae* 01 serovars in oyster meat homogenate by a dipstick-ELISA method, MTS Journal 25(1):52-59.

Sowizral, K.C., Rumsey, G.L., and Kinsella, J.E., 1990. Effect of dietary a-linolenic acid on n-3 fatty acids of rainbow trout lipids, Lipids 25(5):246-253.

Sullivan, A.L., Otwell, W.S., 1992. A Nutrient Database for Southeastern Seafood, Report No. SGR-109, Florida Sea Grant College Program, 202pp.

Surette, M.E., Croset, M., Lokesh, B.R., and Kinsella, J.E., 1990. The fatty acid composition and Na^+-K^+ ATPase activity of kidney mircosomes from mice consuming diets of varying docosahexaenoic acid and linoleic acid ratios, Nutrition Research 10:211-218.

Surette, M.E., Whelan, J., Broughton, K.S., Kinsella, J.E., 1992. Evidence of mechanisms of the hypotriglyceridemic effect of n-3 polyunsaturated fatty acids, Biochemica et Biophysica Acta 1126:199-205.

Surette, M.E., Whelan, J., Lu, G.P., Broughton, K.S.,

Kinsella, J.E., 1992. Dependence of dietary cholesterol for n-3 polyunsaturated fatty acid-induced changes in plasma cholesterol in the Syrian hamster, J. Lipid Res. 33:263-271.

Tindall, D.R., Miller, D., and Kohler, C., 1991. Production, identification, and characterization of multiple toxins responsible for ciguatera in the Caribbean and tropical Atlantic, Report No. ILIN-0-91-001 (IL-IN-SG-R-91-5), Illinois-Indiana Sea Grant College Program, 41pp.

Tom, P.D., Price, R.J., 1991. Bacteria causing foodborne illness, Report No. CUIMR-G-91-004 (UCSGEP 91-6), California Sea Grant College Program, 6pp.

Tosteson, T.R., 1992. Ciguatera in the northeastern Caribbean, Datos Marinos, Puerto Rico Sea Grant College Program, 4pp.

Tosteson, T.R. (ed.), 1992. Proceedings: Third International Conference on Ciguatera Fish Poisoning, Polyscience Pub., 204pp.

Voiland Jr., M.P., Gall, K.L., Lisk, D.J., MacNeill, D.B., 1991. Effectiveness of recommended fat-trimming procedures on the reduction of PCB and mirex levels in brown trout (*Salmo trutta*) from Lake Ontario, J. Great Lakes Res. 17(4):454-460.

Wander, R.C. and Patton, B.D., 1991. Lipids and fatty acids of three species of northeast Pacific finfish harvested in summer, J. Food Comp. Anal. 4:128-135.

Wang, Y.J., Miller, L.A., Perren, M. and Addis, P.B., 1990. Omega-3 fatty acids in Lake Superior fish, J. Food Sci. 55(1):71-73 & 76.

Wang, Y.J., Miller, L.A., and Addis, P.B., 1991. Effect of heat inactivation of lipoxygenase on lipid oxidation in lake herring (*Coregonus artedii*), JAOCS, 68(10):752-757.

Ward, D.R., Flick, G.J., 1990. The effects of salinity and temperature on selected elements in oysters (*Crassostrea virginica*), J. Agric. Food Anal. 3:96-98.

Weist, J.L., Karel, M., 1992. Development of a fluorescence sensor to monitor lipid oxidation. 1. Fluorescence spectra of chitosan powder and polyamide powder after exposure to volatile lipid oxidation products, J. Agric. Food Chem. 40(7):1158-1162.

Wells, M.L., Mayer, L.M., Guillard, R.R.L., 1991. A chemical method for estimating the availability of iron to phytoplankton in seawater, Marine Chemistry, 33:23-40.

Whelan, J., Broughton, K.S., and Kinsella, J.E., 1991. The comparative effects of dietary a-linolenic acid and fish oil on 4-and 5-series leukotriene formation in vivo, Lipids 26(2):119-126.

Whelan, J., Broughton, K.S., Lokesh, B., and Kinsella, J.E., 1991. In vivo formation of leukotriene E_5 by murine peritoneal cells, Lipids 41:(1).

White, A.W., 1990. Toxic algal blooms: an international directory of experts in toxic and harmful algal blooms and their effects on fisheries and public health., Report No. WHOI-D-90-001, Woods Hole Sea Grant Program, 216pp.

White, A.W., Smayda, T.J., 1990. Has there been a global expansion of algal blooms? If so, is there a connection with human activities?, in Toxic Marine Phytoplankton, pp. 516-517.

Williams, L.L., Glesy, J.P., DeGalan, N., Verbrugge, D.A., Tillitt, D.E., and Ankley, G.T., 1992. Prediction of concentrations of 2,3,7,8 tetrachlorodibenzo-p-dioxin equivalents from total concentrations of polychlorinated biphenyls in fish fillets, Environ. Sci. & Tech. 26:1151-1159.

Winkler, M., McCarthy, M.J., German, J.B., 1991. Noninvasive measurement of lipid and water in food using magnetic resonance Imaging, J. Food Sci. 56(3):811-815.

Handling and Processing Technology

Anonymous, 1992. Bleeding and storage of fluke (*Paralichthys dentatus*), Report No. VSGCP-92-001 (AR #45), Virginia Sea Grant College Program, 1pp.

Anonymous, 1991. Monkfish: Guidelines for liver removal and storage, Report No. VSGCP-91-001, Virginia Sea Grant College Program, 1pp.

Anonymous, 1991. Scallops-guidelines to improve quality: The use of insulated totes at sea, Report No. VSGCP-G-91-003, Virginia Sea Grant College Program, 1pp.

Anonymous, 1990. On-board quality control: Preparing mid-Atlantic fisheries for the future, Report No. 38, Virginia Sea Grant College Program.

Arnold, R.E., Gall, Ken, 1991. Service Seafood

Management and Operations, Cornell University Home Study Program, 184pp.

Baker, D.A. and Genigeorgis, C., 1990. Predicting the safe storage of fresh fish under modified atmospheres with respect to *Clostridium botulinum* toxigenesis by modeling length of the lag phase of growth, J. Food Protection 53(2):131-140.

Bankston Jr., D., Moody, M., and Roberts, K., 1991. Brine freezing, Report No. LSU-G-91-002, Louisiana Sea Grant College Program, 16pp.

Barkston, J.D., et al, 1991. Energy conservation self-audit manual for fish processing plants, Report No. LSU-H-91-002, Louisiana Sea Grant College Program, 17pp.

Beal, L.K., 1991. Soft-shell clams: Nutrient-packed food from the sea, Report No. MEU-G-91-004 (RF-MSG-91-8), Maine/New Hampshire Sea Grant College Program, 4pp.

Bernstein, S.E., McDaniel, M.R., and McMichaels, N.J., 1990. Nitrogen freezing of Dungeness crab: Effects on quality and frozen storage stability, Report No. NCRI-W-90-002, National Coastal Research Institute, 100pp.

Boyle, J.L., Lindsay, R.C., Stuiber, D.A., 1991. Adenine nucleotide degradation in modified atmosphere chill-stored fresh fish, J. Food Sci., 56(5):1267-1270.

Carrero, Leonides, 1990. Conservacion del pescado, Report No. PRU-G-90-001, Puerto Rico Sea Grant College Program, 7pp.

Chen, H.C., Moody, M.W., Jiang, S.T., 1990. Changes in biochemical and bacteriological quality of grass pawn during transportation by icing and oxygenating, Jour. Food Sci, 55(3):670-673.

Crapo, C., Lee, J., and Brown, E., 1991. Halibut quality: chilled seawater storage of dressed and round fish., Report No. AKU-G-91-001 (MAB-42), California Sea Grant College Program, 12pp.

Crapo, C., Paust, B., 1991. Air shipment of fresh fish: a primer for shippers and cargo handlers, Report No. AKU-G-91-006 (MAB-32), Alaska Sea Grant College Program, 32pp.

Crapo, C.A., Crawford, D.L., 1991. Influence of polyphosphate soak and cooking procedures on yield and quality of Dungeness crab meat, J. Food Sci., 56(3):657-659.

Crapo, C., Lee, J., Brown, E., 1991. Halibut quality: chilled seawater storage of dressed and round fish, Marine Advisory Bulletin No. 42, Alaska Sea Grant College Program.

Doyle, J.P., 1992. Care and handling of salmon: The key to quality, Marine Advisory Bulletin No. 45, Alaska Sea Grant College Program.

DuPaul, W.D., Fisher, R.A., and Kirkley, J.E., 1990. An evaluation of at-sea handling practices: effects on sea scallop meat quality, volume, and integrity, Report No. VSGCP-T-90-004 (VSG 91-01), Virginia Sea Grant College Program, 76pp.

Dupuy, H.P., Flick, G.J., Bailey, M.E., St. Angelo, A.J., Legendre, M.G., Sumrell, G., 1990. Direct sampling capillary gas chromatography of volatiles in vegetable oils, Report No. VSG-90-111R, Virginia Sea Grant College Program.

Fisher, R.A., 1990. On-board quality control. Preparing mid-Atlantic fisheries for the future, Report No. VSGCP-G-90-004, Virginia Sea Grant College Program, 10pp.

Flick, G.J. and Attaway, D.H. (eds.), 1991. Seafood Science and Technology, devoted issue of the Marine Technology Society Journal, Volume 25(1), 71 pp.

Flick, G.J., Hong, G.P. and Knobl, G.M., 1991. Non-traditional methods of seafood preservation, MTS Journal, 25(1):35-43.

Gall, K., 1992. Seafood savvy, Information bulletin 104IB226, Cornell University Cooperative Extension, 34pp.

Gates, K.W. and Parker, A.H., 1992. Characterization of minced meat extracted from blue crab picking plant by-products, J. Food Sci., 57(2):267-270.

Hamann, D.D., 1990. Surimi, a building block for formulated foods, in Chilling and Freezing of New Fish Products, Int'l. Inst. of Refrigeration, Paris.

Hicks, D., 1992. A consumer guide to safe seafood handling, Report No. DELU-H-92-001, Delaware Sea Grant College Program, 8pp.

Hong, G.P., Flick, G.J., Knobl, G.M., 1992. Development of a prediction computer model for blue crab meat yield based on processing and biological variables, JAFPT 1(3/4):109-132.

Huang, Y.W., Kouadio, K., Gates, K.W., 1992. Effect of packaging on chemical changes and

quality of refrigerated spot (*Leiostomus xanthurus*), JAFPT 1(2):111-127.

Jahncke, M., Baker, R.C., Regenstein, J.M., 1992. Frozen storage of unwashed cod (*Gadus morhua*) frame mince with and without kidney tissue, J. Food Sci. 57(3):575-580.

King, T.L., 1991. Freezer burn, Report No. WASHU-G-91-007 (WSG-AS 91-08), Washington Sea Grant College Program, 2pp.

King, T.L., 1991. Bioluminescence, Report No. WASHU-G-91-008 (WSG-AS 91-09), Washington Sea Grant College Program, 1pp.

King, T.L., and Peters, J.B., 1992. Northwest seafood processors' glossary, Report No. WSG-AS 91-16, Washington Sea Grant College Program, 29pp.

Kolbe, E., 1991. An interactive fish freezing model compared with commercial experience, in Proceedings of the XVIIIth Int'l Cong. of Refrigeration, Inst. of Refrigeration, Paris, pp. 1902-1905.

Kolbe, E., 1990. Estimating energy consumption in surimi processing, Applied Engineering in Agriculture 6(3):322-328.

Kolbe, E., 1990. Refrigeration energy prediction for flooded tanks on fishing vessels, Applied Engineering in Agriculture 6:624-628.

Kolbe, E., and Schnekenburger, R., 1991. Temperature monitor for freezers and cold stores, Rev. Int. Froid,, 14:117-119.

Lanier, T.C., 1990. Packaging, in The Seafood Industry, Martin, R.E. and Flick, G.J. (eds.), Van Nostrand Reinhold, pp. 194-204.

Lin, C.F. et al, 1990. Efficiency of removing volatiles from menhaden oils by refining, bleaching, and deodorization, J. Food Sci. 55(6):1669-1672.

Otwell, W.S. (ed.), 1991. Tropical and Subtropical Fisheries Technological Conference of the Americas in Second Joint Meeting with Atlantic Fisheries Technology Conference: Proceedings of the Fifteenth Annual Conference, Florida Sea Grant College Program, 543pp.

Otwell, W.S. (compiler), 1991. Tropical and Subtropical Fisheries Technological Conferences of the Americas: Proceedings of the Sixteenth Annual Conference, Florida Sea Grant College Program, 294pp.

Otwell, S., Lawlor, F., 1991. Recreational seafood safety: a guide for marine recreational fishing, Report No. FLSGP-H-91-003 (SGEB-18), Florida Sea Grant College Program, 20pp.

Pedrosa-Menabrito, A. and Regenstein, J.M., 1990. Shelf-life extension of fresh fish-a review. Part II-preservation of fish, J. Food Quality 13:129-146.

Peters, J.B., 1990. Temperature and storage life of fresh seafood. Report No. WASHU-G-90-001(WSG-AS 89-10), Washington Sea Grant College Program, 7pp.

Peters, J.B., 1991. Sanitation for seafood retailers. Report No. WASHU-G-91-001 (WSG-AS 90-03), Washington Sea Grant College Program, 7pp.

Price, R.J., 1990. Controlling gulls at seafood plants. Report No. CUIMR-G-90-007 (UCSGEP 90-9), California Sea Grant College Program, 1pp.

Price, R.J., 1990. Spiced and pickled seafood, Report No. CUIMR-G-90-011 (UCSGEP 90-13), California Sea Grant College Program, 2pp.

Price, R.J., 1990. Retail seafood temperature control, Report No. CUIMR-G-90-003 (UCSGEP 90-5), California Sea Grant College Program, 2pp.

Price, R.J., 1990. Seafood Training videos, Report No. CUIMR-F-90-001 (UCSGEP 90-3), California Sea Grant College Program, 2pp.

Price, R.J., 1991. Seafood Training videos. Report No. CUIMR-F-90-001 (UCSGEP 91-5), California Sea Grant College Program, 2pp.

Price, R.J., Tom, P.D., 1991. Smoking fish, Report No. CUIMR-G-91-006, UCSGEP 91-9), California Sea Grant College Program, 2pp.

Price, R.J., 1990. Retail seafood cross-contamination. Report No. CUIMR-G-90-004 (UCSGEP 90-6), California Sea Grant College Program, 2pp.

Price, R.J., 1990. Freezing seafood at home, Report No. CUIMR-G-90-013 (UCSGEP 90-15), California Sea Grant College Program, 2pp.

Price, R.J., Melvin, E.F. and Bell, J.W., 1991. Postmorten changes in chilled round, bled and dressed albacore, J. Food Sci. 56(2):318-321.

Santos, E.E.M. and Regenstein, J.M., 1990. Effects of vacuum packaging, glazing, and erythorbic acid on the shelf-life of frozen white hake and mackerel, J. Food Science 55(1):64-70.

Simpson, R., Almonacid, S., and Torres, J.A., 1990. Computer control of batch retort process opera-

tions, Report No. ORESU-R-90-025, Oregon Sea Grant College Program, 10pp.
Snyder, F.L., 1989. Fish smoked at home. Report No. OHSU-G-89-016 (OHSU-FS-032), Oregon Sea Grant College Program, 2pp.
Sylvia, G., Morrissey, M.T., 1992. Pacific whiting: Harvesting, processing, marketing, and quality assurance, Report No. ORESU-W-92-001, Oregon Sea Grant College Program, 112pp.
Sylvia, S. and Morrissey, M. (eds.), 1992. Harvesting, Processing, Marketing, and Quality Assurance, A Workshop: Newport, Oregon, Report No. ORESU-W-92-001, Oregon Sea Grant College Program, 112pp.
Tom, P.D. and Price, R.J., 1990. Vacuum packages and retort pouches for smoked seafood, Report No. CUIMR-G-90-014 (UCSGEP 90-16), California Sea Grant College Program, 1pp.
Voiland, Michael et al., 1990. The effectiveness of recommended fat-trimming procedures on the reduction of PCB and mirex levels in Lake Ontario brown trout, Report No. NYSGI-T-90-002, New York Sea Grant College Program, 17pp.

Economics and Marketing

Dupaul, W., Wallace, J.L., 1990. Export market potential for Hong Kong and Singapore, Report No. VSG-90-116R, Virginia Sea Grant College Program.
Farrell, J.G. and Hicks, D.T., 1990. Buying guide for fresh Delaware seafood, Report No. DELU-G-90-001, Delaware Sea Grant College Program, 1pp.
Gall, Ken, 1991. New York's seafood industry: Fish market, Report No. NYSGI-G-91-003, New York Sea Grant College Program, 8pp.
Gillespie, S.M., 1990. Marketing soft-shelled crawfish, Report No. LSU-T-90-001, Louisiana Sea Grant College Program, 11pp.
Griffith, David et al, 1990. Getting to know southeast seafood consumers, Report No. NCU-G-90-001 (UNC-SG-90-04), North Carolina Sea Grant College Program, 12pp.
Herrmann, M., Hwan Lin, B., and Mittelhammer, R.C., 1990. U.S. salmon markets: A survey of seafood wholesalers, Report No. AKU-Q-90-001, Alaska Sea Grant College Program, 30pp.
Hicks, D. (coordinator), 1992. Seafood information package for food writers, Mid-Atlantic edition, Delaware Sea Grant College Program.
Lipton, D.W., 1990. Understanding fish pricing: From production to the table, Report No. MDU-G-90-001 (UM-SG-MAP-90-001), Maryland Sea Grant College Program, 4pp.
Matulich, S.C., Mittlehammer, R.C. and Greenberg, J.A., 1990. Predicting Japanese wholesale price and demand for Alaskan king crab, Report No. WASHU-T-90-001 (WSG-MR-90-05), Washington Sea Grant College Program, 10pp.
Price, R.J. and Tom, P.D., 1990. Consumer tips for purchasing high quality seafood, Report CUIMR-G-90-009 (UCSGEP 90-11), California Sea Grant College Program, 2pp.
Price, R.J. (eds.), 1990. Menu and advertising guidelines for California restaurants, retailers, and their seafood suppliers, Report No. UCSGEP 90-2, California Sea Grant College Program.
Reinert, R.E. et al., 1991. Risk assessment, risk management, and fish consumption advisories in the United States, Fisheries 16(6):5-12.

HUMAN RESOURCES

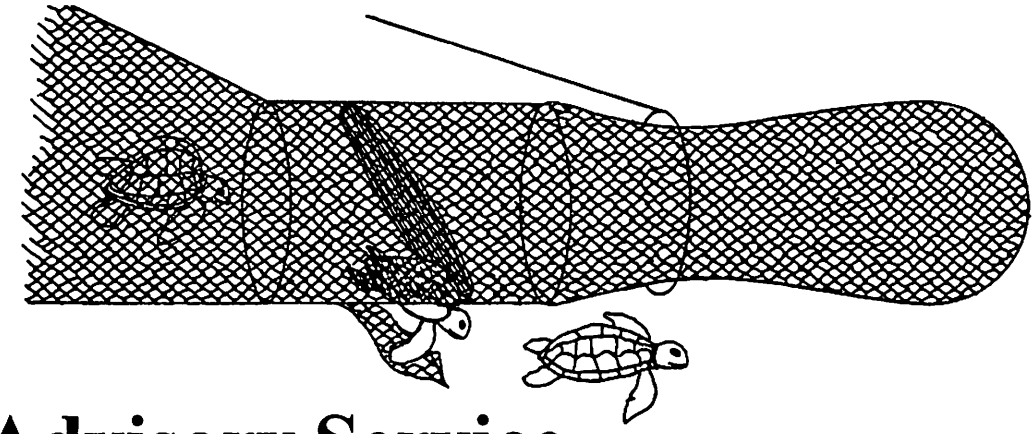
CHAPTERS

Human Resources

Translating sound contemporary research into appropriate public policy and resource management and then gaining public support for it has always been challenging. Sea Grant law and marine policy and social science programs address important aspects of resource public policy issues and their implementation mechanisms.

Sea Grant outreach programs, which include Marine Advisory Service, education and training and communications, support unique technology transfer capabilities. They have the ability to reach decisionmakers and the public with research-based information in forms that guide policy and human behavior.

The following discussion of the Human Resources Division will highlight issues and accomplishments of its programs areas, which in FY 1992, totaled $17.7 million or 43 percent of federal core funding. These programs, in turn, attracted $14.4 million in matching and other agency funds for enhancement of the federal dollars.



Marine Advisory Service

Introduction

The Marine Advisory Service (MAS) makes Sea Grant one of the most unique extramural programs in government. MAS is the arm of Sea Grant that provides formal research-based extension, education, and technology transfer to a variety of stakeholders. Much of the information and technology that MAS transfers to users is Sea Grant-based but can come from any good science-based source if it addresses information needs. MAS programs may focus on targeted issues for small audiences or may provide large, generic educational experiences for more general audiences. Programs are extremely diverse in scope, but all relate to creating and maintaining sustainable resource and economic development within the marine and Great Lakes sectors.

MAS programs, like all other Sea Grant activities, are funded through a detailed peer review that incorporates assessment of accomplishment as well as rationale for proposed programs and approach. Much of the required Sea Grant nonfederal match funding targets MAS activities. The very nature and responsiveness of the program together with its task orientation attract other sources of funding into its mission. As such, MAS is a true partnership between NOAA and state, local, and private sector entities. MAS plays a key role in carrying out national programs at the state and regional level as well as responding to more local resource issues. All address national program issues, albeit some more directly and visibly than others. Smaller institutional programs tend to be more focused, yet the broad context of the resource issues in which they are immersed still serves in the national interest.

Program Trends

Table 1 summarizes MAS core funding over the last nine years. It shows a 17 percent overall increase in total core funds, the biggest share coming from nonfederal match. Loss of buying power over that time span due to inflation is reflected in MAS agent and specialist position declines from approximately 350 in 1984 to 284 in 1992. To fill an increasing need to address practical research-based problems, MAS has shifted from high prominence of local, broad-based agents to a majority of university department-based specialist (98 agents, 186 specialists) in 1992. This staffing trend, along with the recognition of MAS' unique capability by other agencies having a technology-transfer mission, has facilitated an increase in short-term pass through funding since 1989 to accomplish special projects. These funds, provided for work directly associated with the Sea Grant mission, totaled $428.5 K, $874.7 K, $322.2 K and $962.5 K in 1989, 1990, 1991, and 1992 respectively. Grant funds provided directly to the universities without passing through NOAA have also increased during these years. These funds have been instrumental in maintaining critical mass in many Marine Advisory Service programs.

Core Funding for Sea Grant MAS Activities

	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
FY 1990	9,030,682	8,838,061	17,868,747
FY 1991	10,129,769	9,414,047	19,543,816
FY 1992	10,052,581	8,529,789	18,582,370

Table 1

Progress and Achievements

This discussion follows the programmatic structure provided in the annual *National Guidance* to Sea Grant institutions by the National Office.

Aquaculture

Together, Sea Grant research and MAS provide expanded opportunities to pursue aquaculture, and there are several general ongoing areas of progressive programming. Aquaculture is being developed in large vertically-integrated businesses, in backyards and garages, and as a diversification for traditional agriculture. Concomitant development of water-recirculating systems is a subset of this activity, allowing for development away from the coast. Other opportunities being explored are associated with platform-based pens for finfish culture in collaboration with offshore oil and gas drilling operations and also in dredge spoil containment areas.

To enable entrepreneurial entry into aquaculture, MAS economic and marketing studies help develop rational decisions and fiscal resources. Legal analysis of existing legislation and regulatory requirements lead to entrepreneurial guidance and logical model legislation, and many state plans for aquaculture development as an economic stimulus have been guided by MAS specialists.

MAS specialists are developing better technological approaches to raising a plethora of animals and plants: kelp, blue mussels, urchins, rock scallops, tilapia, bay scallops, freshwater perchids, crawfish, alligators, baitfish and sturgeon as well as the more traditional shrimp, clams, and hybrid striped bass. Special work to try to help manage around Chesapeake Bay oyster disease problems includes development of genetically resistant strains combined with new techniques such as off-bottom culture.

Coastal Resources

MAS's ability of sharing technology and information to directly affect resource management is best illustrated in its coastal resources work. Many programs have been directly involved in coastal management and land use planning processes at the state level since 1990. Western regional programs in particular have been involved in planning for outer continental shelf impacts and developing mitigation and rapid response plans. In

cooperation with NOAA's Office of Coastal Resource Management (OCRM), coastal resources inventories have been conducted for many U.S. Island Trust Territories and in proposed new federal marine sanctuaries. The use and coordination of volunteers to provide water-quality monitoring data for coastal ponds, estuaries, and bays was fostered by New England Sea Grant MAS specialists. Data from these programs is now readily accepted by environmental agencies because of Sea Grant quality control. The concept has spread to many other states, greatly expanding the data gathering efforts of management agencies.

Salt marsh and wetland management programs are becoming more important. MAS is involved in: experimental demonstrations of salt-tolerant marsh grasses for beach stabilization and dune restoration; education programs on the intrinsic as well as economic value of wetlands for realtors, developers and planners; and general maintenance of coastal wetland resources in the face of development pressures from many nonwater dependent uses. There are also well-regarded programs of training SCUBA certified divers in fundamental research and monitoring methods for coastal resource inventories. These inventories are used in OCRM activities, shoreline stabilization technology-transfer activities in most areas susceptible to coastal erosion, and coastal management programs designed to mitigate cyclic water level fluctuations and their effects on Great Lakes shoreline uses.

Pollution and Water Quality

Pollution and water quality are closely related to coastal resource programming (discussed above) since coastal water quality issues are intertwined with coastal resource management and development. Water quality issues are becoming paramount in MAS because they are of increasing concern to the public. Environmental contaminants and toxics have been a problem in the Great Lakes for many years. Great Lakes MAS programs have worked together to foster public participation in the formal process being overseen by the U.S. Environmental Protection Agency (EPA) to rehabilitate areas of special concern in all the lakes. The Great Lakes MAS network has also worked with state agencies and the medical community to help realistically communicate and minimize the risk associated with eating potentially contaminated Great Lakes fish. MAS programs are working closely with EPA in its National Estuary Program, providing the public education and awareness of critical environmental quality issues in places such as Long Island Sound, Albemarle Sound, Mobile Bay, and Puget Sound.

Toxic algal blooms are an increasing concern that may be related to water quality. Programs on the West Coast responded to a rare domoic acid outbreak, produced by a large diatom bloom, by providing information to shellfish harvesters, processors, and managers concerning its implications to the industry. They also helped set up a monitoring strategy to help identify the domoic acid source and to provide some predictive capability. Thus, a potentially chaotic situation in the shellfish industry was averted.

On the East Coast, brown tide outbreaks have decimated some bay scallop beds. MAS has led a successful reseeding effort. An innovative project in cooperation with the U.S. Department of Agriculture has just begun, which promises to develop geographic information system technology for use in mapping, monitoring, and managing nonpoint source agricultural runoff into coastal environments.

Finally, wastewater and solid waste from fish processors is a significant problem. Regulations are becoming stringent and threaten widespread shutdown of processing plants. MAS works diligently to provide opportunities for use of best available technology in many of these situations, and has kept several of these plants in operation as a result.

Marine Safety/Coastal Hazards

MAS is the only government entity conducting fishing vessel safety education. While the U.S. Coast Guard has major legislative responsibility for this important issue (commercial fishing is continually among the top two or three most dangerous professions in the U.S.), it does not have the human or fiscal resources to respond in a continuing, national-level educational effort. The Coast Guard recognizes MAS as a uniquely capable resource and works cooperatively with it. There are MAS-supported fishing vessel safety training programs in each region

of the United States; many focus on ethnic minority communities. The Coast Guard supported production of a training manual by Texas MAS for the Southeast Coast that serves as a national model. The Alaska Marine Safety Education Association (AMSEA), developed under guidance from Alaska MAS, also serves as a model for developing training volunteers at individual isolated ports to give training on demand. These programs serve not only to save lives (a documented fact), but also to provide the industry with real-time information on current safety regulations and legislative changes. In other areas of safety, MAS works with the marine recreation sector and emergency response personnel for public education on lightning, lifesaving, and cold-water-near-drowning situations.

Most MAS efforts involving coastal hazards are usually focused on certain targeted missions where Sea Grant has particular capability even amid chaos. In the *Exxon Valdez* oil spill, local Alaska agent Rick Steiner became somewhat of a national hero by coordinating early local response and leading the effort to protect important Prince William Sound salmon hatcheries. Florida MAS responded to Hurricane Andrew by helping the large, South Florida recreational boating community document losses. MAS involvement in economic studies for damage assessment involving many local oil spills are a major support to resource agencies.

There are, however, proactive programs. MAS is widely involved in contingency planning at both the state and local levels for coastal hazards such as severe storms and oil spills. As an example, a recent spill in Tampa Bay was well controlled because of MAS contingency efforts. North Carolina Sea Grant contributes greatly to a national effort to improve storm- and corrosion-resistant construction methods and to foster new codes that, where adopted, save lives and property.

Ports and Marine Transportation

Sea Grant MAS programs in ports and marine transportation have declined since 1990. Only three focused programs on maritime port management remain: one focuses on maintaining the economic vitality of many disaggregated small ports along the west central coast of the Gulf of Mexico; another focuses on the Port of Los Angeles; and the remaining MAS program in Washington is truly international in scope. It focuses on capital investment planning, partitioning commodity and business opportunities, and long-range strategic planning for ports of all sizes.

On a broader scale, there is general MAS accomplishment regarding economic development, fiscal management, and environmental response for the marina industry. These programs generally serve to help small ports, harbors, and marinas recognize economic opportunities, capitalize on strengths, and maximize economic potential.

Fisheries

Fisheries remains the largest MAS programming area (20 percent of total activity), but it has declined from 25 percent eight years ago. MAS is the primary source of translated educational information to fishermen concerning regulations, legislation, taxes and investment alternatives, and social management problems. Without it, fishermen, a highly disaggregated group possessing limited ability to communicate with the bureaucracy, would suffer. While MAS educational activities are varied and wide ranging, they tend to aggregate under five subcategories: habitat management, energy conservation, resource management support, fisheries development, and bycatch.

Programs in habitat management relate to those discussed under wetland-related programs above and to programs aimed at riparian and stream habitat restoration for both Northeast and Northwest anadromous species.

Energy conservation accomplishments are associated with: developing models for retrofitting fishing boats with properly designed propellers, improved coatings, etc.; changes in towed-gear twine size and configuration as experimentally determined in tow tanks (these also frequently have the advantage of reducing by-catch); and the experimental introduction of a new high-tech fiber, SPECTRA, which possesses increased characteristics of strength and durability with smaller, lighter twine size. These experiments suggest that a fuel savings of 15 percent is reasonable.

MAS specialists continue to develop information supporting better management decisions through the fishery management councils. Debates

on new approaches, pro and con, to new limited entry schemes (e.g., ITQ's) and their social consequences have been constructively joined by California and MIT MAS programs. MAS, from its neutral, educational position, has been at the forefront of communicating ITQ ideas and impacts to the industry. MAS programs produced information necessary for the councils to adopt new or different strategies relating to sponge harvest in the Southeast, sea scallops in the Mid-Atlantic, and lobsters in New England.

Sea Grant MAS was the lead organization in stabilizing the conflict between NOAA's National Marine Fisheries Service and the shrimp fishery regarding the use of turtle excluder devices (TEDs). All programs along the Southeast and Gulf coasts have contributed to development of certification procedures and new TED models, which in turn contributed to decreased anxiety on both sides. While potential future conflicts remain, the situation is currently improved, primarily because of MAS technology-transfer activities.

Much TED technology is contributing to early gear improvements to reduce trawl fisheries bycatch. Across the network, MAS programs are at the forefront of bycatch reduction research and development in both shellfish and finfish fisheries. In concert with the fishing industry, Oregon Sea Grant was the host to a major national bycatch workshop which resulted in plans for gear and data development, technology transfer, and demonstration projects.

Since 1990, fisheries development activities have increased landings and economic activity in many species and have frequently diverted effort from overharvested traditional stocks. Newly developed fisheries include: Bristol Bay halibut and kelps, dive fisheries for urchins and sea cucumbers in Alaska and Maine, and hagfish (for leather) on both coasts. Accompanying such developments are activities to assess the management implications of exploitation of new stocks in cooperation with appropriate management agencies. With MAS's involvement, plans have been developed and adopted for resources such as Florida sponges, West Coast urchins and sharks, and Delaware Bay horseshoe crabs.

Frequently, MAS personnel are called upon to seek compromise in fisheries conflicts. In Mississippi, a study of Vietnamese fishing methods showed those methods to be no more destructive to habitat than traditional ones. These findings relieved tensions with ethnic overtones. In New Hampshire, importation of European sonic devices to hang from gill nets seems to be promoting net avoidance by harbor porpoises. Conflicts with outer continental shelf oil and gas drilling are common, but creation of specific special-use zones for towboat operation, publication of maps showing locations of submerged wellheads, and simple enhancement of communication has mitigated much antagonism on the West Coast. Finally, another aspect of MAS' activity in fishery development has been its activity in planning, siting, and assessing (both biologically and economically) an expanding national program of artificial reefs. Japanese advanced technology in reef construction, which seems to improve actual production, has been imported to U.S. waters. The Atlantic States Marine Fishery Commission has adopted an artificial reef policy on siting and engineering produced by North Carolina MAS.

Seafood Technology

MAS activity in seafood technology is extensive and important in keeping many small, low-profit-margin operations in business as they face rapidly increasing responsibilities for quality and safety, waste management/disposal, and effluent quality improvements. Accomplishments in this area tend to accrue plant-by-plant, depending on individual plant configuration and systems, and result from using the best available technology provided by MAS specialists. Taken together, there have been major industry-wide upgrades in: waste reduction and by-product recovery; waste reutilization such as by-products being used on agricultural crop land for fertilization and soil enhancement; water conservation, sanitation, and effluent biological oxygen demand. These improvements will continue at an accelerated pace.

Additional efforts are aimed at improving seafood quality by changing onboard handling techniques to include use of chilled seawater and by using plastic bin boards in holds to increase the effectiveness of sanitation practices. Experimental work with 4-hexylresorcinol as an alternative

sulfiting agent for prevention of shrimp melanosis may prove to be a major positive health factor. Developed by Florida MAS, the introduction of voluntary use of product quality codes, an idea to direct industry compliance and buyer selection, is endorsed in principle by the National Food Marketing Institute. Finally, the function of MAS specialists is identical to fisheries specialists in providing the seafood industry with translation of regulations, legislation, and other relevant information important to the industry's well-being. MAS specialists are a principal resource for training in Hazard Analysis and Critical Control Point (HACCP) techniques to be required under emergency seafood safety legislation. Such training already occurs at all levels within the industry nationwide.

Coastal Business and Economic Development

Most activities and accomplishments summarized above have economic derivatives that are usually derived secondarily. Many MAS accomplishments, however, are from projects based solely on establishing new or benefiting existing coastal business through economic development. No business demonstrates this more than the development of the Great Lakes charter fishing business. While its beginnings were dependent on rebuilding fishery resources, the subsequent development of a basin-wide charter industry comprising over 3,000 individual operators with a conservatively estimated total annual value of $80 million is the result of continuing Sea Grant extension work. Sea Grant MAS was also involved in the development and expansion of Great Lakes state-authorized underwater preserves. Recreational diving in these preserves is now valued at over $6 million (and growing) annually in additional revenue to small communities scattered throughout the upper Great Lakes. MAS conceived the idea to work with local communities, state archaeologists (who identify and catalogue Great Lakes shipwrecks), and businesses to enhance both the preservation of underwater cultural resources and the contribution to the local economies.

A novel approach to development of aquaculture businesses in Texas was inaugurated by that program. In this approach, a landowner will sell land to the state, which will then lease land back to the original owner for aquaculture development with funds derived from the sale.

International trade in seafood products has been greatly stimulated since 1990, beginning with the development of Japanese export markets for soft-shell crabs. This has more recently been followed by substantial markets for fresh sushi-quality tuna, urchins and sea cucumbers, and a developing trade in American lobsters. Other economic benefits accrued from activities during the reporting period include: increased income to Great Lakes Indian tribes from improvements in marketing and value-added products for their fishery products, creation of cooperatives for disaggregated fishermen and recreational businesses throughout the county, computerized investment analysis for use by bankers for small coastal business ventures, and development of economic valuation models suitable for analyzing potential resource uses under variable water quality conditions.

Future Directions, Plans, and Opportunities

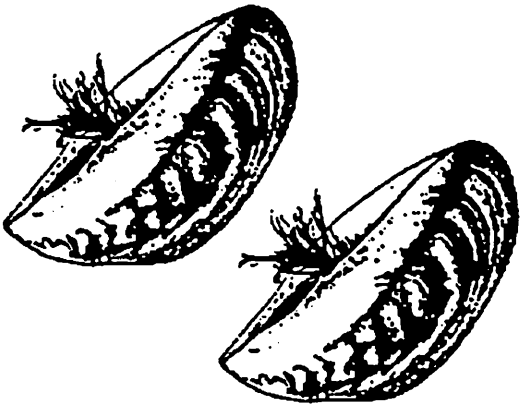
During the years 1990-92, a special task force was developed at the joint request of the National Sea Grant Program Director and the Council of Sea Grant Directors to provide a "think piece" on the long-term future of MAS—to insure that it is as relevant in 10 years as it is now. This resulted in a report, *MAS 2000*, which has taken the form of a long-range plan concerning the process of MAS outreach activities. The paper has been adopted by the Sea Grant community as the fundamental long-range guidance for MAS. The report addresses the issues of maintaining currency in the rapidly emerging field of electronic-communications technology for educational purposes; solidifying relationships with the private sector and developing strong cooperative bonds with industry to improve technology and its transfer; increasing international perspective for importing and exporting ideas and technology; and developing further opportunities for MAS personnel to carry out applied research fundamental to their educational efforts.

In addition, programming efficiencies will continue to need improvement. Improvements include increasing the ability to work with agencies

that have similar missions. MAS is uniquely qualified to meet the outreach needs of a plethora of other organizations that do not have the internal capability. Rather than reinventing MAS, they should use existing capability. This is compatible with the new Clinton Administration's approach to solidifying government relations with the private sector and expanding government-technology transfer functions to support that effort.

Programmatically, there are several opportunities for expansion. NOAA's Office of Global Programs expects its education effort with MAS, primarily focused on training trainers, to expand over the next five years. The large interdisciplinary issue of insuring economic vitality to the nation's seafood industry provides expanded opportunities for programs in seafood safety, ecosystem health, bycatch, aquaculture development, and support of the processing industry. Nonindigenous species will continue to be a threat to the integrity of native ecosystems.

Finally, MAS education staff, located within all 29 state Sea Grant programs, is becoming increasingly involved in complex and conflicting resource issues. As experts in a wide array of disciplines, they are uniquely positioned to do this. Their model of operation is always from a neutral nonpartisan position, and they are generally recognized by protagonists on both sides of an issue as providing the best information available for decisionmaking. In this way, MAS has a major role in developing management sustainability of marine resources through helping to resolve conflict.



Zebra Mussels

Introduction

Dreissena polymorpha (the zebra mussel), a native of the Black, Caspian, and Aral Seas was introduced into North America in discharged freshwater ballast of ships from ports in Europe and western Asia. The mussel was first discovered in Lake St. Clair between Lakes Huron and Erie in June 1988. Extensive colonies, as many as 40,000 mussels per square meter, were reported in Lake Erie the following summer. By autumn 1992, the mussel was found throughout the Great Lakes; the St. Lawrence, Mohawk and Hudson Rivers; the Erie Canal; the Finger Lakes; the upper Susquehanna River; and the Illinois, Mississippi, Tennessee, Ohio, and Arkansas Rivers. Maximum density has been measured at over 700,000 animals per square meter.

Throughout its range, the mussel fouls municipal drinking water, electric power generation and industrial water intakes; it restricts water flow, obstructs valves, and clogs heat exchangers and condensers. Mussel impacts are also being felt in aquatic food webs, ecosystems, sportfishing, navigation, recreational beach use, and irrigation. There are a wide array of stakeholders, which include those mentioned above plus local, state and regional resource management agencies, as well as elected and appointed officials.

In 1989 and 1990, Sea Grant was among the leaders in developing a coordinated, interagency research plan aimed at controlling the animal's spread and developing a broad-based ecological understanding of the mussel. Congress recognizes Sea Grant's unique capability to address an array of basic issues within this plan and to provide technology transfer and educational programs to the many stakeholders. It appropriated $2.0 million, $3.0 million, and $2.8 million to Sea Grant in FY 1991, 1992, and 1993 respectively to support the interdisciplinary research and outreach programs. As with base Sea Grant funds, these federal resources were to be matched 2:1 with nonfederal money, and all projects were peer reviewed for both technical excellence and program relevance.

The Outreach Program

Sea Grant's Great Lakes Marine Advisory Network led in developing public awareness of the zebra mussel problem and methods to slow its spread. These outreach efforts have also enhanced the ability of researchers and the media to track and report on progress made in mitigating the mollusk's adverse effects on water supplies, industrial processing, transportation, and recreation.

In 1991, each Great Lakes Sea Grant program established a zebra mussel information center—a single contact point and depository that coordinates and distributes information to all audiences, including researchers, management agencies, businesses, and the media and public. Together, the programs track, confirm, and record the progression of zebra mussel infestation in their states and nationwide. A wide range of approaches, including news releases, newsletters, magazine articles, videos, public presentations, and direct consultations are under-

taken to keep concerned audiences informed. Since 1989, The Great Lakes Sea Grant Network has hosted and co-sponsored an annual international zebra mussel research conference. It has become the primary meeting of researchers and stakeholders, and attendance has grown from fewer than 50 people to over 700 in 1993.

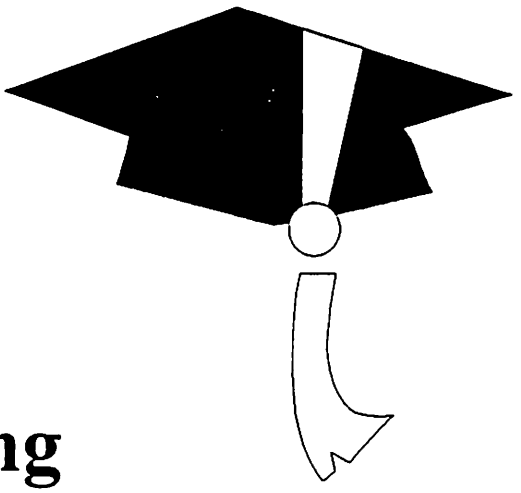
As the mussel invaded U.S. inland waters, Great Lakes Marine Advisory Service (MAS) staff helped sister Sea Grant programs and other agencies and industries to prepare for the mussel's arrival and its effects. In 1992, programs from New Hampshire to North Carolina also established information centers. Educational programs in these states as well as Tennessee, Pennsylvania, Vermont and Canada have been led or guided by Sea Grant MAS specialists. As Mississippi River barge traffic has accelerated the spread of the mussel downstream into the south-central U.S., programs are now being planned by Louisiana and Mississippi specialists. Many of these programs include agency training on implementing standardized mussel monitoring programs for early warning/detection. Shared resources, materials, and common databases maximize the efficiency of these programs.

The Zebra Mussel Information Clearinghouse was established in 1990 to collect and disseminate information about the zebra mussel spread, impact, and control. Co-funded with a consortium of electric utilities and housed at New York Sea Grant, it facilitates and helps coordinate information sharing among university, government, and private industry researchers throughout the United States and Canada, and also provides continuity to the timely dissemination of interim findings of ongoing research projects. The Clearinghouse works with Sea Grant programs in the Great Lakes, New England, Mid-Atlantic, and Gulf regions, as well as universities, government agencies, industries and others involved in zebra mussel information and research projects throughout the United States, Canada, and abroad. It also serves as a focal point for zebra mussel research inquiries and requests and assists other state, provincial, and regional zebra mussel information centers by providing them with real-time access to the most current research and technology available for dissemination to local audiences. Clearinghouse resources are available to all user audiences listed above. In its first two years, the clearinghouse responded to more than 1,800 requests from North America. Its primary information tool is a bimonthly research-based newsletter, *The Dreissena polymorpha Information Review*, which has become critically acclaimed.

The Research Program

Approximately 20 percent of the research projects submitted for consideration in response to formal requests for proposals were funded: 19 in 1991 and 18 in 1992. Proposals were funded from nine Sea Grant Programs in 1991, and seven programs in 1992. The scope of the projects is wide, but the bulk of projects is biological/ecological in nature. These relate to the effect of zebra mussel nutrient cycling and trophodynamics in freshwater communities, their osmoregulatory physiology, their effect on fate and transfer of environmental contaminants, and their biological and physiological requirements throughout their life cycle as indicators of "weak links" that may be attacked by various control strategies. Other projects address the significance of spreading vectors, various environmentally sound control strategies, and economic costs and policy implications related to the occurrence of zebra mussels.

While the research projects are all still in various stages of completion, there are some preliminary findings that should prove useful in predicting areas of potential future outbreaks to levels high enough to cause economic and operational concern. The ecological and environmental response to serious zebra mussel outbreaks is being defined, the current major concern being alteration of the invertebrate community structure. To date, effects on economically important Great Lakes fish species have been small. Ongoing research should also define areas where zebra mussels cannot survive in abundance. Finally, there is some indication moderate levels of potassium salts may prove to be a species specific control agent.



Education and Training

Introduction

The education and training mission of the National Sea Grant Program is broad and pervasive—the program enhances education of primary and secondary school teachers in aquatic sciences; educates and prepares the next generation of scientists, resource managers, and policymakers; and enhances the scientific literacy of the public at large. Sea Grant's education program 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, university courses and curricula, vocational/technical training, improvement of precollege education, continuing education, fellowship programs, and both formal and nonformal public education.

Sea Grant funds several different types of education and training projects: university-level education, including fellowships and scholarships, research assistantships, and university courses for graduates and undergraduates; K-12 and teacher training; and public education and training. Much of the nonformal education mandate is carried out by the Marine Advisory Service (MAS) and is described in that report. In actuality, educational activity is a continuum from the most traditional, university-based education, to the lifelong learning that is part of public outreach. Education specialists perform the range of educational activities sometimes as extension agents or specialists and sometimes as marine educators and trainers. This continuum of activities will be described below with examples and accomplishments.

During the last three years, the Sea Grant education network responded to a challenge by the Sea Grant Director and National Review Panel to develop a long-range plan and statement of priorities. With the excellent help of the education specialists, that task has been completed. The task force report has resulted in publication of the brochure, "Shaping the Future. Sea Grant, Science and Society: The Role of Marine Education" which includes a vision statement and an action plan to move Sea Grant's education efforts into the 21st century. It identifies teaching teachers, and attracting and retaining young people, women and minorities to marine and aquatic sciences as a national priority.

Table 1 summarizes federal, matching and pass through funding for education and training projects over a four-year period from FY 1989 to FY 1992.

Education project funding has steadily declined since 1989, but much of the apparent decrease is due to year-to-year inconsistencies in classifying projects. The downward trend may be a continuation of the de-emphasis on education during the early and mid-1980s. Sea Grant is highly committed to education, teacher training, and marine literacy, but despite this commitment, has been unable to reverse the decline in overall dollars

Marine Education Funding, 1989-1992

	Federal	Match	Pass-through
FY 1989	$3,022,581	$1,916,950	$ 239,581
FY 1990	$2,863,624	$1,205,842	$ 856,785
FY 1991	$2,701,467	$1,289,369	$ 436,849
FY 1992	$2,653,276	$ 837,977	$ 249,391

Table 1

allocated to education efforts.

University-level Education Projects

Education projects in this category include fellowships, scholarships, research assistantships, and specially designed academic courses which fill a need in a particular university system. These educational activities are an investment in the nation's future scientists, resource managers, and marine policy specialists. The projects contribute to development of well-trained and highly qualified scientists. Sea Grant does this by supporting research assistantships and traineeships at academic institutions, by supporting course development and faculty involvement for undergraduate and graduates in marine sciences and marine policy, and by providing university scholarships or fellowships for promising students in marine policy and sciences. Sea Grant supports high-quality curricular projects at the university level. As an example, the University of New Hampshire has developed a course that provides students with multidisciplinary problem-solving experiences in undergraduate science and engineering. The purpose is to overcome the narrow, disciplinary focus that characterizes most advanced education and to make students deal with the challenge of real-world problems. Over the 1990-1992 period, New Hampshire projects included the development of an automated, remote plankton sampler that can also record physical data; a diver-operated machine to remove and collect biofouling materials; and an ocean acoustics project to help solve the problem of harbor porpoises becoming entangled in gillnets. Regarding this latter project, NOAA's National Marine Fisheries Service has recommended listing the Gulf of Maine harbor porpoise as "threatened." The project required students to identify acoustic signatures of various types and to develop a system to modify gillnet acoustic properties to increase harbor porpoise avoidance. As a result of the project, the faculty advisors successfully applied for S-K funding to do follow up research on the best course of action.

MIT has an undergraduate research opportunities course in which undergraduates work with world-renown researchers on developing technologies for applying science and engineering to marine and environmental problems to encourage marine science as a career path. Sea Grant-supported students have established the world record for the fastest human-powered water vehicle. They have also worked on automated underwater vehicle development.

University-sponsored, competitive fellowships and scholarships are an important part of the Sea Grant education program. An example is the Mississippi/Alabama Sea Grant Fellowship program. The fellowship is a regional competitive program for graduate research assistantships. Awarded yearly, they provide support for marine- or coastal-related research and for learning experiences of qualified graduate students through the medium of tutored fellowships. Over 50 students have been supported since the project's inception.

Other fellowship projects include a marine policy fellowship that is administered by North Carolina Sea Grant (East Carolina University), state legislative fellowships (California), and an annual fellowship awarded to a California high school senior for four years' stipend and research support.

Another type of advanced graduate support is postgraduate educational experience. The University of Georgia Marine Extension Service funds a 36-week internship program for recent college graduates to train them in environmental education outreach, for schools, aquaria, environmental centers.

An important initiative in the last three years has been the establishment of a graduate fellowship program sponsored cooperatively between Sea Grant programs and NOAA/National Estuarine Research Reserve System (NERRS). Funding is provided jointly between Sea Grant and the NERRS program. The fellowship competition is juried by the local Sea Grant director and the NERRS office and supports research by a student on a problem or issue of mutual interest. A pilot project was established in 1992 between Virginia Sea Grant and the Chesapeake Bay NERRS. It is hoped that other Sea Grant programs will follow this model and design fellowships that parallel the intent of the pilot project.

Collectively, these university-level education efforts are an investment in future marine and aquatic scientists, resource managers and decisionmakers.

Sea Grant has become a major national source of marine scientific, engineering, and management personnel, having supported undergraduate and graduate students specializing in marine disciplines that range from oceanography to seafood technology to law. Between 1980 and 1991, a total of 5,982 graduate students has received Sea Grant support nationwide, an average of 498 per year, while working on cutting edge marine -related research project and learning skills that they will employ in their chosen profession. The total effect of graduate and undergraduate training explains why one Sea Grant director has called graduation "our most effective mechanism for technology transfer."

John A. Knauss Sea Grant Fellowships

Since the program began in 1979, a total of 215 fellows has participated in the program. Twenty-five were selected and funded in FY 1992. The John A. Knauss Fellowship program is a national, competitively selected program for master's or doctoral students with interests in marine affairs and aquatic issues. It provides the students the opportunity to have a unique educational experience for one year in the nation's capital, working either in the executive branch or the legislative branch of government. Because of their experience, most fellows have gone on to serve the marine resources or coastal sector in leadership roles across the United States. An analysis of the fellows program as of 1991 showed that nearly 40 percent have gone into resource management-related areas in state, local and federal government. Approximately 21 percent are in the academic sector, either with public or private universities and colleges. Almost 14 percent have gone into the private sector, either with industry, industry associations or consulting firms. About 7 percent work for interest groups, usually private nonprofit environmental groups.

K-12 and Teacher Training Projects

Science educators have pointed to a crisis in science education. Teachers are scarce, and science is not regularly taught at elementary school level. Teacher testing over the past five years by some Sea Grant-education projects has shown that marine literacy and basic knowledge of the environment is lacking even in high school teachers. These results have inspired the attempt to improve educational preparation through summer-training workshops for in-service teachers. The Sea Grant in-service teachers investment translates to the classroom through their contact with hundreds of students over the years. This "multiplier effect" is a pillar of the education program philosophy and is a cost-effective investment. Sea Grant supports projects which can demonstrate the multiplier effect and can provide high quality educational efforts for in-service teachers. Pre- and post-evaluation are a necessary component of teacher training.

Among the many examples of Sea Grant in-service teacher training are Georgia's two-week,

intensive workshops during the summer. The workshops include lectures, presentations, laboratory work, fieldwork on barrier islands, salt marshes, estuaries and use and management of marine resources. They provide marine training for about 200 teachers each summer in the University of Georgia Marine Extension Service education center on Skidaway Island. The workshops are accompanied by pre- and post-tests to determine learning level and types. The teachers earn 10 graduate credits in the University of Georgia's College of Education. The education center staff coordinates with NOAA's Grey's Reef Sanctuary program, the U.S. Department of Education Eisenhower Grant, USFWS, the Ossabaw Foundation, Georgia Department of Natural Resources, the statewide Georgia Association of Marine Education, and the National Marine Educators Association. Teachers graduating from the summer training have developed a two-day winter workshop to further multiply the results and have presented papers on the workshops at the National Science Teachers Association meetings.

In the Mid-Atlantic region, the Delaware Sea Grant has developed, through securing outside funding to enhance staffing, a variety of in-service teacher opportunities. Its goal is to make in-service training opportunities for science educators available year-round. Delaware received a National Science Foundation (NSF) state-systemic initiative (SSI) grant to enhance K-12 educational capabilities in states. To that end, it has been proactive in developing week-long, in-service workshops in cooperation with Delaware's Department of Public Instruction (DPI) and the Teacher's Center. Teachers can receive a three-credit option from the University of Delaware or through DPI. Additionally, they have developed middle school in-service workshops, funded through competitive Eisenhower funding, and have developed a set of in-service weekend programs together with DPI. The workshops reach over 300 teachers per year.

Marine education in the Caribbean is an important undertaking. The Puerto Rico Sea Grant marine education program strives to be comprehensive by attacking the lack of marine environment knowledge on several fronts. In the classroom itself, the Puerto Rico education program has established an experimental course and activities to introduce high school students to the sea as a source of inspiration and knowledge. There are now six schools throughout the island which participate, with over 200 students participating directly in the activities.

On the teacher training front, there is an exciting accomplishment in Puerto Rico. At the request of the Commonwealth's Department of Education, the marine education program has developed a Marine Education Institute, which will train teachers in marine sciences. The first class of graduates is expected in 1992, with 80 teachers. Eventually, the Institute will train over 200 teachers throughout Puerto Rico to produce classroom materials for marine education activities and instruction in their school districts. The teachers will then implement marine education activities through their science courses and reach over 2,000 students in Puerto Rico as a result. New England continues to provide teacher training for Long Island Sound teachers; and New Hampshire Sea Grant has trained more than 200 teachers by an education program through Odiorne Point marine education center; in Oregon, Sea Grant MAS specialists offered labs, summer workshops, in-service programs, short courses and guest lectures about marine science to more than 150 educators over a three-year period.

Minority Education

Minority science education and teacher training have been identified as important needs by many educational organizations, including Sea Grant. As a small but important part of Sea Grant educational activities, it includes outreach to American Indians in college and K-12, and teacher training for African Americans and students, as well as educational programs for inner-city youth.

Public Outreach/ Lifelong Learning

Public educational outreach takes many forms. Sometimes called informal education, lifelong learning, the idea is that adults and children continue to learn as they are exposed to new information and experiences. Many people voluntarily take additional training in areas of their interest. Sea Grant supports informal education to

enhance the public's knowledge about marine and coastal environments, their use and development. Many Sea Grant public outreach activities are done jointly with or as a part of MAS activities.

In both the New England region and on the West coast, the education specialists have been leaders in capitalizing on highly-trained docents to leverage their ability to reach the public. In New Hampshire, about 90 docents act as an outreach arm to educate the public about coastal ecosystems and issues. The marine education specialist conducts the training and manages the docents program. Docents undergo six months of training for eight hours a week that includes sessions on marine science, coastal issues, Sea Grant research, classroom teaching techniques, and program development. The bulk of the docents effort is devoted to actual teaching in subjects ranging from aquaculture to salt marshes to tides and currents. Primary audiences are K-12, teachers, and the public. The docents' impact on the region is significant -- they gave more than 500 programs/lectures to audiences totaling nearly 45,000 individuals during the 1990-1992 biennium.

Activities and efforts of specialists and MAS personnel have culminated in the opening of a new, $1.2 million Seacoast Science Center at Odiorne Point, New Hampshire. A successful capital campaign was carried out solely by volunteers representing a network of private, nonprofit and public constituency groups. Previous marine science education programs were only offered seasonally, and now they can be offered year round. The primary purpose of the facility is to allow expansion of marine science education, and it will house, among other things, the continuing efforts of the marine education specialist to meet the demand from schools, teachers, and the public in the region. In the 1990-1992 biennium, 10 teacher workshops for 300 teachers were offered. Ten university undergraduates were trained, assisting with program development and with programming for school children and their parents.

A similar success story occurred on the West Coast, as Oregon Sea Grant worked closely with public civic and private groups to develop the popular coastal attraction Oregon Coast Aquarium (a $24 million facility). Over 500,000 visitors can view the Center's public educational displays, developed with interpretative support from Sea Grant. The Oregon program also organized a volunteer program to provide interpretive programs for aquarium visitors.

Additional examples of educational outreach include technical and vocational training and educational opportunities. Much of this is done together with MAS. For example, MIT Sea Grant with Massachusetts Maritime Academy provides training for fishing vessel safety. They conducted training for courses and curriculum at a variety of fishing ports in New England. Rhode Island and Alaska Sea Grant also cooperate extensively with the U.S. Coast Guard in providing training directly to fishing vessel captains and crew. Fishing vessel safety training and education are described in the Marine Advisory Service report.

Global Change Education

There have been increasing interest and activity in global change education for teachers, the public, and students. Many activities have been funded by other NOAA components or other agencies such as the NSF, through successful proposals by the Sea Grant marine education network and the MAS network. Sea Grant funding in the Great Lakes region has produced a series of short publications (one-page scenarios) to understand the potential effects of climate change on the Great Lakes.

With ideas from NOAA-wide education offices, and with funding provided by NOAA's Office of Global Programs, the Sea Grant MAS and education specialist network is gearing up to provide global change education programs. Capitalizing on the outreach capability of Sea Grant's MAS network, NOAA's Office of Global Programs has funded a coordinated set of pilot projects developed by individual states. The projects include both short- and long-term initiatives to address the program's objectives. Short-term initiatives will focus on training educators about global change processes, issues and impacts to prepare them for educating local resource managers and the public. Beginning efforts will also be directed at developing an infrastructure, demonstrating and evaluating various approaches to global change education, and providing educational material. In addition, estab-

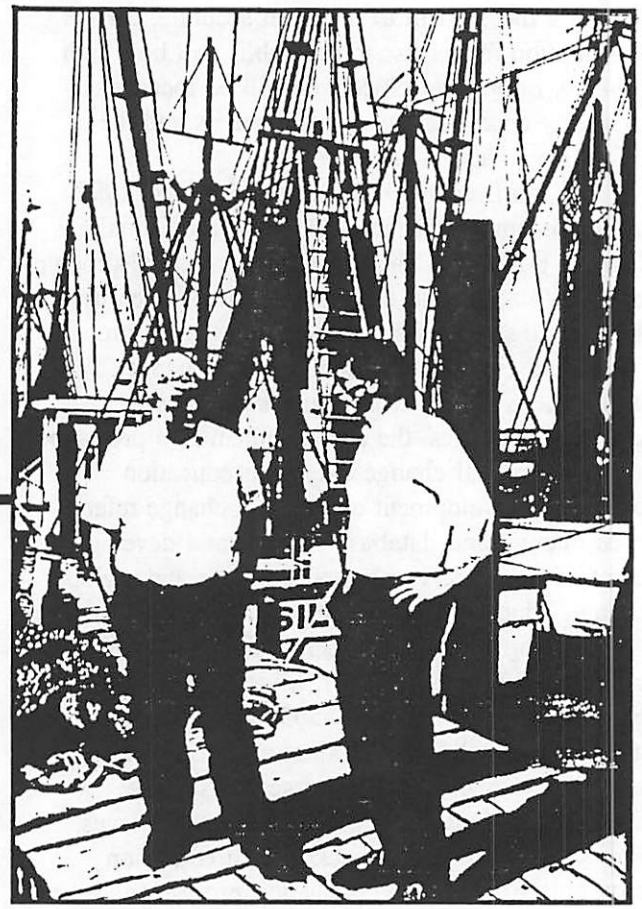
lishing a mechanism to maintain accurate, current information for release to the public will be a high priority. Long-term objectives will be focused primarily on educating decisionmakers and the public on a national scale.

In the framework of these objectives, 1992 accomplishments include training of a "Global Change Education Task Group," a selected group of MAS leaders and educators who will then train agents and specialists in their regions; pilot projects to educate civic leaders about global change, implications of sea level changes for coastal Louisiana parishes, the establishment of a prototype statewide global change extension education program, development of a global change reference manual and database system, and development of public service announcements and a global change education newsletter.

Acting in a leadership role for the Sea Grant educators' network, in 1991, Mississippi/Alabama Sea Grant was awarded a $503,000, 36-month grant from the NSF to conduct a prototype intensive three-week summer course for science teachers which focused on global change issues. This course will be the backbone of education programs for extension education professionals.

On a pilot basis, Mississippi/Alabama Sea Grant provided workshops for middle school teachers to test the concept. Based on the willingness to consider funding a larger effort, other Sea Grant regions will submit proposals for funding coordinated efforts. The effort is a national effort, and the objective is to have other regions submit follow-on proposals to offer workshops in their areas following the Mississippi/Alabama set of workshops.

Social Science & Marine Policy



Introduction

Sea Grant's social science and marine policy program is guided by the belief that most coastal and marine environmental issues have a human component. Either the problems are created by humans or they have an important anthropogenic component; or they are the work of nature which affects humans —that is, the way they live, their health, recreation or consumption. Consequently it is important to understand human behaviors and institutions as they interact with coastal environments. And humans, being the "driving forces" behind environmental change, are important to understand in their own right.

The social and policy research supported by Sea Grant addresses coastal resource management issues that include understanding the increasing conflicts over the use of marine and coastal resources; the contemporary economic and social transformation of commercial fisheries in domestic waters; the introduction of new technologies such as aquaculture and the production of genetically engineered organisms; and issues of public health and safety. These are a sampling of the kinds of issues that Sea Grant social science and policy research attempts to address.

Sea Grant social science and marine policy research focuses on theory and conceptual development. It pursues research on underlying mechanisms and processes. Policy research searches for innovative techniques of national relevance and attempts to push forward knowledge in areas where new approaches or information to solve problems is needed. Sea Grant research supplements and contributes to the other NOAA missions—particularly coastal zone, sanctuary, and fisheries management and the development and conservation of marine resources. As a foremost source of support for domestic fisheries and marine policy and social science, Sea Grant coordinates closely with other federal agencies and line organizations of NOAA, particularly its National Marine Fisheries Service (NMFS).

Program Trends

The social science and marine policy program supported 35 projects in FY 1992. Total funding, including federal, matching and pass through funds was $2,020,764, or 6.8 percent of the overall Sea Grant research effort. This proportion compares with the FY 1989 figure of 6.7 percent of the research effort.

In this report, social science refers to those projects using traditional sociology, anthropology, political science or geography approaches to understand humans as they relate to natural resources; it also includes interdisciplinary research with a strong social science intent or collaboration. The category of marine policy and management studies refers to those projects seeking primarily to advance understanding of management options and effects, policy choices or directions and, sometimes, the working of institutions and laws rather than focusing on the behavior of humans or their communities per se. Naturally there is a fine line between the two types of studies and, sometimes, projects straddle both categories. Sea Grant has a commitment to both approaches to advancing knowledge about coastal resources, because both the human dimensions and the institutional or management research are important aspects of human activity along coastal margins.

Table 1 shows that the proportions of social sciences and marine policy projects have remained fairly steady between FY 1989 and FY 1992. Although the data shows variation across years in the proportion of policy versus social science projects, the oscillation does not suggest the demise of either. There is a critical mass of projects in both categories and the variation in numbers of projects appears to move in both directions.

Table 2 shows the proportions of federal, matching and pass through funds for the major types of social science and management categories from FY 1989 to FY 1992. This table reflects the overall commitment to social science funding from all sources, including the ability to attract pass through funds from other agencies or parts of NOAA. The funding across categories or topics varies from year to year, but it would be stretching the interpretation to identify causal factors. In general the funding across categories appears to be fairly stable.

When parsing out the contributions of each funding source (federal, matching and pass through, see Table 3) over time, it appears that part of the reason for social science and marine policy program stability may be due to an increase in pass through funding. Again, it is difficult to tell if this is a trend or random event, but it is worth noting that pass through funding across the entire Sea Grant program is on the increase.

Number of Social Science and Policy Projects by Fiscal Year

	1989	1990	1991	1992
Social Sciences	16	16	20	23
Policy & Management	19	10	11	12
Total	35	26	31	35

Table1

Program Accomplishments and Directions

The following sections take a broad look at major accomplishments and trends in the social and policy sciences. The narrative synthesizes research, publications and accomplishments over nearly four years of work. While it has not been possible in this report to cover all the areas in social science, the report focuses on a few broad areas, particularly where work has resulted in programmatic thrusts that have been extended through working with the Marine Advisory Service (MAS).

Preserving the Past; Investing in the Future

Although the overall investment in historical archeology and prehistory continues to be small (under $25,000 total), the interest in the results of archeological projects is substantial. There have been many funded as "project development projects" over the past four years, and these have provided a remarkable return on investment.

The Great Lakes region has been a particularly rich area for underwater archeological projects. Recent federal guidelines accompanying the Abandoned Shipwreck Act give the states responsibility for managing historic shipwrecks including public recreation and commercial salvage regulation. Some Great Lakes states are creating marine reserves or marine sanctuaries. So the need to identify and assess historic shipwrecks is pressing; especially given the economic impact of the growing recreational dive industry.

Social Science & Policy Funding by Research Area

Total Funds, including Federal Sea Grant $, Match, and Pass Through
(in thousands of dollars)

	1989	1990	1991	1992
Recreation & Tourism	$ 266/12%	$ 362/27%	$ 45/1.8%	$ 107/5.2%
Commercial Fisheries	$ 568/26%	$ 439/30%	$ 1,300/51%	$ 326/16%
Policy & Resource Management	$ 1,280/59%	$ 821/47%	$ 815/32%	$ 915/45%
Archeology	$ 24/1%	$ 35/2%	$ 15/.06%	$ 19/9.3%
Public Health/ Safety	N/A	N/A	$ 273/11%	$ 441/22%
Valuation	N/A	N/A	$ 99/4%	$ 209/10%
Marine Industry & Ports	$ 23/1%	0	0	$ 4/.20%
Totals (in dollars)	$2,159,693/99%	$1,756,921/106%*	$2,548,789/99.8%*	$2,020,764/107%*

Table2

Fieldwork in one project focused on wrecks such as the *Byron*, a small coastal trade schooner; the *Walter B. Allen*, a three-masted schooner of Civil War vintage with a special steam engine rig for deploying sail tackle; the *T.H. Camp*, a wooden tug transporting the overwintering supplies to a logging camp; and the *F.J. King*, another three-masted schooner used in the iron-ore trade. Together these wrecks provide details of life in the upper Wisconsin region that augment historical understanding of the region's forces and economics. The data will be used to develop interpretive materials for dive sites and for communities near the wrecks and are a good investment in the past and future.

In Michigan, archaeologists and MAS recreation specialists have worked together to identify wrecks in Lake Michigan and worked with communities to develop interpretive materials surrounding these wrecks. The goal is to encourage appropriate diving activities around the popular shipwrecks. Michigan has established seven bottomland preserves—designated areas containing historical and geological significance—to preserve the Great Lakes underwater heritage. Sea Grant's role has been to help locate and verify the historical significance of the wrecks, promote an understanding of the concept, and assist local leaders with the initial development necessary to capture the economic and tourism potential of the underwater resources. Interpretive centers and maritime museums are an important aspect of public education.

Adaptation to marine ecosystems has been the other area in which Sea Grant has funded successful archaeological research during the past three years. Rhode Island Sea Grant provided funds to investigate the role of maritime adaptation and subsistence patterns of late woodland peoples on Block Island (Rhode Island). Because the site spanned pre- and post-European contact, it provided unique opportunities to examine the changes that

occurred with the introduction of pottery, agriculture, and European contact. Sea Grant also provided additional funding for radiocarbon dating from the site. The result, featured on the front page of the *Providence Journal,* was the discovery of the oldest village occupied year-round in southern New England (1,000 years older than earliest settlements, dating from five centuries B.C.), and of a maritime economy that relied entirely on ocean resources. Reliance on maritime resources was the foundation for the villagers' stable economy and subsistence, and they ventured far out on the ocean in 40-foot dugout canoes with large crews. Prior to this, it was believed that Indian settlements were predominantly seasonal, moving from summer to winter harvesting and hunting encampments. A permanent settlement, such as identified by McBride and his co-workers, indicates a level of sophistication and social organization that was previously thought rare.

Public Health and Safety - Communicating Fish Advisories in the Great Lakes

Over the past four years, Sea Grant has focused on improving knowledge of public health and safety issues regarding recreational fish consumption. Because of historical and long-standing discharge of toxins into the Great Lakes region in particular, states and the Environmental Protection Agency (EPA) have issued advisories about eating too much fish or fish from particular geographic areas. Controversy surrounds these advisories, from how best to word them for effective communication, to whether they are having any effect on people's eating habits. This concern falls squarely within the domain of communication theory and risk communication.

The problem is to develop and maintain the quality of sport and subsistence fishing and human health in the context of contaminated fish. Unacceptable levels of PCBs, Mercury, chlordane and dioxin, kepone, DDT, PAHs have been found in fish. The government has a role to warn fishermen and consumers of potential risks. Advisories are the primary mechanisms to alert anglers to avoid eating fish and to recommend specific amounts of fish for specific at-risk populations (such as pregnant women and children).

Sea Grant social science has played an educative and investigative role in this dilemma. First, they identified and clarified federal and state roles. When it comes to fishing, the role of advisor is shared by federal and state governments. The federal role is typically risk assessment, done by EPA and the Food and Drug Administration. Each agency has a different legislative mandate and, consequently, a different interpretation of how to assess risk to human health. The federal standards are voluntary and are advisory to the states. Adding to the com-

Social Science & Marine Policy
Federal Funding
FY 1989-1992
(in dollars)

	1989	1990	1991	1992
Federal	997,464 46%	972,009 55%	1,219,219 48%	868,765 43%
Match	936,229 43%	715,281 41%	929,731 36%	824,620 41%
Pass Through	226,000 10%	69,631 4%	399,839 16%	327,379 16%
Total	2,159,693	1,756,921	2,548,789	2,020,764

Table3

plexity, the state risk-assessment process is not standardized across states, and they use a variety of state agencies and federal standards to assist them.

Observing current trends, social scientists have pointed out that fishery managers are being asked to step into the relatively new role of **risk communicators.** The work of Knuth is especially important as she has brought the framework of risk communication to understand and rationalize the advisory process. The risk management perspective partitions the processes of setting risk levels and of advising the public into discrete phases. Risk assessment, the determination of risk levels, is a first step. Subsequent decisions, called risk communication, involve determining the most appropriate way to get the message out, such as which "channels" to use (newspaper, charter boat captains, TV, fishing license regulations); and, finally, estimating the effectiveness of advisories in reaching target populations and in changing behavior.

Much attention has focused on the first part of the risk management process: risk assessment. Social scientists in collaboration with fisheries scientists have illuminated the conservative nature of the EPA risk assessment standards and called for a new look at the ways risks are communicated: They have suggested alternative ways of expressing risk in advisories such as communicating risk in comparative perspective, comparing risk from eating fish with risk from drinking diet drinks with saccharine, or drinking milk or eating peanut butter.

Currently, social scientists are turning their attention to the risk communication process, the second major phase of the risk management process. Social scientists have answered the first important question: do people know about the risk advisories? Results to date from several studies indicate that among licensed anglers there is general awareness of advisories. In New York, for example, 82 percent of licensed anglers knew about fish advisories. This compares with 72 percent in Wisconsin and 87 percent in Michigan. In a recent survey of the entire Great Lakes Basin, carried out for the Great Lakes Protection Fund, the investigators found that 83 percent of licensed fishermen were aware of the advisories. A Sea Grant study determined that advisories awareness has increased since 1988 (from 80 percent to 85 percent) among New York licensed anglers, particularly among young, low income, and less-educated anglers.

These responses indicate a **general awareness** of fish advisories, as noted above, but results do not tell all that is needed to be known. Social scientists have pointed the way to the next questions: (a) does this general knowledge translate to changes in behavior, (b) is general knowledge different from thorough knowledge about risk. Results of the Basin-wide study, for instance, revealed that about one-third of the licensed anglers said they had made changes in their fishing behaviors or fish consumption in response to the health advisories. Most people, however, did **not change** their behavior because they believed they were not at risk. Finally, (c) we do not know about non-licensees and consumption of contaminated fish -- presumably more high-risk subpopulations such as subsistence fishing families, minority and low-income groups, and women.

In addition to refining knowledge about effectiveness of advisories, the next phase of the research focuses on effectiveness of the message and messengers: risk communication. This means refining the ability to reach the two-thirds of the population which does not perceive risk.

If the goal is to change behavior, there is a need to understand how people think about fishing, fish consumption and its risk. Communications theorists point out that successful advisories are "receiver-centered" and based on knowledge of the individuals ultimately needing to change their behavior. Assuming there is risk to the public from eating fish from contaminated bodies of water, who are the subpopulations most at risk (for instance, subsistence, low-income, or urban people)? What is the best method to communicate the proper risk and "avoidance behavior" to those groups and the fishing public? Even if they know about the advisories, do they or can they change their behavior to avoid risk? Who or what type of outreach is most effective in changing their behavior? One finding to date is very intriguing and has obvious implications for extension: People were more likely to change behavior (trim fish to avoid contamination) when they learned about the advisories through a charter boat captain or charter operator.

The work done to date has led to the threshold

of an opportunity. Much more needs to be known about the people not changing their behavior (60 percent Basin-wide) and about optimal communication strategies for reaching them. And more needs to be known about at-risk subpopulations (such as low income, low education, non-licensed, and women) - and the identification of communication strategies to reach them.

The Transformation in Fisheries Management

Since the 1976 Magnuson Act, domestic commercial marine fisheries have expanded to dominate the U.S. Exclusive Economic Zone. This was one goal of the act, so partial success can be claimed. Most United States' fisheries are open access, with restrictions placed only on gear, time, and location. But, for a variety of reasons, either many fish stocks are depleted or fisheries are overcapitalized and, in some cases, both. Among fisheries managers and fishermen in general there is dissatisfaction with the results of the law and its implementation.

In the midst of this reappraisal, a dramatic transformation is occurring in fisheries management, as Regional Fishery Management Councils consider moving fisheries from open to limited access management. Sea Grant- and NMFS-funded social scientists are providing councils with important information to design the management plans and to assess the social and economic impacts of changing the regime from open to limited access to a common property. The work both informs and derives momentum from the awakening global interest in reassessing the dynamics of "the commons," led by cultural anthropologists, political scientists and economists. This movement has spawned a rapidly growing international association, the International Association for the Study of Common Property, dedicated to understanding management and use of the commons, from grasslands to tropical forests; fisheries social scientists have played a major role providing experiences from fisheries management.

The first move toward limited access to fisheries management in the United States was a vessel moratorium for the Surf Clam fishery instituted in 1978. In 1990, Amendment 8, to the Surf Clam and Ocean Quahog Fishery Management Plan, ushered in quasi-rights for fishermen to fish for a predetermined portion (quota) of the clams. The process of choosing the ITQ (individual transferable quota) by the Surf Clam industry has been documented by B. McCay and C. Creed, of New Jersey Sea Grant, who followed-up with studies of the impacts of the new management regime. They have worked closely with the Mid-Atlantic Fishery Management Council and the industry.

As predicted by McCay and Creed, there have been changes in the industry structure as a result of the ITQs. There has been a reduction of vessels in the fleet. One-third of the vessels have left the fleet and about one-third of the men working in the fishery have left—most for jobs unrelated to fisheries. The regulations have created what to some owners seems an artificial business environment with the cost of business now being the cost of buying and/or leasing ITQs. These increased costs are taken out of the crew's share, passing the burden on to the wage base of the crew members. The ITQ system has received mixed reviews from the fishing community, and results are being closely watched, since other fisheries are coming "on-line" for some form of restricted access.

The South Atlantic Bight wreckfish fishery was the second fishery to come under ITQs, followed by the Florida spiny lobster. The Florida fishery, primarily in state waters, piloted the development of a new "transferable trap certificate," the fishermen's choice for managing their fishery. The trap certificate was identified through the leadership of social scientists M. Orbach and J. Johnson, who worked with the industry completing baseline social science research and meeting with fishermen in this ethnically diverse fishery, sorting through a variety of options to limit access. The fishermen finally chose the transferable trap certificate, which Orbach terms a type of "effort limitation."

The New England groundfish fishery is under severe pressure, and NMFS agreed in a court settlement with the Conservation Law Foundation to implement a groundfish plan by the end of 1993 that would rebuild the stocks. The social and economic dislocation from this plan will likely be enormous, since it will involve a 50 percent fishing effort reduction in the ports like Gloucester and New Bedford, Massachusetts, and other new England ports. Hall-Arber at MIT has begun a project to

assess the socioeconomic impacts of the proposed plan, and has received some matching funds from the New England Fishery Management Council. She will be identifying both the intended and unintended consequences of management schemes so that negative impacts may be addressed or mitigated.

The Secretary of Commerce has approved community development quotas (CDQs) in Alaska. CDQs allocate a portion of the groundfish fishery for the next three years to social and economic development in the predominantly Eskimo and Aleut villages of the western Alaska coast. Villages get (a quota) and for their share of fish can use it for training, education, local development or investment in vessels. Although controversial, it is seen as one way to develop fishing potential for the villages and allocate a portion of the harvest's benefits to community-based groups. Social scientists should be involved in assessing the effectiveness of this management strategy, and should see this as an opportunity to add to their knowledge of management regimes and community viability.

A halibut and blackcod IFQ (individual fishing quota) program for Gulf of Alaska fisheries, a quota share management plan, may be in place by March 1994. It will allow year-round fishing, a significant advantage in the marketplace since it spreads deliveries over longer periods. It will promote greater safety in the fishing operations by eliminating the six-hour "derbies," or race for fish. Social scientists, including the work of Gunnar Knapp in Alaska, have been instrumental in calling attention to the social and economic advantages of pursuing this management strategy. On the other hand, the likely reduction in the fleet will hurt coastal communities due to the demise of smaller-scale fishermen and eliminating open competition on the fishing grounds. It is expected that all fisheries off Alaska will come under similar limited access programs.

Several fisheries social science workshops have been co-sponsored by Sea Grant in the last three years. As part of the effort to push forward thinking about the social and economic effects of limited access as a management tactic for commercial fisheries, Sea Grant and NMFS co-hosted a workgroup on limited access in 1991. It was organized and chaired by Peter Fricke (NMFS) and Shirley Fiske. The interdisciplinary group identified the research gaps concerning limited access and made recommendations for the implementation of limited access regimes across the U.S. A second workshop convened by John Gates in 1992 addressed a much larger question of articulating the needs for social science research in commercial fisheries for the future. The University of Rhode Island (URI) Sea Grant, the URI Resource Economics Department and NOAA Economics Group co-sponsored the workshop.

Aquaculture and Biotechnology Policy

There are important relationships between the development of aquaculture in the U.S. and social and policy concerns. In 1992, the National Research Council published *Marine Aquaculture. Opportunities for Growth* which included substantial input from Sea Grant aquaculture specialists and from Sea Grant programs across the nation, It included chapters on social sciences and policy which called attention to the fundamental policy choices and social implications of the shift to aquaculture as a preferred mode of production.

Nearly every state has a Sea Grant guide to "permits and laws for aquaculture," but these are not analytical studies for the most part. Except for the NRC report, one of the few empirical studies on aquaculture involves an analysis of private oyster planting in Virginia. The study concludes that while the oyster disease MSX has received much attention as the reason planting is not profitable, the economic factor of the rising real cost of oyster seed is very important for the reduced private harvests.

The possibility of producing and patenting transgenic animals such as fish and shellfish raises new issues for fisheries managers and aquaculture entrepreneurs. Initial work by A. Kapuscinski and E. Hallerman has focused on public policy regarding laboratory production and field testing of such animals. Questions are posed about the distribution and final use of transgenic fish and the role of fisheries professionals in the various stages of production of transgenic fishes. The work in this area pushes forward our thinking about biotechnology—particularly when applied to the introduction of new genetic materials into higher organisms and implications for resource managers.

Governing the Coast

The last three years have been active in the field of ocean and marine policy. Sea Grant funding has, in part, encouraged the formation of the Ocean Governance Group, a network of analysts and scholars who share the vision of rethinking the U.S. approach to ocean policy and resource management.

The Ocean Governance Study Group is an initiative of the academic marine policy community to examine the status of U.S. ocean governance. Initiated with leadership from Delaware Sea Grant's Biliana Cicin-Sain and Bob Knecht, it responds to a major policy void in U.S. ocean policy to assess how well the U.S. management regime is working 24 years after the 1969 Stratton Commission. The Ocean Governance Group is a broadly-supported initiative in the Sea Grant system and has been supported by contributions from at least 11 Sea Grant programs.

The group has convened three meetings to date, including a Congressional briefing, and has developed a work program of analytical studies including the evaluation of institutional and policy fragmentation in national ocean policy, ocean use conflicts, and intergovernmental relations in ocean governance. The network is well-linked with NOAA and Congressional interests and will contribute to the needed debate on ocean policy. The last three years have also marked the formation of Marine Affairs and Policy Association (MAPA), which is dedicated to advancing marine affairs and policy education and research.

An early article by L. King and S. Olson pointed out the importance of "state institutional capacity" or readiness to manage ocean resources. Essentially, states vary in their ability to take responsibility and authority toward ocean resources and policy. There have been several important studies to identify state ocean policy/governance capacity. Robert Friedheim brings the paradigm and dilemma of common property to bear on the next steps needed for ocean governance. Because Mississippi's ocean management infrastructure is at an early stage of development, Richard Laughlin and Laura Howorth completed a Mississippi Ocean Policy Study to encourage the state to adopt an effective ocean management institutional framework. A detailed casebook on the latest legal decisions involving coastal and offshore issues including public and private rights in the coastal zone, preserving shore rights and resources, cooperative management of ocean and coastal resources, and conflict management involving offshore resources for the U.S. and Florida has been completed.

Work continues in interpreting the public trust. New court decisions and pending cases in Rhode Island are refining thinking about public trust responsibilities and rights. The recent *Hall* v. *Nacimiento* decision by the Rhode Island Supreme Court ruled that extensions of the seaward boundary through landfill, for example, are part of the public trust (state), and do not necessarily accrue to the private landowner. A pending decision will deal with the related question of ownership of bottomlands under piers that are privately owned.

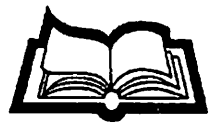
Coastal management planning and zoning may become more problematic and the taking issue may be on the forefront as the United States becomes more populous and litigious and as coastal areas become more developed. The implications of the Supreme Court decision in *Lucas* v. *South Carolina Coastal Council* have heightened interest in this area, although it is not clear that agencies denying coastal permits without compensation will, across the board, be more difficult to support.

Global Change

It would be remiss not to mention the work on global change, which to date has focused almost entirely on effects and prospects of sea level rise. Sea level rise in Maine, for example, has occurred in all coastal municipalities over the last 50 years and is expected to continue. Questions involve resolving property rights and access to shoreline. The University of Maine Marine Law Institute is identifying the legal aspects of sea level rise and examining Maine's state policies in response to the threat of sea level rise in a citizen's guide. The Mississippi/Alabama program has sponsored a conference on the long-term implications of sea level change for the Mississippi and Alabama coastlines. The contents of the proceedings include public trust issues, land use implications, and planning and coastal management

implications. Using a case study approach, one project examined the land use implications of alternate sea level rise scenarios on the city of Myrtle Beach, South Carolina. Type and values of land development likely to be affected are estimated, and management options are explored. In the international arena one project focused on the potential for impacts in the western Indian Ocean coastal zone where the indirect pressures of climate change and anthropogenic forcings (pollution, dredging, coral mining) and policy (land use, coastal zone) collide.

In this report, it is not possible to cover all the important accomplishments in every area of social science and marine policy. The above selection is a sampling of accomplishments and opportunities that is intended to illustrate examples of work funded over the last four years, the usefulness of the results for contemporary issues, and the opportunities for future research inherent in coastal resources development nationwide.



Selected Publications

(The following publications are funded by Sea Grant funds unless otherwise noted.)

Sea Level Rise

Burrage, David (ed), 1990, "Long Term Implications of Sea Level Change for the Mississippi and Alabama Coastlines," Proceedings, MASGP #90-015.

Caron, D.D. 1990 "When Law Makes Climate Change Worse: Rethinking the Law of Baselines in Light of a Rising Sea Level." *Ecology Law Quarterly* 17: 621-653.

Gable, F.J. and Aubrey, D.G. and Gentile, J. H. "Global Environmental Change Issues in the Western Indian Ocean Region," *Geoforum* 22(4): 401-419, 1991.

Knapp, J. P. 1990 "The Rising Sea Level and an Anticipatory Public Trust Doctrine in California." Technical report. Boalt Hall School of Law, U.C./Berkeley. 27 pp.

London, James B. and Claudio R. Volonte, 1991, "Land Use Implications of Sea Level Rise: A Case Study at Myrtle Beach, South Carolina," *Coastal Management* 19: 205-218.

Yohe, Gary W., 1991, "Selecting 'Interesting' Scenarios with Which to Analyze Policy Response to Potential Climate Change," *Climate Research*, 1:169-177, December 30, 1991.

Fish Advisories

Brown, T. L., Knuth, B.A. and Menz F.C., 1991, "Lake Ontario's Sport Fisheries: Socioeconomic Research Progress and Needs," *Canadian Journal of Fisheries and Aquatic Sciences* (48(8):1595-1601.

Knuth, B., 1989, Implementing Chemical Contaminant Policies in Sport-Fisheries: Agency Partnerships and Constituency Influence," *Journal of Management Science and Policy Analysis.* Summer 1989, 6(4); 69-81.

Knuth, B., 1990, "Risk Communication: A New Dimension in Sport -Fisheries Management," *North American Journal of Fisheries Management* 10:374-381.

Reinert, R.E., Knuth, B.A., Kamrin, M.A., and Stober, Q.J., 1991, "Risk Assessment, Risk Management, and Fish Consumption Advisories in the United States," *Fisheries*, 16(6):5-12.

Connelly, N.A., Knuth, B.A., 1993, "Great Lakes Fish Consumption Health Advisories: Angler Response to Advisories and Evaluation of Communication Techniques," HDRU Series No. 93-3, Department of Natural Resources, Cornell University. (Funded by Great Lakes Protection Fund)

Fisheries Management and Common Property

Friedheim, Robert, "Managing the Second Phase of Enclosure," *Ocean and Coastal Management* 17:217-236, 1992

Hall-Arber, Madeleine, 1993 Winter, "Doom and Gloom in Fisheries Management: Reality or Self-Fulfilling Prophecy?" MIT Sea Grant College Quarterly Report.

Hall-Arber, Madeleine, 1992, "Solution to the 'Tragedy of the Commons' or Tragedy for the Common Man?" *Commercial Fisheries News*, November 1992.

Knapp, Gunnar, 1992, "Commercial Fishing in Alaska: A Very Dangerous Occupation," *Arctic Research of the United States* 6:26-29. Fall 1992.

McCay, B. and Acheson, J. 1987 *The Question of*

the Commons. The Culture and Ecology of Communal Resources. Tucson: University of Arizona Press.

McCay, B. and C. Creed, 1990, "Social Structure and Debates on Fisheries Management in the Mid-Atlantic Surf Clam Fishery," *Ocean and Shoreline Management* 13:199-229.

McCay, B. Gatewood, J., and Creed, C. 1990. "Labor and Labor Process in a Limited Entry Fishery," *Marine Resource Economics* 6: 311-330.

Aquaculture and Biotechnology Policy

Kapuscinski, A. R., Hallerman, E.M., 1991, "Implications of Introduction of Transgenic Fish into Natural Ecosystems," *Canadian Journal of Fisheries and Aquatic Sciences* 48 (Suppl. 1):99-107.

Fiske, S.J., Jean-Pierre Ple, 1992, "Sociocultural Aspects of Domestic Marine Aquaculture," in *Marine Aquaculture. Opportunities for Growth.* Washington, D.C.: National Research Council.

Ocean Policy and Governance

Christie, D.R., 1992, "Ocean and Coastal Law and Policy: A United States and Florida Perspective," Florida Sea Grant Publication.

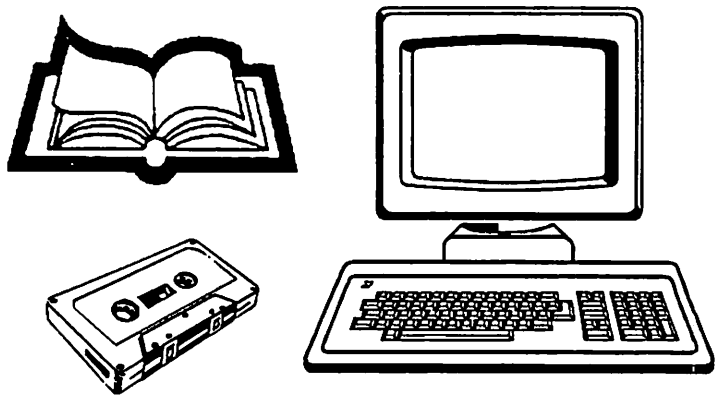
Cicin-Sain, B., 1990, "California and Ocean Management: Problems and Opportunities," *Coastal Management* 18: 311-335.

Matlock, *Water Log*, Vol 12 (2), 1992, Mississippi-Alabama Sea Grant Consortium.

King, L. and Olson, S., 1988, "Coastal State Capacity for Marine Resources Management," *Coastal Management* 16: 305-318. (not Sea Grant funded)

McLaughlin, R., Howorth, L.S., 1991, Mississippi Ocean Policy Study. MS-AL Sea Grant Legal Program, University of Mississippi Law Center, University, MS

Jarmin, M. Casey and R. J. McLaughlin, "A Higher Public Purpose? The Constitutionality of Mississippi's Public Trust Tidelands Legislation," *Mississippi College Law Review*, Fall 1990 11(1):6-37.



Communications

Introduction

To disseminate useful information arising from Sea Grant research, education and advisory services, the National Sea Grant College Program draws upon a network of professionals with educational and practical experience in communication theory and methods. These communicators utilize a wide array of media to ensure that new technologies and information are transferred into the hands of users in both the public and the private sectors.

Each of the 29 Sea Grant programs has designated a communications coordinator whose overall goals are to create better understanding of Sea Grant activities and accomplishments while helping to promote an awareness of ocean, coastal, and Great Lakes issues.

While communications projects at individual programs vary in staff size, funding and emphases, they are designed to provide communications expertise and advice to all components of Sea Grant, including management, advisory/extension staff, researchers and educators. Strong writing and editing capabilities are a defining characteristic of Sea Grant communicators, but their backgrounds can also encompass experience as radio, film and video producers, graphic designers, computer publishing specialists, conference and exhibit planners, and teachers.

Along with core communications projects at individual programs, the Sea Grant communications network also includes three specialized projects. The National Sea Grant Depository at the University of Rhode Island serves as the archive and lending library for all publications generated by Sea Grant programs nationwide, while the quarterly *Sea Grant Abstracts* document summarizes newly-issued publications and videos. Now in its 20th year, the "Earthwatch" radio program produced by Wisconsin Sea Grant is heard on more than 140 stations in the United States, Canada and overseas.

Funding

The following table shows the level of support for communications from Fiscal Year 1990 through Fiscal Year 1992 (October 1, 1989 -September 30, 1992).

Sea Grant Communications Funding

FY	Federal	Match	Total
1990	$3,455,968	$2,152,056	$5,608,024
1991	$3,745,280	$2,278,687	$6,023,967
1992	$3,874,890	$2,338,179	$6,213,069

Table 1

Network Publications Productivity in Major Categories

	87	88	89	90	91	92 (to date)
Advisory/ Extension Reports	101	82	96	103	105	31
Books	2	5	3	5	4	4
Educational/ Curricular Materials	15	4	5	7	1	6
Handbooks/ Guides	21	20	15	28	29	11
Journal Article Reprints	548	577	566	489	432	129
Proceedings	32	38	33	32	21	12
Technical Reports	89	78	86	49	38	18

Source: National Sea Grant Depository database total 30,373 records as of February 1, 1993.

Table2

Network Publications Productivity

Sea Grant communicators are involved in writing, editing, and publishing a variety of materials, including conference proceedings, technical reports, and guides and handbooks, many of which are targeted for specialized audiences served by the Marine Advisory Service. These audiences include aquaculturists, coastal planners, port and harbor managers, commercial and recreational fisherman, and seafood processors. In working with scientists, Sea Grant communicators track peer-reviewed journal articles and write stories to disseminate research results more widely. In addition, communicators write and distribute news and feature articles on Sea Grant activities to the mass media in order to reach the general public with information on marine and coastal topics. The following table provides one measure of communications productivity, but it should be noted that communicators are also called upon to produce program and project directories, annual reports, and omnibus proposals for funding. Please note that figures for Fiscal Year 1992 are preliminary, with many more publications from that year as well as some from 1991 still expected to arrive at the National Sea Grant Depository for processing in 1993.

Publication Highlights

Accolades

Still the foundation upon which other communications efforts are built, publications in the Sea Grant network covered the full spectrum of the marine sciences and brought accolades to communicators and their programs. Begun in Spring 1989, *Nor'easter*, the Sea Grant network's first-ever regional magazine, completed its fourth year in 1992, with the active participation of communicators

from the Connecticut, Maine, MIT, New Hampshire, New York, Rhode Island, and Woods Hole Sea Grant Programs. In the process, it won two national, peer-reviewed awards for innovative resource management and overall publication excellence from the Council for the Advancement and Support of Education, an association set up to honor outstanding achievements at institutions of higher education in the United States and Canada. In addition, in 1992 it won one of eight coveted "Ozzie" awards for best overall design in the educational magazine category; more than 1,600 entries were received in this national magazine competition.

On the West Coast, in an example of Land Grant honoring Sea Grant, Alaska Sea Grant won two first place prizes in the 1990 Agricultural Communicators in Education (ACE) national awards program. An article by a communicator on seafood by-products, which was published in Alaska's leading business magazine, won first place for magazine writing as well as first place in all writing categories. Also in 1990, the American Library Association's Government Documents Roundtable recognized in its "Notable Documents" competition the booklet *Persistent Marine Debris: Challenge and Response*, a joint effort of Alaska Sea Grant and the NOAA Chief Scientist's Office.

Debuts

Among other noteworthy developments during this reporting period were the debuts of the *Sea Grant in Brief* report from California, the *Fathom* magazine from Florida, the *Malama Kai* (Care for the Sea) magazine from Hawaii, the joint *Seafare* tabloid newspaper from Maine and New Hampshire, the magazine *Watershed* from Maryland, and the *Sea Grant in the Caribbean* newsletter from Puerto Rico. In addition, North Carolina totally revamped its *Coastwatch* newsletter into a more comprehensive magazine, and several programs, including Delaware, Illinois/Indiana, and Virginia, saw their newsletters doing double duty—as annual program reports to their constituents.

Collaborations

In an example of outstanding Sea Grant regional cooperation that also drew upon private sector involvement, the Sea Grant programs in Connecticut, New Jersey, and New York joined forces on a 1990 Earth Day project to write the *Earth Guide: 88 Action Tips for Cleaner Water.* The guide promotes energy and environmental conservation by emphasizing simple actions individuals can take to reduce pollution and improve water quality in their watershed. WCBS News Radio in New York City paid for the layout and design, and then promoted the publication to listeners in the Tri-State area. The original print run of 53,000 copies was later supplemented by an additional 15,000 copies to meet the high demand. In addition to distribution to the general public, the guide found favor among dozens of local, state and federal legislators from all three states who requested additional bulk quantities of the guide to distribute among their constituencies.

In 1989, the Ohio program produced an overview of the zebra mussel infestation of the Great Lakes which proved to be an extremely popular publication. After seeing a Sea Grant story about the pest in a trade magazine, the boatbuilding company Brunswick Marine offered to print 200,000 copies of the publication at no charge. These copies have now been distributed by the Great Lakes Sea Grant Network, the Environment Canada organization, and several other agencies and associations. As the infestation spread, the Great Lakes programs quickly collaborated to produce a comprehensive outreach plan combining advisory services and communications to develop public awareness of the problem and methods to slow the mussels' spread. For more background regarding this specially targeted outreach and research, please refer to the "Zebra Mussels" section in this review document.

Crossing the country to the West Coast, the regional Pacific Sea Grant College Program issued a project directory covering programs in Alaska, California, Hawaii, Oregon, Southern California, and Washington. In addition, the group also issued a popular fold-out brochure that lists all of the region's *Publications for Commercial Fishermen and Processors.*

Broadcast Media Developments

Since 1984, the National Sea Grant Office has encouraged Sea Grant programs to use the broadcast media more extensively given the fact that more and more people get their information from radio and television. Realizing that budgetary constraints prohibited the hiring of additional personnel, national communications guidance suggested that efforts be made to place Sea Grant individuals with interesting stories to tell on radio and television interview shows, to try relatively inexpensive-to-make public service announcements, and to adapt already existing materials for use in radio and television news shows.

In some cases, as staff turnover occurred, replacements with broadcast media backgrounds have been hired, as has occurred in Hawaii, Louisiana, New Jersey, Virginia, and Texas. In other instances, programs have developed closer working relationships with their campus radio stations, instructional media services, or free-lance videographers.

That video productivity has increased over the past eight years was certainly evident when the National Sea Grant Office was able to arrange film festivals at both Sea Grant Week and the Coastal Zone conference held in summer 1991. To serve as a guide to currently available videos, the national office produced the document *Marine Resource Videos* which was distributed to programs in March 1992. Among the noteworthy videos produced during the past three years are: "Ocean Ranching" about salmon hatcheries from Alaska; "Vanishing Wetlands" from Louisiana; "Making New Waves: Aquaculture in Maine"; "Keeping Score" about releasing fish unharmed from Maryland; "Too Much Mussel" from Ohio; "Oregon's Ocean"; and "Texas Shores: Saving What's Left."

A particularly innovative approach to using the media occurred in 1990-91 when Florida Sea Grant received a $112,000 grant from the Governor's Office of Environmental Affairs to fund an environmental education project. As a result, Florida prepared a series of 52 broadcast-quality news stories or video releases about the state's environment, including several focusing on Sea Grant-related topics. The completed videos were broadcast as a regular part of the evening news produced by 11 television stations throughout Florida, and have given Florida Sea Grant greater visibility with the media as a reliable source of marine and coastal information.

On a global scale, the "Earthwatch" radio program produced by Wisconsin Sea Grant received an award for "outstanding environmental achievement" from the United Nations Environment Programme (UNEP) during the June 1992 Earth Summit in Rio de Janeiro, Brazil. UNEP established the Global 500 award in 1987 to "each year pay tribute to individuals and organizations whose everyday actions and leadership in the front lines of the environmental agenda push forward the urgent goal of safeguarding the planet and building sustainable development." "Earthwatch" marked its 20th birthday in September 1992 and is believed to be the longest running series of radio programs on science and the environment in the United States. More than 5,000 two-minute programs have been produced during the past two decades.

National Products

To foster better understanding of how Sea Grant can solve marine and coastal problems on a national scale, the Sea Grant network and the national office produced a variety of publications during the past three years. In January 1991, a revision of *Marine Education* was produced by Texas Sea Grant and distributed by the Mississippi/Alabama Sea Grant Consortium. This publication provides an updated bibliography of educational materials available from the nation's Sea Grant College programs. Teachers and other individuals interested in helping students explore and understand the oceans and Great Lakes have reported on the value of this educational tool.

A brochure describing *The National Sea Grant Advisory Service: Serving the Nation's Marine Community* first appeared in March 1983 and was reprinted several times over the years. With advisory services tackling new issues such as plastic debris, global climate change, and solid waste disposal, the Sea Grant network needed a new guide to provide information about current advisory thrusts and contact points. With input from individual programs

and the national office, Minnesota Sea Grant published in April 1991 the brochure *Sea Grant's Marine Advisory Service: Looking to the Future.*

Marine Biotechnology: Competing in the 21st Century, a document issued in 1992, served to introduce decisionmakers to a new Sea Grant initiative which was coordinated on behalf of the network by Maryland Sea Grant. Also in 1992, the national office, with input from the network, began working on a new document titled *Sea Grant: Addressing Contemporary Marine and Coastal Issues*. Seven themes highlighting Sea Grant success stories were selected for further elaboration.

Begun in July 1989 by Alaska communications manager Kurt Byers, the *Sea Grant Communicators' Newsletter* was inherited by South Carolina communications coordinator Leigh Handal in spring 1992. The now retitled *Communicator*, designed by Bill Hartley, provides a wealth of information for Sea Grant communicators. From special articles by communications professionals outside the network to news from the network chair, this publication goes a long way toward encouraging information sharing.

Reaching Out in the 21st Century

On the procedural front, just like proposals from scientists, researchers and advisory service leaders, communications proposals undergo thorough peer review to examine both past accomplishments and future plans and projects. Given the evolving system for competitive proposal review, the Joint Committee on Modified Procedures has established a subcommittee to explore new procedures for reviewing and evaluating proposals for funding communications projects. This subcommittee will begin meeting in the new 1993 fiscal year.

During 1991, a special task force was formed at the request of both the National Sea Grant Director and the Chair of the Council of Sea Grant Directors (CSGD) to prepare a "think piece" on Sea Grant communications strategies into the next century. The task force prepared the report *Sea Grant Communications: Reaching Out in the 21st Century* which was distributed at Sea Grant Week '91 and then finalized and submitted to the CSGD in November 1991.

Describing Sea Grant as the "nation's primary marine information program," the report notes that Sea Grant's audiences are growing beyond those reached during the last 25 years and that, in order to reach these new audiences and help assure a scientifically literate society for the next century, "Sea Grant must be willing to adopt nontraditional and innovative communications strategies." The task force emphasized the underused potential of both the mass media, specifically radio and video, and of new technologies such as computer-based interactive videos and hypertext presentations.

In addition, the task force made several recommendations to position Sea Grant as a significant source of marine-related information for the coming decades, including: obtaining advice from communications experts outside the Sea Grant network on improved communications strategies and methods; improving computer networking among communications programs throughout the country; encouraging more professional development and talent sharing opportunities; and making marine science experts more readily accessible to the press.

Discussions at Sea Grant Week '91 and an addendum to the task force report focused on developing better marketing plans for Sea Grant products. A network marketing committee has been formed to find a way to market, advertise, and distribute Sea Grant products more efficiently. As the committee chair reported in the Spring/Summer 1992 issue of the *Communicator* newsletter, several options have been considered including: national marketing, including direct mail and display advertising; more sharing of information and advice within the network; discouraging production of products very similar to materials already in the network and buying into print runs when appropriate; and encouraging more regional marketing approaches. As one step in this direction, the National Sea Grant Office and the Maryland Sea Grant Program, on behalf of the network, have begun intensive discussions with the National Technical Information Service (NTIS) to explore ways in which selected Sea Grant products could be further marketed through the international capabilities of NTIS.

Ocean Law

Introduction

Total funding for ocean law program projects in FY 1992 was $620 thousand, an increase from the FY 1991 level of $594 thousand, and a decrease from the FY 1990 level of $747 thousand. In FY 1992, federal funding amounted to $286 thousand, compared to $202 thousand in FY 1991, and $286 thousand in FY 1990; matching funds were $450 thousand versus $392 thousand in FY 1991, and $461 thousand in FY 1990.

Most federal funding for ocean law supports three major ongoing Sea Grant programs which are listed below.

Oregon Legal Program

Oregon is the most comprehensive legal program funded by Sea Grant. It combines research, education, and advisory services. During FY 1992, major funded efforts included studies of the integration in international law of the sea developments into domestic federal and state law. The program also sponsored a study of the domestic and international responses to predicted sea level rise from global warming, and the legal rights of the shoreline property owners. In addition, the *Federal Fisheries Management Guidebook* was further updated and publication of the *Ocean Law Memo* continued.

Mississippi/Alabama Legal Program

The Mississippi/Alabama Program continues to analyze the current marine and environmental policy trends in legislation, regulations, and case law. Publication of the quarterly *Water Log* also continued through the year. This timely analysis and reporting of coastal law and policy issues is of crucial benefit to business and industry, government officials, and public interest organizations.

Working closely with law students and practicing attorneys, the program has fostered new areas of interest and study including the legal and regulatory aspects of exporting seafood products to Japan, the legal impediments to limited entry in the Gulf region, and the legal constraints associated with the ocean enterprise concept in the Gulf of Mexico. This year, the program will also contribute a chapter to the *Magnuson Fishing Act Guidebook* and produce a guidebook for the taking of marine mammals for scientific research or public display.

Louisiana Legal Advisory Program

The Louisiana legal advisory program provides an extensive education and public service program related to the use, conservation, and management of coastal resources unique to Louisiana. Law students participate in the program's legal research and case studies which provide crucial updated information to regulatory agencies, state and local governmental bodies, fishermen's organizations, and conservation,

recreational, and business groups. The program also continues to publish its research results in the *Louisiana Coastal Law* newsletter and in legal journal articles.

Other Legal Projects

Sea Grant supported three other specific projects. The first of these was the California Sea Grant project that investigated and assessed the impact of recent changes associated with Exclusive Economic Zone policies, Law of the Sea innovations, and the emergence of new management regimes that challenge the existing structure of U.S. participation in Pacific marine fisheries management. Through the search of government and university archives, the program supports state, national, and international interests in the impact of public measures on Pacific Coast marine industries. The results of similar studies have been used in the development of legislation and regulations.

Second is a Delaware Sea Grant project that recognizes the limitations and problems of the largely single-purpose approach to ocean resources management. This two-year project is developing a multi-use approach. Through analysis, it identifies and evaluates benefits of such an approach to ocean and U.S. public lands management. This analysis will be the basis for discussion and development of a conceptual framework for policy standards in managing multiple-use, publicly-owned ocean resources. Members of the executive and legislative branches and representatives of major ocean interests will participate in a workshop in Washington, D.C., to evaluate the plan.

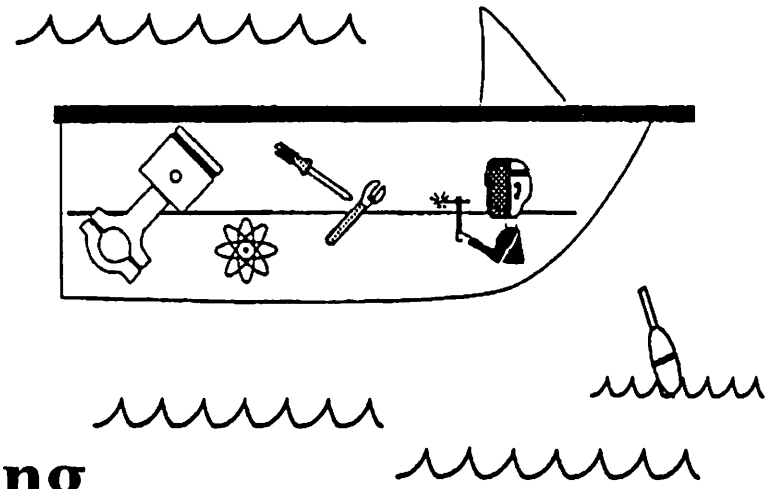
Third is an ongoing Hawaii Sea Grant project that has sponsored 24 conferences and 10 workshops, maintaining an international forum to exchange ideas and information on the rules for using the sea and its resources. As a result of this project, books and occasional papers are published for the use of scholars, practitioners, libraries, governments, and public interest organizations.

TECHNOLOGY AND COMMERCIAL DEVELOPMENT

CHAPTERS

Technology and Commercial Development

The most critical challenge facing the American economy is to rebuild the country's competitive position in the global marketplace. The lesson has never been more clear. There is 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 the nation's once dominant production economy. There is a need to become much more aware of how science is translated into commercial goods and services. The Division of Technology and Commercial Development is directly concerned with bringing the results of Sea Grant scientific research to the commercial sphere. This report covers four Sea Grant program areas: ocean engineering, marine economics, marine recreation and tourism, and international activities.



Ocean Engineering

Introduction

The Sea Grant ocean engineering program focuses on improving the ability to work effectively, efficiently, and safely in the marine environment. It is concerned with keeping abreast of the rapidly changing technology that is vital to economic competitiveness. This is not a large segment of the overall Sea Grant program. In FY 1992, 50 projects were supported with total federal funding of $3,021,543 and nonfederal match of $1,150,948 (the federal funds include $1,275,082 which were provided by pass through from other agencies). However, in spite of this limited effort, substantial progress and contributions were made in several areas during the past three years.

Progress and Significant Achievements

Education and Outreach

Engineering curricula are typically crowded with various mathematics, science, and applied science courses, but have a difficult time managing an emphasis on the engineering dimension, such as integration across scientific disciplines, synthesis, design—all areas related to the doing of engineering. For many years, several Sea Grant colleges have successfully included undergraduates in real-world, marine problem solving. The fruits of these studies have been manifest in the past three years. These courses have the advantage of interesting the students in ocean engineering during their formative years of studies. The courses also provide excellent visibility within the college for Sea Grant and its mission interests, and often provide a preliminary study of a problem that serves as the basis for a later research thrust by the institution.

As an example, a preliminary design of a collision-tolerant, navigation channel marker pile by New Hampshire students was subsequently followed by an interdisciplinary engineering faculty team design. The marker pile was successful in prototype installations, and the U.S. Coast Guard has adopted it for high incident locations. The Coast Guard expects that this pile structure may save millions of dollars annually.

Another interesting and valuable recent project in this category is MIT Sea Grant's use of graduate students to provide high technology advisory services. Examples include: an excellent report on marine dredged materials management which reviews the legal structure affecting dredging and gives options; a current study of using chitosan in water treatment as an alternative to alum which is being outlawed in some areas; a report analyzing the probable impacts of dredging pollutants from New Bedford, Massachusetts harbor. These studies have been excellent from an educational point of view, but have also proven to be an excellent method of providing community outreach for the university.

Artificial Intelligence and Knowledge-Based Systems

An FY 1989 workshop developed a research agenda for the "Application of Artificial Intelligence and Knowledge-Based Systems Techniques to Fisheries and Aquaculture." Computer science academics have not been generally incorporated into Sea Grant studies in the past. During these past three years, this report has been distributed among Sea Grant researchers and real progress has been made. Active projects in 1992 include an attempt to develop a system for estimating angler harvests, intensive closed-system aquaculture, and microcomputer-based automation. Further implementation of the workshop recommendations is expected.

Ship Design, Construction, and Safety

Activities have been heavily focused in this area, and notable progress has been made on several fronts. Previous studies by many Sea Grant programs of controls and navigation systems for submersible vehicles led to the design of an inexpensive, deep diving, autonomous vehicle at MIT Sea Grant. This vehicle is presently undergoing sea tests and will be adapted to several types of future scientific missions.

At Michigan Sea Grant, naval architects are currently concentrating on recreational boat design and the problem of fishing vessel capsizing. In both cases, substantial contributions to safety problems are being made.

Also at MIT Sea Grant, geometric studies related to Computer Aided Design and Manufacturing have been fruitful, and have led to considerable Navy attention and support. These contributions should be valuable in many types of manufacturing, and are beginning to attract industrial attention.

Rehabilitation of Aging Structures

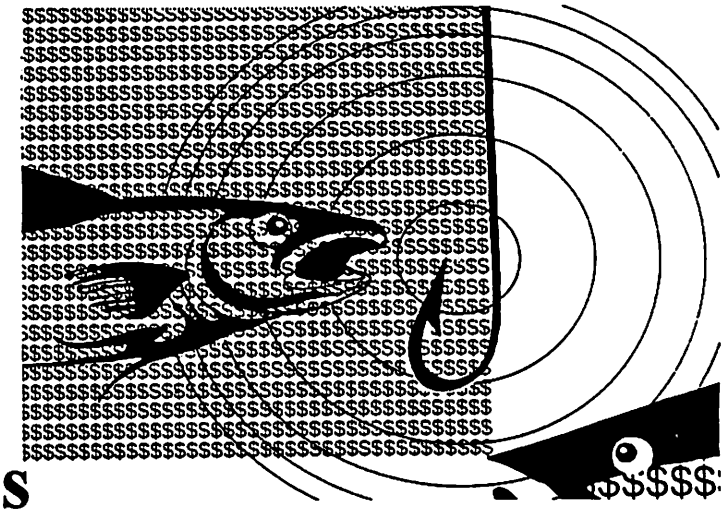
Sea Grant has previously supported studies related to the analysis of offshore structures. These studies have evolved recently into a new and important focus of activities. There are many aging oil production platforms in U.S. waters. These structures have been damaged through collision, fatigue, corrosion, and earthquakes. Assessing the present integrity and safe remaining lifetime is a lengthy and expensive process. New techniques for simplifying the assessment of offshore structures are being developed in cooperation with U.S. industry and regulatory agencies. Correspondingly, techniques will be developed to detail the increase of the structure's useful life which would result from specific repairs. Since these structures cost as much as $1 billion each, the savings from identifying repairs which can extend their useful life will be a substantial aid in keeping U.S. oil industry competitive.

Corrosion

Approximately five years ago, Sea Grant contributed heavily to the understanding of the electrochemical nature of corrosion, especially concerning the effects of calcareous deposits and the localized corrosion of aluminum and stainless steel. During the past three years, this emphasis has shifted to the influence of marine bacterial films on corrosion. It is too early to report substantial achievements, but this is an important area of study and progress is being made. Related studies are concentrating on developing inhibitors of adhesion of biofilms and corrosion.

Relations with Industry

Engineering faculty and students need a close relationship with industry engineering practitioners to keep abreast of the state-of-the-art and to test out the relevance and usefulness of their studies. MIT and Michigan Sea Grant have both provided excellent forums for achieving this through research jointly sponsored by Sea Grant and industry. Also, MIT Sea Grant has a very effective Marine Industry Collegium which has a membership of nearly 100 companies. This collegium sponsors four or five meetings each year at which industrial professionals discuss the commercial relevance of research areas with interested faculty. At each of these meetings, an attempt is made to include the academic community beyond MIT, and currently, efforts are being made to further extend the concept and its benefits.



Marine Economics

Introduction

Sea Grant's economics research program seeks to provide an understanding about 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 helps improve the competitiveness of this economy.

The economic growth of marine resource-based industries is an underlying goal of the National Sea Grant 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 FY 1992 marine economics program includes 33 projects, with total funding of $1.6 million, down 2 percent from FY 1989. Federal funding amounted to $1.1 million, including $420 thousand in pass through funds from other federal agencies. Matching funds from Sea Grant programs amounted to $531 thousand. Seventeen Sea Grant institutions currently participate in the marine economics research program, and at least 12 have an economics specialist on their Marine Advisory Service staff.

Sea Grant-supported economists are studying a full range of resource-use issues in: fisheries and aquaculture, marine and coastal resources, recreation and tourism, and coastal business and marine industry development. Table 1 provides a breakdown of the marine economics projects by subject area.

Trends

The marine economics program has been between 4 and 5 percent of Sea Grant's research budget the last three years, down from 6 percent in FY 1989. Part of the decline reflects the availability of alternate funding sources (such as the fisheries development foundations, fisheries management councils, and NOAA's damage assessment office) to support marine economics research. In part, it also reflects the reaction of Sea Grant programs to leaner budgets. This has also caused 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 development.

Economics Research Program

Property Rights and Fisheries Management

Ocean management institutions have not kept pace with the technical ability to exploit ocean resources. Interestingly, the historical record of the 18th century English commons enclosure suggests many parallels with current privatization efforts for ocean resources. Sea Grant economists are examining the concept of common property and how resources should be managed. With extended

Marine Economics Projects by Subject Area
Fiscal Year 1992

Subject Area	No. of Projects	Sea Grant (thou $)	Match (thou $)
1. Fisheries and Aquaculture	14	322	229
2. Marine and Coastal Resources	8	482	151
3. Recreation and Tourism	7	200	112
4. Coastal Business and Marine Industry Development	4	84	39
Total	33	1,088	531

Table 1

fisheries jurisdiction, competition at the negotiating table has often replaced competition on the fishing grounds. And, without clearly-defined fisheries property rights, industry overcapitalization and overexploitation of fish stocks continues. To mitigate these problems, various restricted access mechanisms, also known as limited entry, have been proposed. For many fishermen, the risk of exclusion outweighs the expected gain from restricted competition. Sea Grant economists are examining conditions under which fishermen are likely to support entry restrictions.[1]

Recently, individual transferable quotas (ITQs)—allocating individuals a share of the allowable harvest that can be traded in a market—have been advanced as a way to efficiently control fishing exploitation. The primary feature of ITQs is the assignment of exclusive property rights for harvesting a common-property resource. Sea Grant economists from Maine to California are studying the economics of ITQs by looking at the experiences of other countries that have adapted them and by investigating their use in the U.S. fisheries. However, ITQs are not viewed as a total panacea—they are complex to implement. For example, ITQs did perform, in the short term at least, to rationalize fisheries by providing economic incentives that lead to both economic efficiency and resource conservation. Sea Grant researchers in Delaware and New Jersey have also played a key role in the design of an ITQ system for the Atlantic Surf Clam and Ocean Quahog fishery, the first application of ITQs in the U.S.[2]

Unpredictable fish stock dynamics pose a major challenge to effective fisheries management. A bioeconomic model that uses chaos theory to model observed variability of multispecies systems is being used by Maine Sea Grant researchers to study various management schemes. Results show that the biological and economic sectors interact to produce behavior quite different from that predicted by models built on the more typical stock equilibrium concepts.[3]

Fisheries Development and Rehabilitation

Sea Grant research reported here addresses the economic performance of U.S. fishing industry sectors and the rehabilitation of depleted fish stocks. Washington Sea Grant economists are currently studying the economics of endangered species, in particular, the two stocks of Pacific salmon recently put on the endangered list.

The United States salmon fishery is one of the most valuable domestic fisheries. Until 1980, virtually the world supply of salmon came from wild stock catches, principally by the United States, Canada, and Japan. Since then, however, Atlantic salmon farming has developed to the point that it contributes 30 percent of world salmon supplies, and the supply of farmed salmon worldwide is expected to increase dramatically. Alaska Sea Grant economists are developing econometric models of international salmon markets to forecast the impacts of pen-raised salmon on the U.S. Pacific salmon industry.[4] Similar Sea Grant economic modeling efforts are underway for the Alaskan king crab, Pacific groundfish markets, and the Atlantic sea scallop fisheries.[5]

Fisheries rehabilitation is a widely held goal but, in practice, often controversial. Sea Grant economists have been studying several fishery case examples, analyzing both the economic efficiency and distributional equity issues of rehabilitation plans. For example, American oyster (*C. virginica*) production is declining along the Atlantic and Gulf of Mexico coasts due largely, but not solely, to disease. Total harvest dropped from 90 million pounds in the 1930s to 30 million pounds at the end of the 1980s. Sea Grant economists are working with oyster biologists to analyze various approaches to rehabilitation—from managing-around the disease to developing a disease-resistant native oyster or introducing the nonindigenous Pacific oyster (*C. gigas*).[6] Another case study examined the blueprint to restore the Lake Michigan fishery by reducing current catch to produce higher future catches. Sea Grant economists analyzed the trade-off and found the rehabilitation project to be successful, primarily due to benefits derived from a higher sport catch.[7]

Seafood Consumption and Product Quality

Per capita seafood consumption has risen 35 percent in the last 20 years, even though seafood prices have risen faster (1982:1988 - 38 percent) than for meat and poultry (12 percent). Because of this, Sea Grant economists have focused research on seafood product quality, consumer preferences, seafood marketing and pricing, and trade impacts.[8]

Aquaculture

With increased demand for seafood, the rapid development of aquaculture has large potential. First, however, it will be necessary to develop commercially viable aquaculture production techniques. Sea Grant economists have been helping prospective producers assess the investment risks involved in adopting various culture technologies and system components. Models, to explore implications for financial feasibility, are developed that simulate production costs and the uncertainties associated with survival, growth and disease.[9]

Recreation and Tourism

The burgeoning demand for water-based recreation and coastal tourism drives the investment decisions of governments and the private sector recreation industry. Sea Grant economists are developing models 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. The research provides a tool to evaluate the impact of resource management decisions on tourism development and the economic benefits of tourism investment.[10]

Valuation of Marine Resources and Coastal Environments

Economists use traditional economic theory, often with nonconventional, indirect estimate techniques for measuring the economic benefits derived from natural resources and environmental amenities. Sea Grant's contribution to this research has improved understanding of the value derived from marine resources and the coastal environment. In private markets, a commodity's value can readily be determined. But cost-benefit analyses of environmental assets are difficult because most often such assets are not directly traded in the marketplace. Sea Grant economists have made significant contributions to the problem of valuing nonmarket resources.[11] Recreation travel-cost models use expenditures made in traveling to and from a recreational area as price proxies. Hedonic-price techniques examine real estate prices and labor markets to value environmental assets or

pollution avoidance. Contingent-valuation methods use survey techniques to establish responses to the value of environmental assets.

Nonmarket values focus on the economic value derived from using resources not traded in markets. For example, wetlands provide the carrying capacity for many fishery stocks. For the most part, however, wetland owners cannot capture the implied value. This produces a market failure and an incentive to convert wetlands to uses consistent with organized markets such as residential development and agriculture. Florida Sea Grant economists are studying the incremental contribution of estuarine wetlands to the marine fishery catch. And in California, Sea Grant economists are employing contingent valuation surveys to estimate willingness to pay for wetlands in the San Joaquin Valley.[12]

For more than a decade, the U.S. population has been migrating from the interior to coastal states. Maryland established a set of land use restrictions that limit residential development on critical land areas abutting the Chesapeake Bay. Sea Grant economists estimated the effects of these restrictions on housing prices by observing price changes on houses that sold both before and after the restrictions were enacted. Due to the restrictions, housing prices in the Critical Area increased significantly faster than prices near, but not in, the Critical Area.[13]

"Existence value" refers to the value individuals assign to knowing that certain environmental amenities exist even though they have no contact with the resources involved. In resource valuation, existence values can be substantial and are being given greater consideration in environmental management and resource damage assessment. Sea Grant has undertaken research on correct approaches to empirical estimation, as well as applied studies to estimate existence values in real world situations and explore their implications for public decisions.[14]

Global Environmental Change

Issues revolving around climate change are enormously complex and shrouded in uncertainty. In particular, scenarios about greenhouse-induced sea-level rise vary widely, and careful research is needed just to identify which scenarios should be employed in the economic analysis of possible societal responses. Connecticut Sea Grant economists have taken a few steps toward providing a systematic answer to this question.[15]

Marine Transportation

Ports play a significant role in local economic development by attracting new businesses to relocate in the community or by helping existing enterprises grow. In Oregon, Washington, California and Minnesota, Sea Grant economists have developed various quantitative methods for assisting port authorities to plan for economic expansion and capital investment and development environmental impacts.[16]

Marine Industries

In 1983, the area for potential U.S. economic development was almost tripled by presidential proclamation of a 200 nautical mile Exclusive Economic Zone (EEZ). The EEZ added 3.9 billion acres of marine territory to U.S. economic jurisdiction, but has not yet produced any new significant activities or economic benefits.

Sea Grant has supported studies of how ocean policy and advanced technology drive ocean industry development. From an economic perspective, ocean resource exploitation affords a unique glance into American industrial development, from harvesting living resources to applying science and technology to recover mineral resources from the ocean seabed.[17]

For the United States, the EEZ has yet to produce new economic benefits of significance. Currently, there are many constraints inhibiting the technological advances needed for EEZ resource development. The basic problem in ocean development is that new ocean uses are perceived as having overly high risks and diminished government support and interest. Sea Grant has supported several forums dealing with the concept of "Ocean Enterprise" for overcoming the constraints that have inhibited the development of EEZ resources and uses.[18]

Future Directions

The Sea Grant economics program goals are:

- To improve the efficient allocation of marine resources, especially through using economic incentives and market-based solutions;
- To increase the economic and societal benefit derived from the nation's marine assets; and
- To enhance the competitive position of marine resource-based businesses in order to sustain economic growth and job creation in the long-term.

Research should focus on understanding the underlying economic prerequisites and conditions needed to meet these goals. Research proposals must offer to make a significant contribution both to solving practical problems and to economics scholarship. Interdisciplinary efforts with other social sciences, the natural sciences, engineering, and law are strongly encouraged. Priority research areas are identified and discussed below.

Sea Grant Business Initiative

The economic health of the United States has always been dependent on the economic development and growth of its coastal regions. The Sea Grant network, through a series of workshops and planning meetings, has made a renewed commitment to supporting research and advisory programs related to the long-term economic development, growth, and competitiveness of marine sector businesses, such as:

Aquaculture
Commercial Fisheries
Seafood Processing
Environmental Technology
Marine Trades
Offshore Mining
Ports and Harbors
Water-borne Transportation
Marine Biotechnology
Coastal Recreation and Tourism
Oceanographic Services

Industry studies of productivity, economic performance, business trends and practices, technical change, the impacts of trade policy, and the effects of demographic change or resource regulation on these industries are high priority research areas.

Marine and Coastal Resources

Land and waterfront use conflicts, habitat loss, water quality degradation, and increased waste loadings are severe problems in coastal areas. Remediation of their effects and their cumulative impacts on marine resources present important economic research needs. The ocean disposal of wastes and hazardous materials, the problems of marine debris, and the design of economic incentives for pollution abatement and environmental improvements continue to be important areas of study.

Estimating benefits derived from the use of marine and coastal resources not directly traded in markets—such as those identified with marine recreation, wetlands, habitat preservation, biodiversity, and environmental quality—is an appropriate research area. Analyses of resource values of ecological systems are extremely important, and provide an excellent opportunity for economists and ecologists to work together to integrate their quite different approaches to analyzing economic development.

Fisheries Management

Designing efficient market mechanisms to allocate fishery resources and minimize industry dislocations is the most critical fisheries management problem today. Research is required to analyze how fishing behavior would respond to individual harvesting rights vs. fishery-wide quotas; to measure the benefits and costs and the distributional impacts of regulatory regimes; and to improve empirical techniques to measure the value of fish stocks in alternative uses, including the rebuilding of stocks.

Routine economic baseline studies in support of fisheries management are low priority. However, there is a tremendous need for economists to communicate with fishery managers and industry members about fundamental socioeconomic concepts applicable to the management and allocation of fish stocks. In the process, economists gain

the insight that comes from the questioning of underlying assumptions, analytical paradigms, and research results.

Property Rights in Ocean Space

There is continued need for clarification of ocean property rights across the whole spectrum of marine resource development activities. If ocean property rights are not satisfactorily defined, incentives for technological advancement are lessened. The familiar debates on overfishing, coastal waterfront development, beach access, pollution discharges into estuaries, 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.

Seafood Industry - Environmental Quality and Productivity

There are several key economic issues bearing upon seafood industry growth. Product liability tied to health considerations and calls for mandatory federal seafood inspection are of great concern to domestic producers. A rigorous look needs to be taken at the economics of health, safety, and environmental quality issues related to seafood products.

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. How these functions will alter industry productivity needs to be better understood.

Resources of the Exclusive Economic Zone (EEZ)

The declaration in 1983 of a 200-mile EEZ for the United States presents an 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 continues to be considered high priority.

Climate-Sensitive Ocean Industries

Understanding global climate change impacts on climate-sensitive ocean industries will become an area of increasing importance as the scientific basis for these predictions is refined.

NOTES

[1] Common Property and Property Rights

Hanna, Susan S., "The Eighteenth Century English Commons: a Model for Ocean Management", *Ocean and Shoreline Management*, 14:155-172, 1990.

Queirolo, Lewis E. and Johnston, Richard S. "Distant Water Fishing Nations and Extended Fisheries Jurisdiction", *Marine Policy*, pp. 16-21, January 1989.

Karpoff, Jonathan M. "Characteristics of Limited Entry Fisheries and the Option Component of Entry Licenses", *Land Economics*, 65(4):386-393, 1989.

Wilson, James A., "Fishing for Knowledge", *Land Economics*, 66(1):12-29, February 1990.

[2] Individual Transferable Quotas (ITQs)

Anderson, Lee G., "A Note on Market Power in ITQ Fisheries", *Journal of Environmental Economics and Management*, 21:291-296, 1991.

Anderson, Lee G., "Efficient Policies to Maintain Total Allowable Catches in ITQ Fisheries with At-Sea Processing", *Land Economics*, 67(2):141-157, 1991.

Boyd, Rick O. and Dewees, Christopher M. "Putting Theory Into Practice: Individual Transferable Quotas in New Zealand's Fisheries", *Society and Natural Resources*," 5:179-198, 1992.

Dewees, Christopher M., "Assessment of the Implementation of Individual Transferable Quotas in New Zealand's Inshore Fishery", *North American Journal of Fisheries Management*, 9:131-139, 1989.

Townsend, Ralph E. "Entry Restrictions in the Fishery: a Survey of the Evidence", *Land*

Economics, 66(4):359-378, November 1990.

Townsend, Ralph E. "A Fractional Licensing Program for Fisheries", *Land Economics*, 68(2):185-190, May, 1992.

[3] *Multi-species Models*

Wilson, James A.; Kleban, Peter; McKay, Susan R.; and Townsend, Ralph E. "Management of Multi-species Fisheries with Chaotic Population Dynamics", *ICES Marine Science Symposium*, 193:287-300, 1991.

Wilson, James A.; Townsend, Ralph E.; Kleban, Peter; McKay, Susan R.; and French, John, "Managing Unpredictable Resources: Traditional Policies Applied to Chaotic Populations", *Ocean and Shoreline Management*, 13:179-197, 1990.

Wilson, James A.; French, John; Kleban, Peter; McKay, Susan R.; and Townsend, Ralph E., "Chaotic Dynamics in a Multiple Species Fishery: A Model of Community Predation", *Ecological Modelling*, 58:303-322, 1991.

[4] *Modeling Salmon Markets*

Herrmann, Mark and Lin, Biing-Hwan, "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community", *Canadian Journal of Agricultural Economics*, 36:459-471, 1988.

Herrmann, Mark; Lin, Biing-Hwan; Mittelhammer, Ron C., "U.S. Salmon Markets: a Survey of Seafood Wholesalers", Alaska Sea Grant College Program, 1990.

Herrmann, Mark; Mittlehammer, Ron C.; and Lin, Biing-Hwan, "An International Econometric Model of Wild and Pen-Reared Salmon", Alaska Sea Grant College Program, September, 1991.

Herrmann, Mark; Mittlehammer, Ron C.; and Lin, Biing-Hwan, "Applying Almon-Type Polynomials in Modelling Seasonality of the Japanese Demand for Salmon", *Marine Resource Economics*, 7:3-13, 1992.

Herrmann, Mark, "The Alaska Salmon Price Crash of 1991: An Econometric Analysis", *Arctic Research of the United States*, 6:34-36, Fall, 1992.

[5] *Fisheries Models*

Matulich, Scott C.; Mittelhammer, Ron C.; and Greenberg, Joshua A., *Predicting Japanese Wholesale Price and Demand for Alaskan King Crab*, Washington Sea Grant College Program, 1990.

Hanna, Susan S., "The Supply of Pacific U.S. Groundfish: Harvesting, Processing, Marketing and Regulation", in *Econometric Modelling of the World Trade in Groundfish*, W. E. Schrank and N. Roy (eds.), pp. 225-240, 1991.

Smith, Terrence, "Management of the Groundfish Fisheries Off Alaska: The Race for Bycatch", *Arctic Research of the United States*, 6:31-34, Fall, 1992.

Kirkley, James E. and DuPaul, William D., "Preliminary Assessment of the Economic Impacts of Various Catch and Effort Restrictions on the United States Sea Scallop Fishery", Virginia Sea Grant, 1991.

Kirkley, James E. and DuPaul, William D., "Commercial Practices and Fishery Regulations: the United States Northwest Atlantic Sea Scallop Fishery", *Journal of Shellfish Research*, 8(1):139-149, 1989.

[6] *Oyster Rehabilitation*

Lipton, Douglas, "An Action Plan for Social and Economic Research on the American Oyster Industry", Maryland Sea Grant College Program, 1992.

Bosch, Darrell J. and Leonard A. Shabman, *Reversing the Decline of Private Oyster Planting in the Chesapeake Bay: an Evaluation of Policy Strategies*, Virginia Sea Grant College Program, 1990.

Bosch, Darrell J. and Leonard A. Shabman, "Simulation Modeling to Set Priorities for Research on Oyster Production", *American Journal of Agricultural Economics*, pp. 371-381, May 1990.

Bosch, Darrell J. and Leonard A. Shabman, "The Decline of Private Sector Oyster Culture in Virginia: Causes and Remedial Policies", *Marine Resource Economics*, 6:227-243, 1989.

[7] Fisheries Rehabilitation - Great Lakes

Bishop, Richard C.; Milliman, Scott R.; Boyle, Kevin J.; and Johnson, Barry L. "Benefit-Cost Analysis of Fishery Rehabilitation Projects: A Great Lakes Case Study,", *Ocean and Shoreline Management*, 13:253-274, 1990.

Milliman, Scott R.; Johnson, Barry L.; Bishop, Richard C.; and Boyle, Kevin J., "The Bioeconomics of Resource Rehabilitation: A Commercial Sport Analysis for a Great Lakes Fishery", *Land Economics*, 68(2):191-210, 1992.

[8] Seafood Consumption

Anderson, Joan Gray and Anderson, James L., "Seafood Quality: Issues for Consumer Researchers", *The Journal of Consumer Affairs*, 25(1):144-163, Summer, 191.

Lipton, Douglas W., *Understanding Fish Pricing: from Production to the Table*, Maryland Sea Grant College, 1990.

Griffith, David; Johnson, Jeffrey; Murray, James; and Kemp, Philip, *Getting to Know Southeast Seafood Consumers*, North Carolina Sea Grant College Program, 1990.

Adams, Charles M. and Lawlor, Frank J., *Trends in the Importation of Selected Fresh and Frozen Seafood*, Florida Sea Grant College Program, 1989.

DuPaul, William D.; Fisher, Robert A. and Kirkley, James E., *An Evaluation of At-Sea Handling Practices: Effects on Sea Scallop Meat Quality, Volume and Integrity*, Virginia Sea Grant College Program, 1990.

[9] Aquaculture

Adams, Charles, James C. Cato (editor); James E. Easley Jr., Skip Kemp, William Mahan, John J. Manzi, Mike Oesterling, Robert Pomery, Eric Thunberg, David Vaughn, and Randal Walker, *Investing in Commercial Hard Clam Culture: a Comprehensive Guide to the South Atlantic States*, Florida Sea Grant, 1991.

Myers, Julia A. and Richard N. Boisvert, "The Economics of Producing Algae and Bivalve Seed in Hatcheries", *Aquaculture*, 86:163-179, 1990.

Lipton, Douglas W. and Harrell, Reginal M., *Figuring Production Costs in Finfish Aquaculture*, Maryland Sea Grant, 1990.

[10] Recreation and Tourism

Bell, Frederick W. and Vernon R. Leeworthy, "Recreational Demand by Tourists for Saltwater Beach Days", *Journal of Environmental Economics and Management*, 18:189-205, 1990.

Bell, Frederick W., *Actual and Potential Tourist Reaction to Adverse Changes in Recreational Coastal Beaches and Fisheries in Florida*, Florida Sea Grant, 1992.

Thraen, Cameron S., Napier, Ted L., and McClaskie, Stephen L. "Factors Influencing Attitudes Toward the Commitment of Economic Resources to Outdoor Recreation Development", *Journal of the Community Development Society*," 20(1):19-36, 1989.

Agnello, Richard J., "The Economic Value of Fishing Success: An Application of Socioeconomic Survey Data", *Fishery Bulletin*, 87(1):223-232, 1989.

Milon, J. Walter "Economic Evaluation of Artificial Habitat for Fisheries: Progress and Challenges," *Bulletin of Marine Science*, 44(2):831-843, 1989.

Brown, T. L., B.A. Knuth, and F.C. Menz, "Lake Ontario's Sport Fisheries: Socioeconomic Research Progress and Needs", *Canadian Journal of Fisheries and Aquatic Sciences*, 48(8):1595-1601, 1991.

[11] Nonmarket Valuation

Smith, V. Kerry, "Nonmarket Valuation of Environmental Resources", *Land Economics*, 69(1), pp. 1-26, 1993.

Larson, Douglas M., "Measuring Willingness to Pay for Nonmarket Goods", Paper presented at the American Agricultural Economics Meeting, Vancouver, 1990.

Smith, V. Kerry, "Taking Stock of Progress with Travel Cost Recreation Demand Methods: Theory and Implementation", *Marine Resource Economics*, 6:279-310, 1989.

Smith, V. Kerry, "Estimating Recreation Demand Using the Properties of the Implied Consumer Surplus", *Land Economics*, 66(2):111-120.

Smith, V. Kerry and Kaoru, Yoshiaki, "Signals or Noise? Explaining the Variations in Recreational Benefit Estimates", *American Journal of Agricultural Economics*, 73(2):419-433, 1990.

Jeng, Huei-Yann, *Endogenization of Trip Duration and Costs in Recreation Demand Models*, Ohio Sea Grant, 94pp., 1990.

Smith, V. Kerry, Palmquist, Raymond, and Jakus, Paul, "Combining Farrell Frontier and Hedonic Travel Cost Models for Valuing Estuarine Quality", *The Review of Economics and Statistics*, 73(4):694-699, 1991.

Bishop, Richard C. and Heberlein, Thomas A., "The Contingent Valuation Method", in *Economic Valuation of Natural Resources: Issues, Theory, and Applications*, R.L. Johnson and G.V. Johnson (eds.), 1990.

Palmquist, Raymond, "Hedonic Methods", in *Measuring the Demand for Environmental Quality*, John Braeden and Charles D. Kolstad (eds.), 1991.

Randall, Alan., "Nonuse Benefits", in *Measuring the Demand for Environmental Quality*, John Braeden and Charles D. Kolstad (eds.), 1991.

[12] Wetlands Valuation

Bell, Frederick W. "Application of Wetland Valuation Theory to Commercial and Recreational Fisheries", Florida Sea Grant, 1989.

Hanemann, Michael, John Loomis, and Barbara Kanninen, "Statistical Efficiency of Double-bounded Dichotomous Choice

Contingent Valuation", *American Journal of Agricultural Economics*, 73(4):1255-1263, November 1991.

[13] Hedonic Price Models

Parsons, George R. "The Effect of Coastal Land Use Restrictions on Housing Prices: a Repeat Sale Analysis", *Journal of Environmental Economics and Management*," 22:25-37, 1992.

Parsons, George R. and Yangru Wu, "The Opportunity of Coastal Land-use Controls: an Empirical Analysis", *Land Economics*, 67(3):308-316, 1991.

[14] Existence Values

Bishop, Richard C. and Welsh, Michael P., "Existence Value and Resource Evaluation", *Benefits and Costs in Natural Resources Planning: Third Interim Report*," John P. Hoehn, ed., pp. 268-291, October 5, 1990.

Bishop, Richard C. and Welsh, Michael P., "Existence Values in Benefit-Cost Analysis and Damage Assessment", *Land Economics*, 68(4):405-417, 1992.

[15] Sea-Level Rise

Yohe, Gary W., "Selecting 'Interesting' Scenarios with Which to Analyze Policy Response to Potential Climate Change", *Climate Research*, 1:169-177, December 30, 1991.

Yohe, Gary W., "The Cost of Not Holding Back the Sea: Toward a National Sample of Economic Vulnerability", *Coastal Management*, 18:403-431, 1990.

Yohe, Gary W., "Uncertainty, Climate Change, and the Economic Value of Information: An Economic Methodology for Evaluating the Timing and Relative Efficacy of Alternative Response", *Policy Sciences*, 24:245-269, 1991.

[16] Ports and Marine Transportation

Fawcett, James; Price, Willard; and West, Kathleen, *California Policy Choices*, Volume 7, John J. Kirlin, et al., (eds.), pp. 199-230, University of Southern California, 1991.

Dowd, Thomas J. and Jonson, Candace. *Port Capital Investment Decision-making*, Washington Sea Grant Program, 1991.

Dowd, Thomas J. and Leschine, Thomas M., *Contanier Terminal Productivity: a Perspective*, Washington Sea Grant Program, 1989.

Gitomer, G.S. and Runge, C.F. *Cargo Preference Legislation, Agricultural Exports, and the Future of the Duluth-Superior Economy: A Legislative History and Economic Analysis*, Minnesota Sea Grant, 50pp., 1990.

[17] Marine Industries

Scheiber, Harry N. (compiler), *Ocean Resources: Industries and Rivalries Since 1800.* California Sea Grant, 1990.

Scheiber, Harry N., "U.S. Pacific Fisheries Studies, 1945 to 1970: Oceanography, Geopolitics, and Marine Fisheries Expansion," *Ocean Sciences:*

Their History and Relation to Man W. Lenz and M. Deacon (eds.), pp. 417-421, 1990.

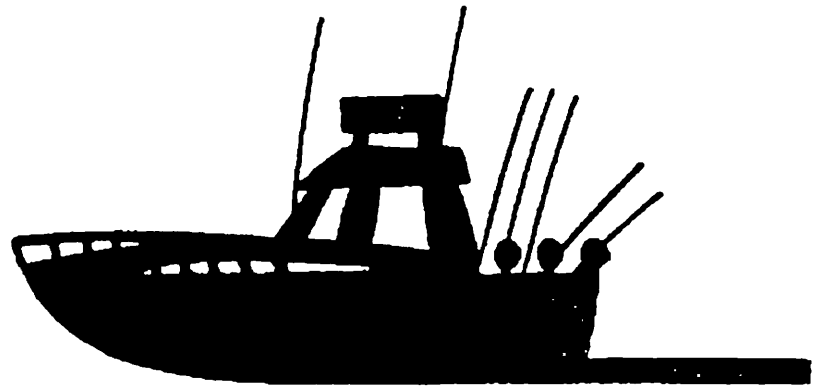
Callies, David L. and Johnson, Charles J. Legal, *Business and Economic Aspects of Cobalt-rich Manganese Crust Mining*, Hawaii Sea Grant 1989.

Hoagland, Porter III. "Administrative Discretion in the Management of Outer Continental Shelf Minerals", *Managing the Outer Continental Shelf Lands*, R.S. Farrow (Ed.), pp. 145-162, 1991.

[18] Exclusive Economic Zone Development

Ross, David A. and James E. Dailey, "Report on the Ocean Enterprise Workshop", WHOI Sea Grant Program, 1989.

Ross, David A., Judith Fenwick, Michael A. Champ, and Robert W. Knecht, "Ocean Enterprises: the Ocean and the Economy in the 1990's", *Coastal Ocean Space Utilization," Proceedings of the First International Symposium*, S. D. Halsey and R. B. Abel, (eds.), pp. 369-371, New York, May 8-10, 1989.



Marine Recreation & Tourism

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. 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 natural sciences. The Marine Advisory Service (MAS), 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 program areas—waterfront revitalization, water quality and pollution control, coastal land uses, 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 FY 1992 consisted of 14 research projects. In addition, most Sea Grant universities conduct a recreation advisory effort to provide industry educational and technical assistance. Federal funding for the recreation and tourism research program amounted to $447 thousand, including $9 thousand in pass through funds from other federal agencies. The Sea Grant colleges contributed another $236 thousand in matching funds. Compared with FY 1989, this is a 15 percent decrease in total funding for the recreation and tourism research program. Table 1 gives the breakdown by major subprogram areas: recreational fishing, boating, and coastal tourism development.

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.

Marine Recreation and Tourism by Subject Area, FY 1992

Subject Area	Number of Projects	Sea Grant (Thou. $)	Match (Thou. $)
1. Recreational Fishing	8	294	139
2. Recreational Boating	3	118	66
3. Coastal Tourism Development	3	44	31
Total	14	456	236

Table 1

Recreational Fishing Development

Sea Grant economists and business extension specialists have analyzed information on recreational fishing participants. This information is critical to coastal communities that provide the infrastructure services, support businesses, and physical facilities serving the marine recreational fishing industry. The economists have given particular attention to areas where recreational fishing participation is steadily increasing. In the Great Lakes, for example, 4 million anglers, fished an average of 10 days annually, spending $2 billion in trip-related costs. The implications of a demographically changing population and subsequent changes in demand suggest the need for expanded strategies to support sportfishery-related participation.[1]

In no small way, the charter fishing industry has been responsible for a significant component of the rapidly growing sportfishing industry. The Great Lakes charter fishing industry, for example, grew from several hundred boats-for-hire in 1975 to over 3,000 boats by 1988. Sea Grant researchers are studying this development to help the industry better understand how to meet the growing demand for access to marine and Great Lakes sportfishing.[2]

Recreational Fishing Management

In areas with rapidly growing angler demand, the management nature of marine fisheries has changed substantially. Changing fishery resource conditions, the emergence and growth of recreational fishing interest groups, and increased political activity by these groups have been influential. Sea Grant researchers have contributed to the understanding of relevant fisheries management issues and the concerns and capabilities of the management agencies. For example, communications is an important but poorly understood component of marine recreational fisheries management. As with commercial fishermen in the 1980s, the need to improve communications with recreational fishermen will grow significantly over the next decade. How best to disseminate information to marine recreational fishermen is the focus of research by North Carolina Sea Grant.[3]

Recreational fishermen are becoming more accustomed to releasing part of their catch. This situation is in part attributable to a growing conservation ethic and, in part, to an increase in government fishery management actions aimed at maintaining healthy fish stocks. Sea Grant has worked with NOAA's National Marine Fisheries Service to increases the survival of fish taken in catch-and-release marine fisheries. In addition, Sea Grant has

cooperated in involving fishermen with tagging their released fish to benefit fisheries science.[4]

Recreational Fishing - Health and Safety

The vast majority of recreationally caught seafood is wholesome and safe to eat. Nevertheless, as for all foods, there are some health risks associated with consumption of certain seafoods from certain locations, and there is the chance that mishandling of the catch can create a health risk. Sea Grant researchers have studied best practices to avoid and prevent seafood-borne illnesses from the recreational catch. Among the problems studied are those incurred from eating raw seafood and seafood affected by ciguatera, red tide, and chemical pollution.

One of the most controversial aspects of fish safety is the use of consumption advisories and the accuracy of their risk estimates. Advisories are intended to inform the public about high levels of toxic substances in fish while still allowing benefits from the fishery to accrue (such as recreation, tourism, and appropriate fish consumption). New York Sea Grant researchers studied the advisory mechanism and concluded that professionals must do a better job of informing anglers about the risks. A proper understanding of fish consumption advisories will increase anglers' concern for water quality, protect their health, and still encourage their enjoyment of the fishery.[5]

Recreational Fishing - Survey Methodology

Sea Grant supports efforts to improve methods for estimating recreational fishing catch and effort. Many believe current methods, both creel surveys and mail surveys, consistently underestimate actual fishing effort, with the magnitude of the bias estimated from 10 to 50 percent. Newly developed methods promise to reduce effort estimation bias.[6]

Recreational Boating

Recreational boating has increased tremendously in the last decade, but its impact has been understated. Sea Grant has undertaken to better identify the boating sector's economic contribution to the economy and to understand the income-generating activities carried out with its various components.

Boating and Marina Development

Continued boating growth 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. Florida Sea Grant economists investigated the economic benefits and costs of "bluebelting," a tax relief practice intended to curb the conversion of waterfront away from water-dependent businesses.[7]

Pollution Management

With boating growth has come the potential for an enormous increase in boating-associated pollutants. Pollution from recreational boats—boat sewage and engine pollution, antifouling paints, and plastic debris—can adversely affect coastal-zone water quality unless carefully managed. Sea Grant research has focused on many major pollution problems associated with recreational boat use.[8]

Recreation and Tourism Development

Coastal tourism growth depends on development approaches taken by coastal communities. 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 they also recognize benefits from new jobs, regional income gains, and community infrastructure improvements.

Recreation Growth and Resource Scarcity

Resource degradation will constrain the projected growth in marine recreation and coastal tourism. Sea Grant researchers are analyzing current recreational and tourism resource uses, such as beaches, to identify levels of use and quality at which tourists begin to substitute alternate recreation and vacation destinations.[9]

Tourism Development

Sea Grant researchers are focusing on helping coastal communities and small businesses efficiently plan for tourism development. For example, socio-economic studies of participants permit a better understanding of the recreation market and more accurate estimates of future demand. Economic valuation and impact analyses provide an estimate of benefits that can be expected from investments made to enhance recreation and tourism opportunities. This information has proved to be a valuable input in framing planning choices, ranging from consideration of whether to redevelop existing or construct new recreation facilities to selection of best financing mechanisms.[10]

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 Great Lakes marina operators workshops sponsored by the regional extension programs. Barrier island dynamics, nearshore sand transport, and shoreline protective structures research is transferred to local or state governments through the Sea Grant advisory program network along the Atlantic seaboard. Recreation safety information is distributed nationwide. It ranges from the prevention of hypothermia, avoiding recreationally caught contaminated fish and shellfish, to detailing how to swim out of a rip current. With NOAA's National Weather Service, Sea Grant prepared weather guides and issued information on severe weather precautions through the local media to coastal recreationists.

Future Directions

Recreation and tourism activities are important uses of Great Lakes and ocean resources. Sea Grant supports research and advisory service programs in this area because of this sector's importance to the national economy and to the economic base of coastal communities nationwide. Interdisciplinary approaches—involving economists, sociologists, psychologists, geographers, lawyers, engineers, natural scientists, diving and safety experts, and others—are encouraged.

Recreation and Tourism Economic Development

Research aimed at providing better planning and analytical tools for use by communities and small businesses considering investment in coastal recreation and tourism development is very important, given the need to make efficient use of limited fiscal resources.

Valuation of Marine and Coastal Resources

The economic and social benefits derived from coastal recreation and tourism are significant. Developing conceptual and empirical methods for valuing marine resources allocated to these purposes must remain in the forefront of this research.

Access to Coastal Recreation Opportunities

Coastal recreation opportunities depend upon the public having access to the shoreline and adjoining waters. Research addressing the technical, legal, or socioeconomic changes needed to broaden recreation opportunities and remove barriers is important. This might include, for example, boating access research that addresses small harbor design, marina management, and pollution control; urban recreation research that focuses on waterfront revitalization; sport angling enhancement looking at the design of fish aggregation devices, artificial reefs, catch-and-release programs; or the study of beach access and congestion as it affects the quality of beach recreation.

Resource Scarcity and User Conflicts

Recreation and tourism issues are often tied to areas such as fisheries or coastal zone management, water quality and pollution control, and transportation. For example, fish resources claims are voiced by competing user groups such as sports, subsistence, and commercial fishermen and environmental groups. Here, recreation research might be part of the broader resource use question. Another example is where conflicts arise from multiple-use of coastal resources such as with shoreline development or the leasing of water rights for aquaculture.

NOTES

[1] *Recreational Fishing Development*

Valdes-Pizzini, Manuel; Chaparro-Serrano, Ruperto; and Gutierrez-Sanchez, Jaime., *In Support of Marine Recreational Fishing: an Assessment of Access and Infrastructure in Puerto Rico and the U.S. Virgin Islands*, Puerto Rico Sea Grant, 72pp., 1991.

Dawson, Chad P. and Brown, Tommy L., "The Demand for Great Lakes Sportfishing: Some Future Marketing Implications" *1990 Outdoor Recreation Trends Symposium III*, March, 1990, New York Sea Grant.

[2] *Charter Fishing*

Golam, Mohammad. *Estimating Recreation Demand for Lake Erie Charterfishing*, Ohio Sea Grant, 147pp, 1990.

Dawson, Chad P. and Voiland, Michael P., *The Great Lakes Charter Fishing Industry in the 1990s*, Presented at the 1990 Outdoor Recreation Trends Symposium III, Indianapolis, Indiana, March 29-31, 25pp., 1990.

Dewees, Christopher M., Strange, Elizabeth M., and Guagnano, Greg, "Competing for the Recreational Dollar: an Analysis of the California Commercial Passenger-carrying Fishing Vessel Industry", *Marine Fisheries Review*, 52(1):1-6, 1990.

[3] *Recreational Fishing - Management*

Ditton, Robert B., Fedler, Anthony J., Christian, Richard T., "The Evolution of Recreational Fisheries Management in Texas", *Ocean and Coastal Management*, 17:169-181, 1992.

Perdue, Richard R. and Betz, Carter J., *Communication Networks in Marine Recreational Fishing*, North Carolina Sea Grant, 108pp, 1991.

[4] **Catch-and-Release**

Tiedemann, John; Lucy, Jon; and Donnelly, Maureen; *et al.*, *An Assessment of Tag-and-Release in the Northeast Region: Report on a Cooperative, Multi-state Sea Grant Project to Develop Educational Materials Promoting Greater Use of Best Available Techniques for Enhancing Catch-and-Release and Tag-and-Release Marine Recreational Fisheries*, Virginia Sea Grant, 75pp., 1990.

[5] **Recreational Fishing - Health and Safety**

Otwell, Steven and Lawlor, Frank, *Recreational Seafood Safety: a Guide for Marine Recreational Fishing*, Florida Sea Grant, 20pp., 1991.

Reinert, Robert E., Knuth, Barbara A., Kamrin, Michael A., and Stober, Quentin J., "Risk Assessment, Risk Management, and Fish Consumption Advisories in the United States", *Fisheries*, 16(6):5-12, 1991.

[6] *Recreational Fishing - Survey Methodology*

Wade, David L.; Jones, Cynthia M., Robson, Douglas S., and Pollock, Kenneth H., "Computer Simulation Techniques to Assess Bias in the Roving-Creel Survey Estimator", *American Fisheries Society Symposium*, 12:40-46, 1991.

Choi, Seungdam; Ditton, Robert B.; and Matlock, Gary C., "Homogeneity Across Mail Survey Waves: a Replicated Study", *Journal of Leisure Research*, 24(1):79-85, 1992.

[7] *Boating and Marina Development*

Bell, Frederick W., *Economic Impact of Bluebelting Incentives on the Marina Industry in Florida*, Florida Sea Grant, 131pp, 1990.

Schuett, Michael A. and Wicks, Bruce E., *The Impact of Recreational Boating in Illinois*, Illinois/Indiana Sea Grant Program, 43pp, 1991.

Lal, Padma Narsey and Clark, Athline M., *Personal Recreation Boating Industry in Hawaii: Physical Characteristics and Economic Contribution*, Hawaii Sea Grant, 39pp, 1991.

[8] *Recreational Boating - Pollution*

Milliken, Andrew S. and Lee, Virginia, *Pollution Impacts from Recreational Boating: a Bibliography and Summary Review*, University of Rhode Island Sea Grant, 1990.

[9] *Recreation Growth and Resource Scarcity*

Bell, Frederick W., *Actual and Potential Tourist Reaction to Adverse Changes in Recreational Coastal Beaches and Fisheries in Florida*, Florida Sea Grant, 86pp., 1992.

Bell, Frederick W. and Leeworthy, Vernon R., "Recreational Demand by Tourists for Saltwater Beach Days", *Journal of Environmental Economics and Management*, 18:189-205, 1990.

[10] ***Coastal Tourism Development***

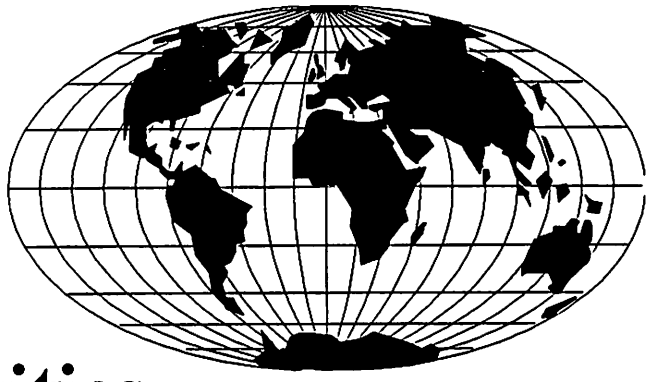
Roehl, Wesley S., Ditton, Robert B., Fesenmaier, Daniel R., "Community-Tourism Ties", *Annals of Tourism and Research*, 16:505-513, 1991.

Gable, Frank., "Caribbean Coastal and Marine Tourism: Coping with Climate Change and Its Associated Effects", *Proceedings of the 1990 Congress on Coastal and Marine Tourism*," Volume I, Marc L. Miller and Jan Auyong, (eds.), pp. 248-258, Hawaii, May, 1990.

Frederick, Lynn and Stadler, James., "Revitalization of a Small City Waterfront: a Focus on Finances", *Coastal Management*, 19:467-479, 1991.

Agardy, M. T., "Integrating Tourism in Multiple Use Planning for Coastal and Marine Protected Areas", *Proceedings of the 1990 Congress on Coastal and Marine Tourism*," Volume I, Marc L. Miller and Jan Auyong, (eds.), pp. 204-210, Hawaii, May, 1990.

Forman, David M., *Laws, Rules, and Policies Governing Ocean Recreation in Hawaii*, Hawaii Sea Grant, 22pp., 1990.



International Activities

Introduction

Sea Grant has a broad legislative charter to conduct international programs. For a half-dozen years up through the mid-1980s, Sea Grant received an annual appropriation to work with developing nations to strengthen their marine research and development capabilities and to promote the international exchange of marine information and data. Sea Grant conducted programs cooperatively with universities in Latin America, Asia and the Pacific Islands, and the Middle East dealing with the issues of scientific and technical development and human resource development.

While these efforts were successful, mounting budget pressures throughout the decade eventually brought an end to the formal international program. Despite this, Sea Grant has remained active in international marine science and extension efforts. Over the last five years, 20 of the 29 Sea Grant colleges report they maintain an international component.[1]

Sea Grant's authorization legislation explicitly allows Sea Grant to continue conducting cooperative international research and to carry out international technology transfer and educational activities. Furthermore, Congress specifically mandates that Sea Grant colleges serve as a resource for other federal agencies on international initiatives whose purposes are related to research, education, and technology transfer concerning ocean and coastal resources.

Current International Activities

While the commitment to international activities at Sea Grant institutions is active, direct Sea Grant funding has been very limited. In FY 1992, federal Sea Grant support amounted to $334 K, with the Sea Grant institutions contributing another $271 K. Pass through funds from other federal agencies amounted to $179 K.

A share of this supported researchers to study issues in international marine law and comparative marine resource management,[2] and to conduct or participate in international marine science symposiums.[3] Several other directed Sea Grant international activities are discussed below.

International Marine Science Cooperation Program - WHOI Sea Grant

At the Woods Hole Oceanographic Institution, Sea Grant carries out the International Marine Science Cooperation Program (IMSCP). At present, when science consistently can be done better and less expensively through international cooperation, the IMSCP serves as a "clearinghouse" for international marine science information. Its goal is to strengthen a global approach to ocean studies and to improve opportunities for collaborative international research in the marine sciences.

For example, WHOI Sea Grant has compiled a guide to potential funding sources for marine scientists. The guide covers private foundations, educational institutions, corporations, government

agencies, national, multinational, and international organizations.[4]

A significant obstacle to conducting oceanographic research is restricted access to foreign countries' coastal waters. With jurisdiction extended by the Law of the Sea Treaty to 200 miles off a nation's shores, opportunities for research have shrunk, mired in clearance requests and policy disputes. IMSCP carries out programs that promote solutions to the access problem, including providing accurate data on coastal nation jurisdiction and the outcome of foreign clearance requests by U.S. marine scientists since 1972, and maps of maritime boundary claims for the 145 coastal countries worldwide.[5]

Toxic algal blooms and red tides represent a global problem for fisheries, mariculture, and public health. When confronted with sudden red tide emergencies, developing countries in particular are in need of rapid, international assistance from experienced scientists and fisheries and public health managers. Therefore, the WHOI Sea Grant Program developed an "International Red Tide Information Directory" to disseminate red tide information worldwide. This activity has expanded and is now conducted by NOAA's National Marine Fisheries Service.[6]

Pacific Island Network

Sea Grant's research program focuses on the goal of marine resource development compatible with environmentally wise use. Sea Grant has long experience in education and extension outreach on marine issues, providing technical assistance through its systems of marine extension specialists and agents. Recently, NOAA and the Department of the Interior have drawn upon the knowledge of Hawaii Sea Grant to help develop the Pacific Island Network (PIN). The PIN uses on-island agents working with government representatives of different Pacific islands to address marine resource development and environmental issues.

In similar ways, the Sea Grant program also provides NOAA with mechanisms to address the environmental and coastal issues, as discussed in the Agenda 21 documents that came out of the United Nations Conference on the Environment held in Rio de Janeiro, June 1992.

American-Irish Aquaculture

Since 1986, Connecticut Sea Grant has played a leading role in establishing a collaboration among Sea Grant programs in the Northeastern states, Queen's University of Belfast in Northern Ireland, and University College Galway in the Republic of Ireland. These activities focus on applied aquaculture, directed primarily at the commercial growing of salmonids and a variety of shellfish. This effort can accelerate the application of mariculture technologies in the U.S. by introducing U.S. scientists to Irish aquaculture production systems which are quite successful. In return, the Irish universities gain from the U.S. expertise in genetics, quality control, and disease prevention. In November 1992, a joint workshop on applied aquaculture was held in Galway, Ireland.[7]

Future Directions

Sea Grant Legislation

Sea Grant's authorizing legislation provides for the conduct of an international program, although no funds are directly appropriated for this purpose. The current legislation (Sec. 205a) authorizes a broad sweep of international activities which, in general, are aimed at mutual gains to cooperating nations:

- Enhance cooperative international research and educational activities on ocean, coastal and Great Lakes resources;
- Promote shared marine activities with universities in countries with which the United States has sustained mutual interest in ocean, coastal, and Great Lakes resources;
- Encourage technology transfer that enhances wise use of ocean, coastal, and Great Lakes resources in other countries and in the United States;
- Promote information and data exchange between the United States and foreign nations with respect to the assessment, development, utilization, and conservation of such resources;
- Use the National Sea Grant Program as a resource in other federal civilian agency international initiatives whose purposes are

related to research, education, technology transfer and public service programs concerning the understanding and wise use of ocean, coastal, and Great Lakes resources; and

- Enhance regional collaboration between foreign nations and the United States with respect to marine scientific research, including activities which improve understanding of global oceanic and atmospheric processes, undersea minerals resources within the exclusive economic zone, and productivity and enhancement of living marine resources.

Revitalized International Program

At the 1991 Sea Grant Week meetings in Denver, 65 attendees met to discuss reviving the Sea Grant international program. The meeting showed support within the Sea Grant network for reviving the program and a task force was formed to push ahead. Why?

- The Sea Grant Act authorizes an international program more robust than Sea Grant's original program. We should capitalize on this.
- For its own vitality and health, Sea Grant must operate consistently with global realities—Earth-scale environmental change, transnational marine ecosystems, instantaneous communications, world markets, regional trading blocks, globalization of science, technology-driven multinational firms.
- While many Sea Grant scientists and extension specialists will do international work independently, the international activities level will continue to be diminished without a formal Sea Grant international program.

Future Goals

Some Sea Grant programs continue to include international components as part of their institutional programs, and this is encouraged. In fact, the Denver meeting affirmed the need for Sea Grant to undertake several pilot projects that take advantage of Sea Grant's broader authority for conducting international programs which might serve as the basis for developing a new international initiative within the National Sea Grant Program. Nearterm, it is likely that most of this funding must come from outside sources. However, the National Sea Grant Office's tactical plan development approach might offer opportunities for funding pilot projects. Longer term, the strategic planning approach offers the opportunity for restoring the Sea Grant international program.

The mission for a renewed international program would be to provide the Sea Grant network with the opportunity to pursue Sea Grant's mandate in a manner that recognizes the global domain of the environment, of science and technology, of communications, and of commerce. As such, international projects would encompass one or more of the following goals, listed without reference to order of priority:

- Promote international cooperative education related to the global environment and transnational marine ecosystems;
- Foster international cooperation in the marine sciences;
- Gain the benefits of technology transfer across national boundaries through programs which capitalize on each country's strengths in marine technology development;
- Strengthen the competitive position of U.S. marine industries in world markets;
- Provide scholarship on significant geopolitical marine policy issues and on comparative institutional arrangements for marine resources management;
- Improve the capability of developing nations to become full partners in the world community's stewardship of the marine environment; and
- Exploit global communications technology as a means to share marine scientific knowledge and enhance global environmental understanding among nations.

Notes

[1] International Projects at Sea Grant Institutions

Fenwick, Judith; Ross, David A., and Schramm, Cynthia T., *International Marine Science Research Projects: Second Inventory of International Projects at Sea Grant Institutions—1990*, Woods Hole Oceanographic Institution Sea Grant Program, 156pp., 1991.

[2] ***International Law and Resource Management***

Kuribayashi, Tadao and Miles, Edward L. (eds.), *The Law of the Sea in the 1990's: A Framework for Further International Cooperation: Proceedings of the Twenty-fourth Annual Conference of the Law of the Sea Institute, Tokyo, Japan, July 1990*, Hawaii Sea Grant College, 1992.

Soons, Alfred H.A. (ed.), *Implementation of the Law of the Sea Convention Through International Institutions: Proceedings of the 23rd Annual Conference of the Law of the Sea Institute*, Hawaii Sea Grant, June, 1989.

Hildreth, Richard G., "Managing Ocean Resources: New Zealand and Australia", *International Journal of Estuarine and Coastal Law*, 6(2):89-126, 1991.

Hildreth, Richard G., "Managing Ocean Resources: Canada", *International Journal of Estuarine and Coastal Law*, 6(3)199-228, 1991.

Hildreth, Richard G., "Managing Ocean Resources: United States", *International Journal of Estuarine and Coastal Law*, 6(4):313-363, 1991.

Friedheim, Robert and Tsuneo, Akaha., "Antarctic Resources and International Law: Japan, the United States, and the Future of Antarctica", *Ecology Law Quarterly*," 16(1):119-154, 1989.

Friedheim, Robert., "The Regime of the Arctic -- Distributional or Integrative Bargaining?", *Ocean Development and International Law*, 19:119-154, 1989.

Friedheim, Robert., "Fishing Negotiations at the Third United Nations Conference on the Law of the Sea", *Ocean Development and International Law*," 22:209-257, 1991.

Burke, William T., "Anadromous Species and the New International Law of the Sea", *Ocean Development and International Law*, 22:95-131, 1991.

McLaughlin, Richard., "Comparison of New Ocean Technologies in the United States and Japan", *Water Log*, 11(3), Mississippi-Alabama Sea Grant College, 1991.

[3] ***Sea Grant International Science Symposiums - A Sample***

Tosteson, T.R. (ed.) *Proceedings of the Third International Conference: Ciguatera Fish Poisoning*, Puerto Rico Sea Grant, 204pp., 1990.

Shomura, Richard S. and Godfrey, Mary Lynne (eds.), *Proceedings of the Second International Conference on Marine Debris*, 1265pp., Hawaii Sea Grant, 1991.

Second International Zebra Mussel Research Conference, New York Sea Grant, 52pp., 1991.

Keller, Sue and Sporleder, Lisa. (compilers), *Proceedings of the International Herring Symposium*, Alaska Sea Grant, 672pp., 1990.

Scheiber, Harry N., *Japan, the United States, and Pacific Ocean Resources: Proceedings of the Sho Sato Memorial Conference*, California Sea Grant, *Ecology Law Quarterly*, 16(1), 1989.

Proceedings of the International Symposium on King and Tanner Crabs, Alaska Sea Grant Program, 633pp., 1990.

Greer, Jack., "The Chesapeake Bay: A Model for Coastal Seas Management", in *Enclosed Seas of the World*, EMECS, Kobe, Japan, 1993.

[4] ***Funding Guide***

Fenwick, Judith; Ross, David A., and Schramm, Cynthia T., *International Marine Science Funding Guide*, Woods Hole Oceanographic Institution Sea Grant Program, 161pp., 1990.

[5] ***International Marine Science - Jurisdiction***

Fenwick, Judith., "Science Willing and Politics Permitting: Oceanographic Research in an International Setting", *Nor'Easter*, 3(1):22-27, Spring 1991.

Fenwick, Judith., *International Profiles on Marine Scientific Research: National Maritime Claims, MSR Justification, and U.S. Research Clearance Histories for the World's Coastal States*, Woods Hole Oceanographic Institution Sea Grant Program, 202pp., 1992.

Ross, David A. and Fenwick, Judith, *Maritime Claims and Marine Scientific Research Jurisdiction*, (Map), Woods Hole Oceanographic Institution Sea Grant Program, 1992.

[6] ***Toxic Algal Blooms: An International Directory***

White, Alan W., *Toxic Algal Blooms: An International Directory of Experts in Toxic and Harmful Algal Blooms and Their Effects on Fisheries and Public Health*, Woods Hole Oceanographic Institution Sea Grant Program, 216pp., 1990.

White, Alan W., "International Red Tide Information and Assistance Service (IRTIAS)", *Toxic Marine Phytoplankton*, Edna Graneli, et al., (eds.), pp. 509-511, 1990.

[7] ***American-Irish Aquaculture***

Van Patten, Margaret, "The American-Irish Aquaculture Venture: Hands Across the Water", *Nor'Easter*, 2(1):18-21, 1990.

Van Patten, Margaret, (ed.), *Irish/American Technical Exchange on the Aquaculture of Abalone, Sea Urchins, Lobsters, and Kelp: Proceedings of Workshop, Galway, Ireland 1992.* Connecticut Sea Grant College Program, (In Press).

Environmental Studies

Chapters

Environmental Studies

Growth of the coastal population and accompanying development have resulted in severe pressures on the coastal environment and ecosystems. If the nation is to continue its economic growth while maintaining and enhancing the quality of the coastal environment, it must understand how that environment functions. The National Sea Grant College Program's Environmental Studies Division supports research aimed at developing an understanding of coastal environmental processes, the impact man's activities have on these processes, and how these impacts can be reduced, eliminated, or reversed.

The division accomplishes its aims through studies of coastal processes and marine and coastal ecology and environmental quality. Coastal processes research focuses on problems in coastal sediment transport, inlets and estuaries, coastal oceanography, and coast and shore protection. Ecology and environmental quality programs focus on research in support of environmental management, exotic and nonindigenous species, global change impacts, habitat issues, natural pathogens and toxins, nutrient and carbon dynamics, and toxic compounds behavior and effects. Closely related to the research of the Environmental Studies Division are the outreach activities of the Sea Grant Marine Advisory Service. Water quality and coastal hazards and planning outreach specialists work closely with researchers to ensure that research findings get into the hands of those who need them. Table 1 gives a detailed summary of the division's program in FY 1992.

In FY 1992, 324 environmental projects were supported by Sea Grant with a total funding of $24,100,000 (Table 1). Of this number, 174 projects were supported by $7,300,000 of Sea Grant base funds and $6,900,000 of matching nonfederal funds. Another 150 projects were supported by $9,900,000 of federal funds other than Sea Grant base funds. Sea Grant environmental research funding has grown significantly over the last decade (Table 2). In that time, Sea Grant base support of environmental projects has grown from about 20 percent of Sea Grant research funds to about 30 percent of available research funds at present. This represents a greater emphasis on environmental research by Sea Grant colleges, who are responding to the priority issues of their state or region.

Of great importance to the growth of Sea Grant environmental research has been project support with other federal funds. Sea Grant's legislation not only permits but encourages Sea Grant to accept other federal funds to support marine research of importance to Sea Grant and the nation. Through the 1980s, these funds averaged about 15 percent of the division's total federal funding. However, starting in 1990 Sea Grant's participation in several new or expanded programs has resulted in a rapid increase in non-base federal funds to the point that, in 1992, they represent 57 percent of total federal funds expended (Figure 1, Table 3).

The major programs which supported environmental research through Sea Grant in FY 1992 were 1) The Sea Grant Zebra Mussel Program ($2,800,000), NOAA's Coastal Ocean Program ($3,200,000), and 3) The Chesapeake Bay NOAA/EPA Toxics Program ($925,000). Sea Grant manages or co-manages these programs, which are described more fully in the Ecology and Environmental Quality report. The balance of the non-base federal funds came to Sea Grant from other parts of NOAA or from other federal agencies to support individual Sea Grant environmental research projects of interest to those organizations.

Distribution of FY-92 Projects
Environmental Studies Division

CATEGORY	No. of Proj.	Funding ($000) Sea Grant	Match	Federal	Total
I. **COASTAL PROCESSES**					
1. Coastal Sediment Transport	17	576.7	429.1	156.9	1,162.7
2. Inlet and Estuaries	5	125.8	127.1	0.0	252.9
3. Coastal Oceanography	18	432.3	296.7	488.5	1,217.5
4. Coast and Shore Protection	15	361.3	329.9	62.5	753.5
5. Instrumentation	8	264.5	122.0	909.9	267.9
TOTALS	**63**	**1,706.6**	**1,304.6**	**1,617.8**	**3,654.5**
II. **ENVIRONMENTAL MANAGEMENT**					
1. Aquaculture	3	117.2	56.4	0.0	173.6
2. Coastal/Wetland Management	22	433.9	357.6	667.2	1,458.7
3. Environmental Quality Assessment	12	85.3	224.4	930.8	1,204.5
4. Waste Disposal	7	273.5	197.4	0.0	470.9
TOTALS	**44**	**909.9**	**835.8**	**1,598.0**	**3,343.7**
III. **EXOTIC AND NONINDIGENOUS SPECIES**	40	326.4	1,762.7	2,823.4	4,912.5
IV. **GLOBAL CHANGE**	12	362.9	270.5	648.1	1,281.5
V. **HABITAT STUDIES**					
1. Habitat Restoration	16	123.8	184.9	567.5	876.2
2. Habitat Utilization	5	138.2	67.2	70.2	275.6
3. Wetland Dynamics	17	433.3	183.6	462.0	1,078.9
TOTALS	**38**	**695.2**	**435.7**	**1,099.7**	**2,230.6**
VI. **HUMAN HEALTH**					
1. Pathogens	8	188.9	138.9	41.8	369.6
2. Toxic Plankton	12	302.0	226.8	50.0	578.8
TOTALS	**20**	**490.9**	**365.7**	**91.8**	**948.4**
VII. **NUTRIENT AND CARBON DYNAMICS**					
1. Eutrophication	22	357.1	307.7	1,143.6	1,808.4
2. Primary Dynamics	12	262.8	170.1	335.3	768.2
3. Trophic Dynamics	21	790.0	542.5	68.2	1,400.7
TOTALS	**55**	**1,409.9**	**1,020.3**	**1,547.1**	**3,977.3**
VIII. **TOXICS**					
1. Effects	11	339.0	231.0	108.7	678.7
2. Transport, Cycling, and Fate	41	1,026.5	705.2	1,026.9	2,758.6
TOTALS	**52**	**1,365.5**	**936.2**	**1,035.6**	**3,437.3**
GRAND TOTALS	**324**	**7,267.3**	**6,931.5**	**9,859.5**	**24,058.3**

Table 1

Environmental Research Funding Growth

Fiscal Year	No. of Projects	Funds ($000)				Funds/Project ($000)		
		Sea Grant	Match	Federal	Total	Federal	Match	Total
83	188	5,831.0	3,993.1	783.5	10,607.6	32.8	21.2	54.0
84	147	4,556.9	2,849.2	1,015.5	8,421.6	38.1	19.5	51.7
85	199	5,705.7	3,833.5	734.0	10,273.2	32.4	19.3	57.6
86	221	6,673.7	4,229.4	1,502.9	12,406.0	37.0	19.1	51.7
87	210	6,805.8	4,522.4	2,094.0	13,422.2	42.4	21.5	56.1
88	201	6,252.1	4,682.2	1,172.9	12,072.2	36.9	23.3	63.9
89	187	5,966.1	4,988.7	1,373.4	12,328.2	39.2	26.7	60.2
90	282	7,335.3	5,875.9	5,886.2	19,097.4	46.9	23.3	65.9
91	334	6,458.4	6,046.1	8,093.7	20,597.9	43.4	18.0	70.2
92	324	7,267.3	6,931.5	9,859.5	24,058.3	52.5	21.1	61.4

Table 2

Utilization of Other Federal Funds
Environmental Studies Division

Fiscal Year	No. of Projects Supported		Funds ($000)		
	Sea Grant	Other Federal	Sea Grant	Other Federal	Percent Other
83	180	8	5,831.0	783.5	11
84	133	14	4,556.9	1,015.5	18
85	180	19	5,705.7	734.0	11
86	240	17	6,673.7	1,502.9	18
87	178	32	6,805.8	2,094.0	24
88	182	19	6,252.1	1,172.9	16
89	-	-	5,966.1	1,373.4	19
90	209	73	7,335.3	5,886.2	45
91	227	107	6,458.4	8,093.7	56
92	178	150	7,267.3	9,859.5	57

Table 3

Coastal Processes

Introduction

The people of the United States are increasingly becoming a coastal population. Coastal counties, including those on the Great Lakes, have an average population density over four times greater than other counties in this country. With increasing population and the associated development, there are an escalating number of problems associated with managing coastal areas and adjacent waters. Exacerbating these problems is the fact that sea level is rising (due to global warming); and, there are indications that coastal storms are increasing in frequency and intensity. The only hope of coping with a suite of problems, which at times seems unreconcilable, is by clearly understanding the physical processes at work along the coast and in nearby waters. Current knowledge of coastal processes is more art than science. However, Sea Grant research is making important progress in developing better conceptual understanding of the processes and applying this knowledge to real problems

Coastal processes in Sea Grant is divided into five subprograms:

- Coastal sediment transport studies concern fundamental research on the measurement and prediction of processes controlling sediment movement and deposition in the coastal zone.
- Inlets and estuaries research concerns the hydrodynamic processes of circulation, wave generation and transformation, wave/current interaction, sedimentary processes of erosion and deposition, sand bypassing, sediment trapping, and channel stability.
- Coastal oceanography concerns research that studies, quantifies, interprets, and predicts physical processes affecting the coastal ocean.
- Coastal and shore protection consists of research and evaluation into methods for protecting coastal areas from natural hazards.
- Instrumentation and technology development includes research to develop instrumentation to measure waves, currents, and sediment movement and concentrations.

Total funds supporting coastal processes research in FY 1992 were $4,462,648 which includes: $1,645,926 federal, $1,233,036 matching, and $1,583,686 in pass through funds. Among the subprograms 26 percent of the funds are expended to study sediment transport, 6 percent on inlets and estuaries, 24 percent on coastal oceanography, 17 percent on coasts and shore protection, and 27 percent on instrumentation and technology development. In the complex interdisciplinary field of coastal processes, most of the 63 individual projects supported by Sea Grant usually do not fall clearly into any single subprogram.

Research currently being supported by Sea Grant in coastal processes is extremely diverse and spans a range from very applications oriented to quite theoretical. Findings from this research is making important improvements in the understand-

ing of coastal processes and in the ability to deal with real world problems. Some of these improvements include: predicting coastal wave conditions; determining the movement of sediment due to waves and currents; developing more effective ways to design coastal structures; predicting the evolution of wetlands in the face of rising sea level; anticipating the movement of oil slicks from oil spills; and finding unique, but efficient, ways to move sand across a tidal inlet.

Coastal Processes Subprograms

Coastal Sediment Transport

Coastal sediment transport studies concern fundamental research on the measurement and prediction of processes controlling sediment movement and deposition in the coastal zone. 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.

Inlets and Estuaries

Inlets and estuaries research concerns the hydrodynamic processes of circulation, wave generation and transformation, wave/current interaction, sedimentary processes of erosion and deposition, sand bypassing, sediment trapping, and 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.

Coastal Oceanography

Coastal oceanography concerns research that studies, quantifies, interprets, and predicts physical processes affecting the coastal ocean. This includes wave conditions and currents in shallow water or near the coast. The subprogram includes aspects of physical oceanography that influence the transport and dilution of pollutants and the transport of larvae. It also includes research related to the generation, propagation, and flooding associated with tsunamis.

Coastal and Shore Protection

Coastal and shore protection 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 important. However, alternate mitigation techniques are often as effective as structures and research in this area can often lead to either cost-effective engineering solutions or improved management strategies.

Instrumentation and Technology Development

Instrumentation and technology development includes research to develop instrumentation to measure waves, currents, and sediment movement and concentrations. It also includes technology development which might be used to navigate autonomous underwater vehicles or for remote sensing of sea and lake surface temperatures.

Current Sea Grant Research

The following paragraphs provide a summary of research currently being supported by Sea Grant within subheadings somewhat more focused than the subprograms.

Beaches

Sand beaches are the most common type of shoreline along the U.S. coast. Beaches are extremely valuable for recreational use, for protecting the hinterland, and for their natural beauty. With increasing development along the coast, it is more difficult to maintain beaches which fulfill their potential. This dilemma is partly due to a lack of knowledge of beach processes. In spite of superficial familiarity with this common landform, the interaction of waves with sand beaches is extremely complex. Florida Sea Grant has supported research to produce improved models of beach profile characteristics and to develop physically

more realistic models to predict both alongshore and onshore/offshore sand movement.

Puerto Rico tourism is dependent on the island's beach system. The beaches are also extensively used by the residents, as are adjacent shoreline areas, for urbanization. Unfortunately, there is a general erosion condition on much of the shoreline. However, the type of shore protection that might be effective for long, continuous stretches of sandy coastline common to much of the U.S., are not appropriate to the complex and compartmented Puerto Rico shoreline. Puerto Rico Sea Grant is defining the magnitude and characteristics of the island's coastal erosion. Some locations, which are typical of a recurring problem, will be studied in more detail to define the processes at work. The effect of rising sea level will also be evaluated.

Sand beaches represent a small part of Maine's coastline, but they are an important recreational and economic resource which may be approaching their natural limits of utilization. To better define these limits, Maine/New Hampshire Sea Grant researches are developing sediment budgets for Maine's sandy embayments. Preliminary findings show there is considerably less sand in the Saco Bay embayment, which includes one of Maine's largest beach systems, than earlier estimates indicated. It was also found that the Saco River is not a source of modern beach sand and that Saco Bay has no surplus or significant new sand sources. These findings are being used to develop policies for conserving the existing sand supplies.

One interesting aspect of beach dynamics is the transfer of wave energy that occurs in the surf zone. Wind waves incident on the beach typically have periods from two to 20 seconds, but these waves will generate wave motions in the surf zone which are five to 10 times longer. These long waves in the surf zone are called infragravity waves. This transfer of energy is related to wave breaking and interaction of incident waves and waves reflected from the beach. The process is complex and poorly understood, but it has an important influence on sediment transport, beach erosion, and ability of storm waves to overwash the shoreline or dunes to a greater extent than commonly expected. California Sea Grant is studying at three southern California beaches which will attempt to define the influence of infragravity waves on nearshore processes. California work is being complemented by a theoretical investigation of the generation of infragravity waves by Delaware Sea Grant researchers. The Delaware research long-range goal is to develop a numerical model which will give a full three- dimensional description of the waves and currents both inside and adjacent to a schematized surf zone. It will also include the generation and influence of infragravity waves.

An interesting feature of many beaches is the offshore bar formations. Generally, bar formations are dynamic in that both move around and also appear and disappear. Currently, there is little agreement regarding the formation and maintenance of bars. One theory is that bar locations and amplitudes result from standing waves formed by the incident waves and the waves reflected from the beach. Another theory has bars formed by breaking waves entraining sediment and inducing a cross-shore current which causes sediment to deposit near the break point. Surprisingly, Lake Michigan bar formations appear to be almost permanent features. Michigan Sea Grant researchers are studying the Lake Michigan bar formations and trying to develop a clear cause and effect relationship between the forcing wave conditions and the effect, as shown by the location and size of the bars. The influence of sediment size will be included in the analysis too, if possible.

Wetlands

Coastal wetlands are metaphorically caught between a rock and a hard place. The rock, in this case, is rising sea level which in a pristine world would cause a wetland to migrate inland. However, in the real world there is usually a hard place which might be an expensive housing development, a shopping center, or interstate highway. This is an unfortunate situation since coastal wetlands are important environmentally, aesthetically, and biologically. Research supported by Connecticut Sea Grant is trying to determine the expected influence of sea level rise on the coastal marshes along Long Island Sound. The strategy for doing

this is to carefully study the geological record in core samples from existing marshes to determine how they responded to previous rises in sea level.

Geological studies supported by Delaware Sea Grant show a consistent trend for Delaware wetlands to migrate landward with sea level rise over the last several thousand years. During this migration, the wetlands width was also decreasing so that total wetland area has been considerably reduced. The research indicates that if the sea level rise rate increases, then the loss of wetlands rate will also increase. These findings appear to be applicable to a considerable portion of the U.S. coastal wetlands beyond Delaware. Today there is clear evidence that Delaware's saltwater marshes are being rapidly destroyed, primarily by shoreline erosion. Research is continuing that will determine the characteristics of the landward edge of the transgressing marsh system and the factors which influence the transgression rate. In addition, predictive models will be developed that can be used to determine the future extent of Delaware's tidal wetlands under projected scenarios of sea level rise over the next century.

Inlets and Estuaries

Delaware Sea Grant has used extensive field observations, including drifters and current meters, to help develop and calibrate Lagrangian models of circulation patterns in Delaware's inland bays. These models can enhance understanding about the transport and distribution of waterborne material in shallow coastal lagoons where the currents exhibit significant temporal and spatial variability. From a local standpoint, the study will provide vital information regarding the long-term transport of sewage discharge, nutrients, and larvae in Delaware's Inland Bays.

New England has many shallow estuaries that lie behind barrier beaches. Locally these coastal lagoons are called salt ponds, although the salinity varies widely from pond to pond and over time from almost fresh water to almost open ocean salinities. In the past, the salt ponds were very productive ecosystems. Unfortunately, with increasing residential and commercial development within the pond's watershed, water quality in some ponds has deteriorated. With the support Sea Grant programs in Rhode Island and Woods Hole Oceanographic Institution (WHOI), volunteers, known as pond watchers, have been organized and trained to collect pond water quality data. A wide range of people has become pond watchers, from high school students to retired engineers, and they have proved to be reliable and skilled data collectors. Certain types of data, such as simultaneous pond measurements, could not have been acquired without volunteers because such labor intensive sampling is costly. Coastal communities are using the data collected by pond watchers to manage the ponds, and to arrest and hopefully reverse water quality and habitat deterioration. The Environmental Protection Agency is using the pond watcher concept as a model for water quality monitors in other areas.

One conspicuous feature of most inlets is the presence of strong currents caused by ebb and flood of the tides. Interestingly, the tidal currents have considerable influence over the characteristics of the waves at an inlet. There are very complex interactions between waves and currents at inlets, making it extremely difficult to predict sediment movement. Unfortunately, these locations are the keys to any successful coastal management plan involving dredging, beach nourishment, or a sediment bypassing system. Delaware Sea Grant has supported extensive research to find solutions to the problems associated with tidal inlets. This research has lead to an extremely efficient sand bypass system at Indian River Inlet on the Delaware coast. In addition, one Delaware Sea Grant investigator won the prestigious American Society of Civil Engineer's Huber Research Prize for progress in understanding wave and current interactions at tidal inlets.

Numerical models are increasingly used to estimate complex pollutants movement in coastal and estuarine waters. Rhode Island Sea Grant researchers are developing a three-dimensional circulation model which will be used to improve the understanding of circulation and flushing dynamics of the Providence River and upper Narragansett Bay. The model will be used to assess the impact of various combined sewer overflow remediation measures on water quality. At MIT Sea Grant, researchers are developing two- and three-dimen-

sional models which will be hybrids of grid-based and particle tracking models. It is hoped that these hybrid models will combine the best features of both model types for simulating the movement of pollutants or larvae in coastal waters.

Coastal Wave Conditions

Waves propagating from deep water into shallow water are influenced by many physical processes, which modify their form and change their size. If the bathymetry is simple, and the waves do not approach the shoreline obliquely, there are three important processes which influence the propagation of waves into shallow water, they are: wave shoaling, breaking, and bottom friction. Shoaling causes the wave heights to increase as they propagate into shallow water until they become unstable, break, and reform at a lower height. During the breaking process waves dissipate much of their energy. Bottom friction also dissipates wave energy and reduces the wave size in shallow water. However, it has only been with recent research at MIT Sea Grant that the influence of bottom friction has been shown to be important and clearly quantified.

Understanding and predicting wave conditions in shallow water is an important but very difficult task for much of the U.S. coastline. A good example of this problem is the Southern California Bight where the wave climate is spatially quite complex due to partial sheltering effects of offshore islands and banks and the nearshore influence of submarine canyons. California Sea Grant with the California Department of Boating and Waterways has supported extensive wave data collection off southern California's coast to help develop and calibrate a numerical wave prediction model. The model will be used to enhance boater safety and to explain beach erosion.

Although the Gulf of Maine is a long way from the Southern California Bight, they have some common problems. It is difficult to predict wave conditions near the Gulf of Maine coast because of the complex bathymetry, irregular shoreline, and the presence of many islands. The complex bathymetry has a strong influence on wave refraction and shoaling, the islands and peninsulas cause wave diffraction to be important, and bottom friction must be accounted for in shallow water. Even wave reflection has to be considered because of the steep rocky islands and coastlines. Maine/New Hampshire Sea Grant researchers have made impressive progress in developing numerical models which can make accurate wave condition estimates along the Gulf of Maine coast for given wave conditions in deep water.

Along some areas of the U.S. coast, the severity of the waves makes their measurement quite difficult. Wave conditions off the Oregon coast have consistently damaged pressure transducer wave gauges, particularly in winter, so that it is difficult to document the wave climate of this area. A novel method to avoid this problem is to use a microseismometer that measures ground movement. This device can be located in a safe place some distance from the coast. Surprisingly, the interaction of incident and reflected waves from the coast causes ground movement which can be measured by a microseismometer, which if calibrated, can act as a wave gauge. Oregon Sea Grant researchers are using a microseismometer at the Hatfield Marine Science Center, about a mile and a half from the coast, to estimate wave conditions in about 40 feet of water near the end of the Yaquina Jetties. Although there are many problems in analyzing and interpreting the data from the seismometer, it appears that it will be possible to make accurate calculations of the wave climate for severe winter wave conditions.

Waves and Structures

Coastal structures sometimes fail under wave loads and damage to structures is quite common. Scale models can be tested in wave tanks, but testing is expensive, time consuming, and still offers no guarantee that a structure will not fail in the field. With the increasing power of computers, it is becoming more practical to develop numerical models which simulate the interaction of waves and structures. This type of research is being supported by New York and Delaware Sea Grant. Currently, the geometry of the structures in the numerical models must be simple so that application of these numerical models is still limited. However, this is a research area that is evolving fast, and more realistic models are expected soon.

Oregon Sea Grant researchers are investigating the interaction of waves with rubble mound coastal structures. This effort involves both physical model tests and numerical modeling. Because rubble structures are both rough and porous, it is extremely difficult to model numerically their interaction with waves. This problem has been reduced by an extensive series of physical model tests which helps to guide and complement the numerical modeling effort. Both large- and small-scale physical model tests have been conducted; the large-scale tests used the largest wave tank in the United States. This tank can generate waves with heights over 1.5 meters The study will result in a suite of numerical models which can be used to improve the design of rubble mound structures exposed to wave attack.

Nearshore Oceanography

Part of the plan to clean up Boston Harbor requires the building a new sewage treatment plant and a new outfall located in 32 meters of water on the bottom of Massachusetts Bay. There is considerable concern about the mixing characteristics of the 4.5 billion liters of liquid effluent and treated sewage which will be discharged daily into the bay. From late spring to mid-fall, there is a strong thermocline in the bay which inhibits vertical mixing, and it is expected that it will prevent nutrients in the effluent from reaching the euphotic zone. WHOI Sea Grant researchers are conducting very sensitive experiments to determine vertical mixing rates across the thermocline. The results will help environmental managers and engineers assess the impact of future sewage effluent in Massachusetts Bay.

At MIT Sea Grant, researchers are utilizing water column and sediment sampling for selected hydrographic variables and radionuclide concentrations. These data will be used to define the temporal and spatial scales over which a suite of particle reactive surrogates are deposited and retained in Massachusetts Bay nearshore sediments. This information is critical to understanding sedimentary deposition and transport processes that affect retention and/or transport of particle reactive contaminants reaching the nearshore sediments of Massachusetts Bay.

Continuing to be of serious concern to New York Sea Grant researchers are Mirex, PCB's, and other hydrophobic organic contaminants because of their persistence at high levels in the biota and aquatic Lake Ontario food chain. This persistence is surprising because of decreases in production and direct inputs of contaminants to the lake from the Niagara River. In fact, Mirex is no longer manufactured or used. Many contaminants tend to deposit with sediment quickly to the lake bed after entering the lake from the Niagara River. This process removes contaminants from the water column, but possibly only temporarily. New York Sea Grant researchers are investigating to see if resuspension of sediments by storms is an important mechanism for returning contaminants to the water column and back into the food chain.

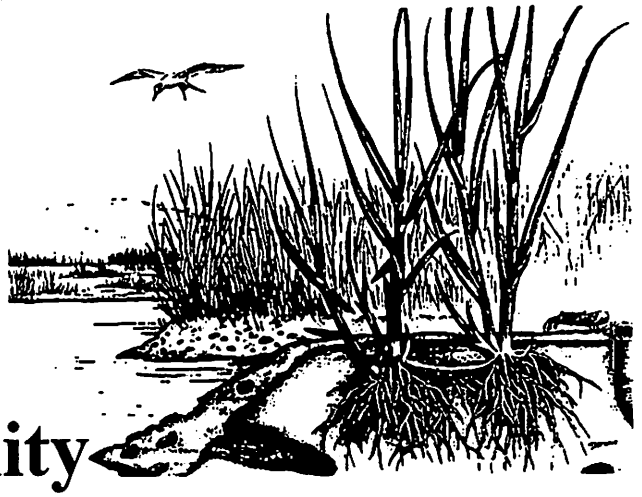
Hazards

Great Lakes water levels are subject to changes of approximately 1.5 meters over irregular periods of five to 10 years. During periods of high water, erosion and flooding become a serious problem for much of the coastline. When water levels are low the perceived erosion problem goes away, and people can enjoy a wide beach or sell their beach property. Unfortunately, it appears that during low water some parts of the coastline are being undermined, technically called lakebed downcutting, so that erosion during high water is exacerbated. Low water levels cause downcutting of certain types of submerged clay layers which are relatively sheltered from the erosional effects of waves and currents by overlying water during periods of high water. Downcutting allows larger waves to reach the shoreline during each succeeding period of high water, causing a trend of increasing shoreline erosion. Downcutting also causes damage to shore protection structures because it causes difficulties in maintaining the toe of the revetments or the base of seawalls and bulkheads. Wisconsin Sea Grant is conducting an extensive survey of the Lake Michigan shoreline to determine more clearly the extent and mechanisms of downcutting.

Recent oil tanker spills in confined shipping lanes have shown the particular susceptibility of the coastal environment to oil spills. Although oil slicks are transported mainly by surface currents, these

currents are constrained to flow parallel to the shore and cannot move an oil slick onto a beach. However, waves are directed by refraction toward fringing beaches and wetlands. Mass transport in wind waves is concentrated near the surface and provides a mechanism for the transport of the slick toward the shore. A preliminary analysis of this problem by California Sea Grant researchers indicates that wave-driven transport is of comparable magnitude to tidal currents or wind drift as a transport mechanism for oil slicks. Surprisingly, the influence of the wave driven surface transport has been ignored in existing oil slick transport models. Research is continuing to establish theoretical predictions of the Eulerian surface current, to generalize these predictions for irregular sea states, and to demonstrate the potential of surface wave drift to transport oil slicks in coastal regions.

Large earthquakes along offshore fault zones are significant hazards to California coastal cities. Unfortunately, it is more difficult to investigate submerged portions of fault systems than the on land components. California Sea Grant researchers are using multifrequency side-looking sonar to map deformation along the San Gregorio fault in Monterey Bay. The San Gregorio is part of the San Andreas fault system and is thought to connect to the Hosgri fault system which poses a seismic risk to the Diablo Canyon Nuclear Power Plant. The study also included a submersible dive to obtain visual observations, video images, and sea floor samples to complement the sonar maps. Further investigation of the fault using a remotely operated, submersible vehicle is a possibility. This research hopes to define more clearly the seismic risk posed by the San Gregrio-Hosgri fault system to coastal California.



Ecology and Environmental Quality

Introduction

In fiscal year 1992, the National Sea Grant College Program supported 261 projects in ecology and environmental quality. The Sea Grant base program appropriation provided support for 132 of these projects in the areas of nutrient and carbon dynamics, toxic pollutants, habitat studies, human health, global change, exotic species, and environmental management. The research was supported with $5,561,000 in Sea Grant funds and $5,627,000 in matching funds from the Sea Grant institutions. Funds from other federal appropriations supported another 129 projects at a cost of $8,241,000. Three major programs accounted for $6,925,000 of these funds. These were:

NOAA Coastal Ocean Program

Sea Grant has been an active participant in the NOAA Coastal Ocean Program since its inception. Sea Grant National Office and academic scientists were closely involved in the development of the program and participate in its management. The two major program areas of Environmental Studies Division involvement are the Estuarine Habitat Program (EHP) and the Nutrient Enhanced Coastal Ocean Productivity (NECOP) Program.

Estuarine Habitat Program

The EHP is focused on two of our most critical coastal habitats, seagrasses and wetlands. The program is cooperatively managed by Sea Grant and NOAA's National Marine Fisheries Service. The EHP has two main components. The first is a research component that is aimed at understanding the structure and functions of these habitats, their contributions to the productivity of our fisheries, and the development of methods for effective restoration and creation of seagrass beds and coastal wetlands. A second component consists of applying remote sensing technology to quantify changes in the aerial extent of wetlands and seagrass beds over three to five year intervals. Both photographic and satellite technology are utilized in this study.

Nutrient Enhanced Coastal Ocean Productivity

The NECOP program has as its goal the understanding of the relationship between nutrient inputs, physical forcing functions, and hypoxia and anoxia on the Louisiana shelf. The program is jointly managed by Sea Grant and OAR's Environmental Research Laboratories. The program, now in its fourth year, has three major components:

- Annual field studies are measuring the variables and rates that control production and hypoxia development.
- Studies of cores are attempting to detect hypoxic events in the sediment record in order to provide understanding of the frequency and duration of hypoxic in the recent past.
- A major modeling effort is developing a water quality mass balance model.

Chesapeake Bay Toxics Research Program

The goals of the Chesapeake Bay Toxics Research Program are:

- to develop a better understanding of how ecosystem processes and trophic dynamics in Chesapeake Bay influence the transport, fate, and effects of toxic substances;
- to understand the effects that toxic substances have upon ecological processes; and
- to determine responses of Chesapeake Bay organisms at the organismal population, and community levels to exposure to toxic substances.

The program is funded by NOAA and the Environmental Protection Agency and is managed jointly by Sea Grant, NOAA's Chesapeake Bay Office, and the EPA. The program is an outgrowth of an earlier five-year research program on the effects of low dissolved oxygen on the Chesapeake Bay ecosystem, and for the past three years, the focus has been on the effects of toxics. The initial program focus was on transport and fate of toxic substances, and the current emphasis is on ecosystem and population effects.

Sea Grant Zebra Mussel Program

The zebra mussel is a European mollusc which has caused considerable economic and environmental damage to the Great lakes region. It is now spreading to other regions. The Sea Grant zebra mussel program (described in detail in a separate section) is focused on research to understand the mussel's ecology, developing control methodology, and providing public outreach and education.

Following Sections

In the sections that follow, current program activities and recent research findings for two areas of emphasis, Toxic Organic Compounds and Wetland Habitats, are discussed in detail.

Toxic Organic Compounds

Current Program

Sea Grant FY 1992 research on the transport, cycling, fate, and effects of toxic metals and organic compounds consisted of 52 projects totaling $3,410,000 of which $2,480,000 was from federal sources with the balance being provided as matching nonfederal funds.

The Chesapeake Bay toxics program is a major component of current Sea Grant toxics research with 12 projects in FY 1992. Primary emphasis is on understanding how toxic compounds can alter the energy flows and productivity of the bay ecosystem. The Great Lakes is another focus of Sea Grant toxics research. Because the Lakes are closed bodies of fresh water with long residence times and serve as sources of drinking water, understanding the ecological impact and public health consequences of toxic organic compounds is a priority concern. Sea Grant researchers are studying the behavior and fate of these compounds in the Lakes and their effects on key species.

Another important area of research is the determination of the role that colloids play in the cycling and fate of toxics in the aquatic environment. Researchers are studying the association of toxic organics and metals with colloids in both marine and fresh water environments to understand the effects of colloids on pollutant transport and biological availability.

Selected Research Findings

There is a continued need for the rapid, accurate analysis of pollutants in field situations. MIT investigators have developed a portable, battery powered mass spectrometer capable of measuring volatile organic pollutants. The spectrometer, mounted on a back frame, weighs about 70 pounds and can be transported by a single individual. The development of this instrument greatly increases the ability of scientists to conduct effective field measurements for the presence of pollutants. (Hemond, 1991)

Accurate analysis of toxic organic pollutants continues to be a challenge to environmental chemists. Coplaner PCBs have been particularly

difficult to quantify because of their very low levels, yet they are considered to be among the most toxic of the PCBs. New York investigators have now developed an analytical method that permits the determination of these PCB residues in fish at parts-per-trillion levels (Hong and Bush, 1990, Hong et. al. 1992).

Fish kills due to pesticides have been a recurring problem. South Carolina scientists have developed an improved method for the analysis of organochlorine, organophosphate, and pyrethroid insecticides from river and seawater. The method uses bonded-phase silica to preconcentrate the pesticide, thus eliminating the need to haul organic solvents to the field site (Hinckley and Bidleman, 1989).

The banning of PCBs has led to their replacement in such products as carbonless copy paper. Wisconsin scientists have developed the analytical methodology to determine these replacement compounds in river waters (Peterman and Delfino, 1990). The environmental effects of these compounds is not adequately known, but some evidence suggests a moderate toxicity.

Understanding the physico-chemical properties and chemical behavior of classes of chemicals in the environment is critical if satisfactory methods to predict pollutant behavior in the environment are to be developed. Wisconsin investigators have been extremely active in this research area. They have determined the solubility of organic compounds in solvent water mixtures (Dickhut et.al., 1989, 1991), and determined the method by which hydroxyl radical can oxidize and thus degrade PCBs (Sedlak and Andren, 1991a, 1991b).

While it has been long recognized that PCBs can be transported through the atmosphere as well as in water, quantifying this transport and understanding the fluxes of PCBs to and from water bodies via the atmosphere is a continuing research effort. Wisconsin investigators have evaluated techniques for making the difficult measurement of PCB transport from the Great Lakes to the atmosphere and from the atmosphere to the lake surface (Murray and Andren, 1991, 1992a). Data from precipitation samples in the region suggest that not only are PCBs present in the dissolved and particulate phases but that a colloidal phase may also be significant in controlling PCB behavior in precipitation (Murray and Anders, 1992b). Measurements in a remote site in the Great lakes watershed showed that there was no apparent reduction in atmospheric PCBs in the last seven years, though the average residence time is estimated to be a few months (Manchester-Neesvig and Andren, 1989). This suggests that PCBs undergo repeated cycling between earth and atmosphere before final removal. Minnesota investigators have also have seen no reduction in atmospheric PCBs over Lake Superior the last 10 years (Baker and Eisenreich, 1990) Their work shows that the amount of PCBs being deposited on the surface of Lake Superior is similar to the quantity being volatilized to the atmosphere from the lake surface.

The interaction of toxic organic compounds with particulate and colloidal fractions of coastal and Great lakes waters and sediments is an important area of research. These interactions control both the ultimate fate and bioavailability of these compounds in the environment. Colloids in particular have recently been recognized as a major factor in controlling the partitioning of toxic organics in the aquatic environment. MIT researchers have developed methods to measure the abundance, distribution, and configuration of colloids in sediments. They found depletion of colloids near the sediment water interface and accumulation of macromolecules at depth. (Chin and Gschwend, 1991). Minnesota investigators have determined that, for highly insoluble toxic organics, less than 10 percent is present in pore water as dissolved material and the rest is associated with colloids. The fraction associated with colloidal material dominated the diffusional fluxes from sediments (Capel and Eisenreich, 1989, 1990). Michigan scientists have developed a thermodynamic model for the sorption of nonpolar organic compounds by organic colloids (Chin et.al., 1991). Such models are essential to understanding and interpreting laboratory and field studies.

The importance of sorption behavior and kinetics by toxics onto natural particles has been studied by a number of investigators. Laboratory experimental studies are used to understand sorption and to develop and evaluate predictive models. Published studies include an evaluation of

flow cytometry as a tool to rapidly detect, count, and size large numbers of particles (Newman et. al, 1990a, Newman et.al.1990b), studies of the particle concentration effect on PCB sorption (Van Hoof and Andren, 1991), investigation of the effects of organic polymers on contaminant sorption by natural particles (Chin and Weber, 1989, Chin et.al., 1990), and a study of the sorption of alkybenzenes to mineral oxides (Peringer et.al., 1990).

Distributions of toxic compounds in the environment are needed to both understand processes and make appropriate management decisions. Wisconsin scientists have determined the PCB concentrations in the tributaries to Lake Michigan. Over half the PCBs were associated with particles (Marti and Armstrong, 1990). Minnesota researchers have studied the internal cycling of particles and associated toxic organics in the water column of Lake Superior (Baker and Eisenreich, 1989). The investigators found the benthic nepheloid layer appeared to have a major role in the overall transport and cycling of toxic organics in the Lake.

The interaction between sunlight and polyaromatic hydrocarbons (PAH) have been investigated by Michigan and Illinois researchers. Daphnia exposed to anthracene in the presence of ultraviolet radiation had significantly greater mortality and lower fecundity than daphnia exposed to anthracene in the dark (Holst and Giesy, 1989). Elutriates of PAH contaminated sediments were found to be toxic to daphnia when sunlight was present, but not in the absence of light. (Davenport and Spacie, 1991). These reports recommend that phototoxicity tests be incorporated into determination of sediment quality criteria.

A similar study by a South Carolina researcher showed that sediment contaminated with the pyrethroid pesticide fenvalerate had no effect on mortality but caused 50-100 percent reduction in egg production and 40-100 percent reduction in mean clutch size of the benthic harpacticoid copepods *Microarthridion littorale* and *Paronychocamptus wilsoni*. This suggests that the sediment-bound residues of fenalerate can significantly impact population growth of these species (Chandler, 1990).

The rates and effects of transport of toxic organics up the food chain has consequences for not only the animals affected but also for human health. Organic compounds are usually biomagnified as they pass up the food chain, thus concentrations in predators can reach very high levels. Michigan scientists have determined the biomagnification of PCBs, DDT residues, and toxaphene in the epibenthic mysid *Mysis relicta* and the benthic amphipod *Pontaporia hoyi*. They determined that, based on estimates of biomass and toxicant concentrations, offshore amphipods contain about 15 times as much toxaphene, 12 times as much PCB, and 9.5 times as much DDT residues as mysids. Thus amphipods may represent a far larger reservoir or contaminant storage, recycling, and transmission (Evans et.al., 1991).

Phytoplankton bioconcentrate but do not biomagnify organic contaminants because uptake is passive, not active. Previous work has shown a bioconcentration factor normalized for lipid content was reasonably well predicted by the octanol-water partition coefficient (Kow) for many organisms. Work by Minnesota researchers, however, has shown that Kow is not an adequate predictor of phytoplankton uptake of PCBs. While the accumulation is correlated with Kow and the bioaccumulation appears to be a partitioning process between water and algal lipids, the time to equilibrium is long and is strongly influenced by growth rates, and the bioaccumulation exceeds that predicted by Kow by one to two orders of magnitude. These findings have resulted in major revisions of the phytoplankton portions of models focused on predicting the flow of toxics through the food chain such as the Green Bay Mass Balance Study model. (Swackhammer and Skogland, 1991).

Woods Hole investigators measured the distribution of PCB congeners in the mussel *Mytilus edulus* transplanted to several stations in Buzzards Bay which is contaminated with PCBs from New Bedford Harbor. The major factors controlling the distribution of PCBs in mussels appear to be the PCB concentration in ambient waters and seasonal variations in mussel lipid content related to spawning activity (Capuzzo et.al, 1989).

Wisconsin investigators have developed an

individual based model approach to predicting the dieldrin and PCB concentrations in lake trout. The model, which follows individual members of the population over time, can be used to predict toxicant concentrations within a cohort or, by applying the model over several cohorts, predict toxicant concentration with age. The model is most sensitive to the toxics concentration in the trout's prey (Madenjian et.al., 1993a, 1993b).

Advisories on fish consumption have been based on the total PCB content of fish. However individual congeners can vary in toxicity by six orders of magnitude. Since the analysis of individual congeners is both difficult and expensive, Michigan investigators have applied a toxicity equivalence model to predicting dioxin equivalents from total PCB levels. There was a good correlation between dioxin equivalents predicted from total PCB concentrations and those measured directly (Williams et.al., 1992).

A long-standing problem in the Great lakes has been the failure of stocked lake trout to reproduce. Failure of introduced stock to reproduce has been ascribed to pollution, loss of suitable spawning habitat, and failure to imprint, among various causes. Now Wisconsin investigators have demonstrated that toxic organics can have a major impact on reproduction of both lake trout and rainbow trout. In an elegant series of papers, the investigators have shown the dioxins, PCBs, and dibenzofurans, in the parts per trillion range, can cause manifest toxicity by sac fry mortality associated with yolk sac edema and hemorrhages. The researchers conclude that, though environmental levels of these compounds do not produce overt lethality in adult fish, their combined presence in feral fish eggs may pose an increased risk to early life stage survival and ultimately, to feral fish populations (Cook et.al, 1991, Walker and Peterson, 1991, Walker et.al., 1991, Walker and Peterson, 1992, Walker et.al., 1992).

The effect of PCBs on birds was the subject of a study by Wisconsin scientists. They found that the reproduction of Forster's tern, a fish-eating colonial bird, has been significantly impaired in Green Bay, which is contaminated with PCBs, when compared to a relatively uncontaminated site inland. Hatching success of eggs collected at Green bay was 50-100 percent lower than those from the control site. Green Bay hatchlings weighed 20 percent less and had liver to total body weight ratios 26 percent greater. the investigators concluded the PCBs were the only contaminants at high enough concentrations in the eggs to produce the observed effects (Kubiak et.al., 1989).

Great Lakes Sea Grant investigators have also studied the levels and impact of toxics in the Great Lakes human population. In 1989, Michigan scientist conducted a follow-on survey to one in 1982 for serum DDT and PCBs in both fish eaters and non-fish eaters. Fish eaters continued to have significantly high DDT and PCB levels than non-fish eaters. No change in PCB levels occurred between 1982 and 1989 in either population. DDT levels, however, declined by about one-third. This indicates that the banning of DDT has resulted in reduced DDT contamination of human populations (Hovinga et.al., 1992).

PCBs have been implicated in human reproductive problems. Wisconsin investigators tested over 1,000 pregnant women for PCB serum level, determined their fish consumption patterns, and evaluated their babies for a variety of factors. Serum PCBs were correlated with fish consumption. After correction for such known negative factors as caffeine, cigarettes, and alcohol, no negative effects of PCBs were found. This result was consistent with a Danish study but not with two studies in Michigan and New York. Analysis of all studies indicates that those of Michigan and New York involved women with much higher PCB levels than the Wisconsin study. For example, only 4 percent of the women in the Wisconsin study consumed as much fish as the average of the Michigan group (Dar et.al., 1992).

Wetland Habitat Research

Current Program

In FY 1992, Sea Grant funded 61 projects on wetlands research and management totalling $3,732,934; of that amount, $2,825,481 were from federal sources and the remainder was provided as nonfederal matching funds. About half the federal support was in the form of pass through grants, funded mainly by the NOAA Coastal Ocean Program Estuarine Habitat Program.

Research efforts in this area focus on assessing the importance of wetlands in supporting living marine resources and in affecting estuarine nutrient cycling and water quality. The issue of wetlands loss and restoration is critical to sustaining responsible coastal development, and Sea Grant researchers are involved in developing techniques for creating and restoring wetlands and assessing the success of those efforts.

Selected Research Findings

The presence of wetlands has a significant influence on animal communities in coastal ecosystems. Seagrass beds increase faunal abundance by encouraging larval settlement due to reduced hydrodynamic effects within the beds and by providing protection to potential prey species (Olmi et al., 1990; Prescott, 1990; Wilson, 1990; Pohle et al., 1991; Bauer and Vega, 1992; Orth, 1992). Within salt marshes, the presence of adult mussels provides additional protection to juvenile mussels subject to crab predation (Lin, 1990). The same structural attributes of salt marshes that protect animals from predation also make it difficult for researchers to sample in those environments; a flume weir was developed to overcome those problems, and it was able to successfully collect a large variety of nekton (swimming) species (Kneib, 1991). Distribution and population dynamics of blue crab populations have been studied in Atlantic and Gulf Coast salt marshes (Ryer et al., 1990; Van Montfrans et al., 1991; Fitz and Wiegert, 1992; Hsueh et al., 1992). Marine and freshwater marshes support abundant insect populations, valuable to aquatic consumers although occasionally a nuisance to humans, and the presence and type of vegetation helps to determine their distribution (McLaughlin and Harris, 1990; Magnon et al., 1990). Saltmarsh tidal creeks and impoundments have been investigated to determine their role in supporting fish populations and in exporting energy from the salt marshes (McGovern and Wenner, 1990; Rountree and Able, 1992).

Wetland restoration activities have focused on developing techniques for restoration and on evaluating the success of the created wetlands. Various techniques for comparing natural to constructed wetlands have been evaluated (e.g. Langis et al., 1991). Researchers have developed techniques for encouraging the growth of various wetland and dune plant species, including baldcypress (Conner and Toliver, 1990), sea oats (Sylvia and Jarstfer, 1991; Seliskar, 1992), saltmarsh cordgrass (Wilsey et al., 1992), and coastal dropseed (Blits and Gallagher, 1991; Straub et al., 1992) so that they can be used to create functioning coastal ecosystems. Mitigation banking programs, involving creating wetlands to offset losses resulting from coastal development, have been implemented with varying degrees of success in several states (Howorth, 1991). A comprehensive manual was developed to guide coastal managers in assessing the success of wetland restoration projects by determining how well the man-made wetlands duplicate the functions of natural ecosystems (Pacific Estuarine Research Laboratory, 1990). Sea Grant has also published non-technical handbooks to introduce the public and local officials to the concept of using coastal plants for landscaping, ecosystem restoration, and erosion control (Barnett and Crewz, 1990; Seliskar, 1991; Van Patten and Crawford, 1992; Broome et al., 1992). Despite the progress that has been made, constructed wetlands still cannot replace the habitat and functional value of natural wetlands, and continued research on restoration techniques is necessary (Zedler, 1991).

Sea Grant researchers have investigated factors controlling primary production in several wetland systems. Louisiana researchers compared five methods of estimating saltmarsh cordgrass production and concluded that for Gulf coast marshes, it was particularly critical to use methods correcting for mortality losses between sampling

periods (Kaswadji et al., 1990). Other Sea Grant investigators found that establishing nutrient limitation for wetland plants is not straightforward and criteria based on the relationship between nutrient concentration and growth response can be misleading (Chambers and Fourqurean, 1991). The presence of sufficient aboveground biomass was critical for saltmarsh cordgrass to survive through the winter in a mid-Atlantic marsh (Wijte and Gallagher, 1991). California researchers found that the maximum depth for seagrasses may not be a function of the mean light environment, but may instead be controlled by intermittent periods of extreme light attenuation (Zimmerman et al., 1991). On a larger scale, saltmarsh plant community structure in a South Carolina estuary was examined relative to changes in salinity that occurred as a result of a reduction in freshwater discharge; the prediction was made that plant diversity in the transition zone from salt to brackish marsh would decrease over time as less salt-tolerant species died out (Bradley et al., 1990).

Wetlands are important sources of the organic production that forms the base of food webs in coastal ecosystems. A comparison of the stable isotope ratios of saltmarsh fauna with those of the available primary producers showed that for Gulf coast marshes, the primary source of organic matter appeared to be benthic microalgae and phytoplankton, not saltmarsh cordgrass (Sullivan and Moncreiff, 1990). That finding emphasizes both the general importance of benthic microalgae in coastal foodwebs and the degree of regional variability that exists in saltmarsh ecosystems, since earlier studies had found that cordgrass was the dominant source of organic matter in a Massachusetts marsh, and that cordgrass and microalgal sources appeared to be equivalent in importance in a Georgia marsh. Subsequent research showed that benthic microalgae were also significant primary producers in a Mississippi seagrass bed, suggesting that the microalgae may also be important in the seagrass trophic web (Daehnick et al., 1992). Much of the organic matter produced in wetlands eventually enters the food web as particulate detritus formed from plant fragments and is consumed by invertebrates and small fish. Sea Grant investigators have now shown that amorphous detritus, aggregates formed by precipitation of dissolved organic matter leached from wetland plants, is potentially a higher-quality food source for marsh consumer species (D'Avanzo et al., 1991); other researchers have followed the initial stages of decomposition in seagrasses, concentrating on the utilization of leached dissolved organic matter (Blum and Mills, 1991). The degree that salt marshes export organic production to estuaries and coastal ecosystems varies; in the Delaware River Estuary, export of organic matter from salt marshes does not appear to be significant (Cifuentes, 1991).

Wetlands play an important role in nutrient cycling in estuaries. Research on several salt marshes showed that the exchange of nutrients between the sediments and the water column appears to be driven mainly by biological processes such as bioturbation, or by resuspension of marsh surface sediments, not by simple chemical diffusion (Chambers and Odum, 1990; Childers and Day, 1990; Chambers 1992; Chambers et al., 1992). Studies of saltmarsh sediments have demonstrated significant short- and long-term changes in sediment chemistry, and used the long-term variation to develop a pollution history (Luther et al., 1991; Varekamp, 1991). Nutrient cycling was followed in a floating freshwater marsh, a habitat where there is a mat of vegetation floating over a layer of free water (Sasser et al., 1991), and in a tidal freshwater bayou (Stren et al., 1991), both in Louisiana. A case study of a Lake Erie coastal wetland, carried out at the Old Woman Creek Estuarine Research Reserve, suggested that those wetlands may be retaining as much as 5 percent of the nonpoint source phosphorus loading that otherwise would enter the lake (Mitsch et al., 1989); the authors pointed out that restoration of wetlands could significantly reduce the remaining nonpoint source loadings. Other investigators have constructed freshwater wetlands in order to determine the effect of varying the timing of wastewater discharge on their usefulness in removing nutrients and metals from wastewater (Busnardo et al., 1992; Sinicrope et al., 1992).

Sea Grant researchers have been evaluating the effects of various management actions on coastal wetland systems. Tidal marshes in Delaware and other mid-Atlantic states have been

invaded by the undesirable reed *Phragmites*. Delaware researchers have determined that coastal managers may be able to control these invasions by controlling water levels and salinity in these marshes (Hellings and Gallagher, 1992). Reduction in the amount of wetlands is a serious problem in Louisiana. A Sea Grant researcher there has examined the contribution of canal and levee construction to the problem and has developed management alternatives to begin recovering some of the wetlands that have been lost (Turner, 1990). A major difficulty in deciding whether to go forward with proposed management actions is the lack of consensus on how to value wetlands. Sea Grant investigators have compiled a bibliography of literature related to placing a value on Great Lakes coastal wetlands (Reeder and Mitsch, 1990).

Publications

Sea Grant Abstracts, a quarterly publication of the National Sea Grant College Program, lists all publications submitted to the Sea Grant Depository. In the sections that follow, selected lists of 1990-1992 Sea Grant publications related to the subject areas discussed above in detail are presented. In addition, two lists of 1990-1992 Sea Grant publications are included, covering the topics of Causes and Effects of Harmful Algal Blooms and Biodiversity, areas of environmental research that have been the subject of much Sea Grant research.

Toxic Organic Compounds

Baker, J. E. and S. J. Eisenreich. 1989. PCBs and PAHs as tracers of particulate dynamics in large lakes. J. Great Lakes Res., 15:84-103.

Baker, J. E. and S. J. Eisenreich. 1990. Concentrations and fluxes of polyaromatic hydrocarbons and polychlorinated biphenyls across the air-water interface of Lake Superior. Envir. Sci. Tech., 24:342-352.

Chandler, G. T., 1990. Effects of sediment-bound residues of the pyrethroid insecticide fenvalerate on the survival and reproduction of meiobenthic copepods. Mar. Envir. Res., 29:1-12.

Capel, P. D. and S. J. Eisenreich. 1989. Sorption of organochlorines by lake sediment porewater colloids, in *Aquatic Humic Substances: Influence on Fate and Treatment of Pollutants*, I. H. Suffet and P. MacCarthy, Eds., American Chemical Society, Washington, DC, pp. 185-207.

Capel, P. D. and S. J. Eisenreich. 1990. Relationship between chlorinated hydrocarbons and organic carbon in sediment and porewater. J. Great Lakes Res., 16:245-257.

Capuzzo, J. M., J. W. Farrington, P. Rantamahi, C. H. Clifford, B. A. Lancaster, D. F. Leavitt, and X. Jia. 1989. The relationship between lipid composition and seasonal differences in the distribution of PCBs in *Mytilus edulis* L.. Mar. Environ. Res., 28:259-264.

Chin, Y-P. and W. J. Weber Jr. 1989. Estimating the effects of dispersed organic polymers on the sorption of contaminants by natural solids. 1. A predictive thermodynamic humic substance-organic solute interaction model. Envir. Sci. Tech., 23:978-984.

Chin, Y-P., W. W. Weber Jr., and B. J. Eadie. 1990. Estimating the effects of dispersed organic polymers on the sorption of contaminants by natural solids. 2. Sorption in the presence of humic and other natural macromolecules. Envir. Sci. Tech., 24:837-842.

Chin, Y-P. and P. M. Gschwend. 1991. The abundance, distribution, and configuration of porewater organic colloids in recent sediments. Geochem. Cosmochem. Acta, 55:1309-1317.

Chin, Y-P, W. J. Weber Jr., C. T. Chiou. 1991. A thermodynamic partition model for binding of nonpolar organic compounds by organic colloids and implications for their sorption to soils and sediments, in *Organic Substances and Sediments in Water: Volume 1 Humics and Soils*, Lewis Publishers, Chelsa, MI, pp. 251-273.

Cook, P. M., D. W. Kuehl, M. K. Walker, and R. E. Peterson. 1991. Bioaccumulation and toxicity of TCDD and related compounds in aquatic ecosystems, in *Banbury Report 35: Biological Basis for Risk Assessment of Dioxins and Related Compounds*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, pp. 143-167.

Dar, E., M. S. Kanarek, H. A. Anderson, and W. C. Sonzogni. 1992. Fish consumption and

reproductive outcomes in Green Bay, Wisconsin. Eviron. Res., 59:189-201.

Davenport, R. and A. Spacie. 1991. Acute phototoxicity of harbor and tributary sediments from lower Lake Michigan. J. Great Lakes Res., 17:51-56.

Dickhut, R. M., A. W. Andren and D. E. Armstrong. 1989. Naphthalene solubility in selected organic solvent/water mixtures. J. Chem. Eng. Data, 34:438-443.

Dickhut, R. M., D. E. Armstrong, and A. W. Andren. 1991. The solubility of hydrophobic aromatic chemicals in organic solvent/water mixtures: evaluation of four mixed solvent solubility estimation methods. Envir. Toxicol. Chem., 10:881-889.

Evans, M. E., G. E. Noguchi, and C. P. Rice. 1991. The biomagnification of polychlorinated biphenyls, toxaphene, and DDT compounds in a Lake Michigan offshore food web. Arch. Environ. Contam., 20:87-93.

Hemmond, H. F. 1991. A backpack portable mass spectrometer for measurement of volatile compounds in the environment. MIT Sea Grant Tech. Rept. MITSG91-4, 14 pp.

Hinckley, D. A. and T. F. Bidleman. 1989. Analysis of pesticides in seawater after enrichment onto C8 bonded-phase cartridges. Envir. Sci. Tech. Vol23, pp. 1995-1999.

Holst, L. L. and J. P. Giesy. 1989. Chronic effects of the photoenhanced toxicity of anthracene on *Daphnia magna* reproduction. Environ. Toxicol. Chem., 8:933-942.

Hong, C-S. and B. Bush. 1990. Determination of mono- and non-ortho coplaner PCBs in fish. Chemosphere, 21:173-181.

Hong, C-S., B. Bush and J. Xiao. 1992. Coplaner PCBs in fish and mussels from marine and estuarine waters of New York State. Ecotox. Envir. Safety, 23:118-131.

Hovinga, M. E., M. Sowers, and H. E. B. Humphrey. 1992. Historical changes in serum PCB and DDT levels in an environmentally-exposed cohort. Arch. Environ. Contam. Toxicol., 22:362-366.

Kubick, T. J., H. J. Harris, L. M. Smith, T. R. Schwartz, D. L. Stalling, J. A. Trick, L. Selio, D. E. Doecherty, and T. C. Erdmore. 1989. Microcontaminants and reproductive impairment of the Forster's tern in Green Bay, Lake Michigan-1983. Arch. Environ. Contam. Toxicol., 18:706-727.

Madenjian, C. P., S. R. Carpenter, and G. E. Noguchi. 1993a. Individual based model for dieldrin contamination in lake trout. Arch. Environ. Contam. Toxicol., 24:78-82.

Madenjian, C. P., S. R. Carpenter, G. W. Eck, and M. A. Miller. 1993b. Accumulation of PCBs by lake trout (*Salvenlinus namaycush*): An individual based model approach. Can. J. Fish. Aquat. Sci., 50:97-109.

Manchester-Neesvig, J. B. and A. W. Andren. 1989. Seasonal variation in the atmospheric concentration of polychlorinated biphenyl congeners. Envir. Sci. Tech., 23:1138-1148.

Murray, M. W. and A. W. Andren. 1991. Preliminary investigation of the potential of gas purging for investigating the air-water transfer of PCBs, in *Organic Substances in Sediments and Water: Volume 2, Processes and Analytical,* Chapter 1, pp. 3-13, CRC Press, Boca Raton, Fl.

Murray, M. W. and A. W. Andren. 1992a. Evaluation of a precipitation collector for PCB analysis. Atmos. Environ. 26A:1097-1101.

Murray, M. W. and A. W. Andren. 1992b. Precipitation scavenging of polychlorinated biphenyl congeners in the Great Lakes region. Atmos. Environ. 26A:883-897.

Newman, K. A., F. M. M. Morel, and K. D. Stolzenbach. 1990a. Settling and coagulation characteristics of fluorescent particles determined by flow cytometry and fluorometry. Envir. Sci. Tech., 24:506-512.

Newman, K. A., S. L. Frankel, and K. D. Stolzenbach. 1990b. Flow cytometric detection and sizing of fluorescent particles deposited at a sewage outfall site. Envir. Sci. Tech., 24:513-519.

Pelinger, J. A., S. J. Eisenreich, P. D. Capel, P. W. Carr, and J. H. Park. 1990. Adsorption of a homologous series of alkylbenzenes to mineral oxides at low organic carbon content using headspace analysis. Wat. Sci. Tech., 22:7-14.

Peterman, P. H. and J. J. Delfino. 1990. Identification of isopropylbiphenyl, alkyl diphenylamines, diisopropylnapthalene, linear alkyl benzenes, and

other polychorinated biphenyl replacement compounds in effluents, sediments, and fish of the Fox River. Biomed. Environ. Mass Spec., 19:770-775.

Sedlack, D. L. and A. W. Andren. 1991a. Oxidation of chlorobenzene with Fenton's reagent. Envir. Sci. Tech., 25:777-782.

Sedlak, D. L. and A. W. Andren. 1991b. Aqueous phase oxidation of polychlorinated biphenyls by hydroxyl radicals. Envir. Sci. Tech., 28:1419-1427.

Shiu, W. Y., W. Doucette, F. A. P. C. Gobas, A. Andren, and D. Mackay. 1988. Physical-chemical properties of chlorinated dibenzo-p-dioxins. Envir. Sci. Tech., 22:651-658.

Swackhammer, D. L. and R. S. Skogland. 1991. The role of phytoplankton in the partitioning of hydrophobic organic contaminants in water. In *Organic substances and Sediments in Water*, R. A Baker, ed. ACS Symposia Series, Lewis publishers, Ann Arbor, MI.

Van Hoof, P. L. and A. W. Andren. 1991. Partitioning and sorption kinetics of a PCB in aqueous suspensions of model particles: Solids concentration effect, in *Organic Substances in Sediments and Water: Volume 2, Processes and Analytical*, CRC Press, Boca Raton, FL, pp. 149-167.

Walker, M. K. and R. E. Peterson. 1991. Potencies of polychlorinated dibenzo-p-dioxin, dibenzofuran, and biphenyl congeners relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin for producing early life stage mortality in rainbow trout *(Oncorhynchus mykiss)*. Aquatic Toxicol., 21:219-238.

Walker, M. K., J. M. Spitzbergan, J. R. Olson, and R. E. Peterson. 1991. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity during early life stage development of lake trout (*Salvenlinus nmaaycush*). Can. J. Fish. Aquat. Sci., 48:875-883.

Walker, M. K. and R. E. Peterson. 1992. Toxicity of polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls during early development in fish, in *Chemically-Induced Alterations in Sexual and Functional Development: The Human/ Wildlife Connection*, Princeton Scientific Publishing Co., Princeton, NJ, pp. 195-202.

Walker, M. K., L. C. Hufnagle, Jr., M. K. Clayton, and R. E. Peterson. 1992. An egg injection method for assessing early life stage mortality of polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in rainbow trout *(Oncorhynchus mykiss)*. Aquat. Toxicol., 22:15-18.

Williams, L. L., J. P. Giesy, N. DeGalan, D. A. Verbrugge, D. E. Tillitt, and G. T. Ankly. 1992. Prediction of concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents from total concentrations of polychlorinated biphenyls in fish. Envir. Sci. Tech., 26:1151-1159.

Wetland Habitat

Bauer, R.T. and L.W.R. Vega. 1992. Pattern of reproduction and recruitment in two sicyoniid shrimp species (Decapoda: Penaeoidea) from a tropical seagrass habitat. J. Exp. Biol. Ecol., 161:223-240.

Blits, K. C. and J.L. Gallagher. 1991. Morphological and physiological responses to increased salinity in marsh and dune ecotypes of *Sporobolus virginicus* (L.) Kunth. Oecologia, 87:330-335.

Blum, L.K. and A.L. Mills. 1991. Microbial growth and activity during the initial stages of seagrass decomposition. Mar. Ecol. Prog. Ser., 70:73-82.

Bradley, P.M., Kjerfve, B. and J.T. Morris. 1990. Rediversion salinity change in the Cooper River, South Carolina: ecological implications. Estuaries, 13(4):373-379.

Broome, S.W., Rogers, S.M. Jr. and E.D. Seneca. 1992. Shoreline erosion control using marsh vegetation and low-cost structures. UNC Sea Grant Publ. SG-92-12. 18 pp.

Busnardo, M.J., Gersberg, R.M., Langis, R., Sinicrope, T.L. and J.B. Zedler. 1992. Nitrogen and phosphorus removal by wetland mesocosms subjected to different hydroperiods. Ecol. Engin., 1:287-307.

Chambers, R.M. and J.W. Fourqurean. 1991. Alternative criteria for assessing nutrient limitation of a wetland macrophyte (*Peltandra virginica* (L.) Kunth). Aquatic Botany, 40:305-320.

Chambers, R.M., Harvey, J.W. and W.E. Odum. 1992. Ammonium and phosphate dynamics in a

Virginia salt marsh. Estuaries, 15(3):349-359.
Chambers, R. M. and W.E. Odum. 1990. Porewater oxidation, dissolved phosphate and the iron curtain. Iron-phosphorus relations in tidal freshwater marshes. Biogeochemistry, 10:37-52.
Chambers, R.M. 1992. A fluctuating water-level chamber for biogeochemical experiments in tidal marshes. Estuaries, 15(1):53-58.
Childers, D.L. and J.W. Day, Jr. 1990. Marsh-water column interactions in two Louisiana estuaries. II. Nutrient dynamics. Estuaries, 13(4):404-417.
Cifuentes, L.A. 1991. Spatial and temporal variations in terrestrially-derived organic matter from sediments of the Delaware Estuary. Estuaries, 14(4):414-429.
Conner, W.H. and J.R. Toliver. 1990. Observations on the regeneration of baldcypress (*Taxodium distichum* [L.] Rich.) in Louisiana swamps. South. J. Appl. Forestry, 14(3):115-118.
Deahnick, A.E., Sullivan, J.J. and C.A. Moncreiff. 1992. Primary production of the sand microflora in seagrass beds of Mississippi Sound. Bot. Mar., 35:131-139.
D'Avanzo, C.D., Alber, M. and I. Valiela. 1991. Nitrogen assimilation from amorphous detritus by two coastal consumers. Est. Coast. Shelf Sci., 33:203-209.
Day, R.H., Holz, R.K. and J.W. Day, Jr. 1990. An inventory of wetland impoundments in the coastal zone of Louisiana, USA: historical trends. Environ. Management, 14(2):229-240.
Fitz, H.C. and R.G. Wiegert. 1992. Local population dynamics of estuarine blue crabs: abundance, recruitment and loss. Mar. Ecol. Prog. Ser., 87:23-40.
Hellings, S.E. and J.L. Gallagher. 1992. The effects of salinity and flooding on *Phragmites australis*. J. Appl. Ecol. 29:41-49.
Howorth, L.S. 1991. Highway construction and wetland loss: mitigation banking programs in the southeastern United States. Environ. Profession., 13:139-144.
Hsueh, P.-W., McClintock, J.B. and T.S. Hopkins. 1992. Factors affecting the population dynamics of the lesser blue crab (*Callinectes similis* Williams) in barrier island salt marsh habitats of the Gulf of Mexico. J. Alabama Acad. Sci., 63(1):1-9.
Kaswadji, R.F., Gosselink, J.G. and R.E. Turner. 1990. Estimation of primary production using five different methods in a *Spartina alterniflora* salt marsh. Wetlands Ecol. Management, 1(2):57-64.
Kneib, R.T. 1991. Flume weir for quantitative collection of nekton from vegetated intertidal habitats. Mar. Ecol. Prog. Ser., 75:29-38.
Koch, M.S., Mendelssohn, I. A. and K.L. McKee. 1990. Mechanism for the hydrogen sulfide-induced growth limitation in wetland macrophytes. Limnol. Oceanogr., 35(2):399-408.
Langis, R., Zalejko, M.and J.B. Zedler. 1991. Nitrogen assessments in a constructed and a natural salt marsh of San Diego Bay. Ecological Applications, 1(1):40-51.
Lin, J. 1990. Mud crab predation on ribbed mussels in salt marshes. Mar. Biol., 107:103-109.
Lin, J. 1991. Predator-prey interactions between blue crabs and ribbed mussels living in clumps. Est. Coast. Shelf Sci., 32:61-69.
Luther, G.W. III, Ferdelman, T.G., Kostka, J.E., Tsamakis, E.J. and T.M. Church. 1991. Temporal and spatial variability of reduced sulfur species (FeS_2, S_2O_3) and porewater parameters in salt marsh sediments. Biogeochemistry, 14:57-88.
Magnon, G.J., Hagan, D.V., Kline, D.L. and J.R. Linley. 1990. Habitat characteristics and phenology of larval *Culicoides* (Diptera: Ceratopogonidae) from a coastal Georgia salt marsh. Environ. Entomol., 19(4):1068-1074.
McGovern, J.C. and C.A. Wenner. 1990. Seasonal recruitment of larval and juvenile fishes into impounded and non-impounded marshes. Wetlands, 10(2):203-221.
McLaughlin, D.B. and H.J. Harris. 1990. Aquatic insect emergence in two Great Lakes marshes. Wetlands Ecol. Management, 1(2):111-121.
Mitsch, W.J., Reeder, B.C. and D.M. Klarer. 1989. The role of wetlands in the control of nutrients with a case study of western Lake Erie. Ecological Engineering: An Introduction to Ecotechnology, Mitsch, W.J. and S.E. Jorgensen (eds.), pp. 129-158.
Olmi, E..J. and R.N. Lipcius. 1991. Predation on postlarvae of the blue crab *Callinectes sapidus*

Rathbun by sand shrimp *Crangon septemspinosa* Say and grass shrimp *Palaemonetes pugio* Holthuis. J. Mar. Biol. Ecol., 151:169-183.

Olmi. E.J. III, van Montfrans, J. and R.N. Lipcius. 1990. Variation in planktonic availability and settlement of blue crab megalopae in the York River, Virginia. Bull. of Mar. Sci., 46(1):230-243.

Orth, R.J. 1992. A perspective on plant-animal interactions in seagrasses: Physical and biological determinants influencing plant and animal abundance. Plant-Animal Interactions in the Marine Benthos, John, D.M., Hawkins, S.J. and J.H. Price (eds.), pp. 147-164.

Orth, R.J. and J. van Montfrans. 1990. Utilization of marsh and seagrass habitats by early states of *Callinectes sapidus*: a latitudinal perspective. Bull. of Mar. Sci., 46(1):126-144.

Pacific Estuarine Research Laboratory. 1990. A manual for assessing restored and natural coastal wetlands, with examples from southern California. California Sea Grant Report No. T-CSGCP-021. La Jolla, CA. 105 pp.

Prescott, R.C. 1990. Sources of predatory mortality in the bay scallop *Argopecten irradians* (Lamarck): interactions with seagrass and epibiotic coverage. J. Exp. Mar. Biol. Ecol., 144:63-83.

Pohle, D.G., Bricelj, V.M. and Z. Garcia-Esquivel. 1991. The eelgrass canopy: an above-bottom refuge from benthic predators for juvenile bay scallops *Argopecten irradians*. Mar. Ecol. Prog. Ser., 74:47-59.

Reeder, B. and W.J. Mitsch. 1990. What is a Great Lakes coastal wetland worth? A bibliography. Ohio Sea Grant College Program Technical Series No. OHSU-TS-007. 18 pp.

Rountree, R.A. and K.W. Able. 1992. Fauna of polyhaline subtidal marsh creeks in southern New Jersey: composition, abundance and biomass. Estuaries, 16(2):171-185.

Ryer, C.H., van Montfrans, J. and R.J. Orth. 1990. Utilization of a seagrass meadow and tidal marsh creek by blue crabs *Callinectes sapidus*. II. Spatial and temporal patterns of molting. Bull. Mar. Sci., 46(1):95-104.

Sasser, C.E., Gosselink, J.G. and G.P. Shaffer. 1991. Distribution of nitrogen and phosphorus in a Louisiana freshwater floating marsh. Aquat. Botany, 41:317-331.

Seliskar, D.M. 1991. Coastal landscaping in Delaware with common marsh and dune plants. Delaware Sea Grant Publ. DELU-G-91-002. 6 pp.

Seliskar, D.M. 1992. Response of *Ammophila breviligulata* to acid rain and low soil pH. Water Air Soil Poll., 63:295-303.

Sinicrope, T.L., Langis, R., Gersberg, R.M., Busnardo, M.J. and J.B. Zedler. 1992. Metal removal by wetland mesocosms subjected to different hydroperiods. Ecol. Eng., 1:309-322.

Stern, M.K., Day, J.W., Jr. and K.G. Teague. 1991. Nutrient transport in a riverine-influenced, tidal freshwater bayou in Louisiana. Estuaries, 14(4):382-394.

Straub, P.F., Decker, D.M. and J.L. Gallagher. 1992. Characterization of tissue culture initiation and plant regeneration in *Sporobolus virginicus* (Gramineae). Am. J. Botany, 79(10):1119-1125.

Sullivan, M.J. and C.A. Moncreiff. 1990. Edaphic algae are an important component of salt marsh food-webs: evidence from multiple stable isotope analyses. Mar. Ecol. Prog. Ser., 62:149-159.

Sylvia D. M. and A.G. Jarstfer. 1991. Strategy for inoculating nursery-grown sea oats with vesicular-arbuscular mycorrhizal fungi. The Rhizosphere and Plant Growth, Keister, D.L. and P. B. Cregan (eds.), p. 378.

Thayer, G.W. (editor). 1992. Restoring the Nation's marine environment. NOAA Symposium on Habitat Restoration, Washington, D.C., September 25-26, 1990.

Turner, R.E. 1990. Managing wetlands in coastal Louisiana for plants, waterfowl, fish and other animals. Bull. Ecol., 21(3):21-24.

van Montfrans, J., Ryer, C.H. and R.J. Orth. 1991. Population dynamics of blue crabs *Callinectes sapidus* Rathbun in a lower Chesapeake Bay tidal marsh creek. J. Exp. Mar. Biol. Ecol., 153:1-14.

Van Patten, P. and H. Crawford. 1992. Restoring Connecticut's coastal resources: a handbook for municipal officials. Workshop summary, Groton, Connecticut, September 1988. Connecticut Sea Grant Publ. CONN-W-88-003. 39 pp.

Varekamp, J.C. 1991. Trace element geochemistry

and pollution history of mudflat and marsh sediments from the Connecticut coastline. J. Coast. Res., Special Issue #11, 105-123.

Wijte, A.H.B.M. and J.L. Gallagher. 1991. The importance of dead and young live shoots of *Spartina alterniflora* Poaceae) in a mid-latitude salt marsh for overwintering and recoverability of underground reserves. Bot. Gazette, 152(4):509-513.

Wilsey, B.J., McKee, K.L. and I.A. Mendelssohn. 1992. Effects of increased elevation and macro- and micronutrient additions on *Spartina alterniflora* transplant success in salt-marsh dieback areas in Louisiana. Environ. Management, 16(4):505-511.

Wilson, F.S. 1990. Temporal and spatial patterns of settlement: a field study of molluscs in Bogue Sound, North Carolina. J. Exp. Mar. Biol. Ecol., 139:201-220.

Zedler, J.B. 1991. The challenge of protecting endangered species habitat along the southern California coast. Coast. Management, 19:35-53.

Zimmerman, R.C., Reguzzoni, J.L., Wyllie-Echeverria, S., Josselyn, M. and R.S. Alberte. 1991. Assessment of environmental suitability for growth of *Zostera marina* L. (eelgrass) in San Francisco Bay. Aquat. Bot., 39:353-366.

Causes and Effects of Harmful Algal Blooms

Anderson D.M. 1990. Toxin variability in *Alexandrium* species. in "Toxic Marine Phytoplankton," E. Graneli, et al. (eds.), pp. 41-51.

Anderson D. M., Kulis D. M. and J.J. Sullivan. 1990. Dynamics and physiology of saxitoxin production by the dinoflagellates *Alexandrium* spp. Mar. Biol., 104:511-524.

Anderson D. M., Kulis D. M. and J.J. Sullivan. 1990. Toxin composition variations in one isolate of the dinoflagellate *Alexandrium fundyense*. Toxicon, 28(8):885-893.

Beitler M.K. 1991. Toxicity of adductor muscles from the purple hinge rock scallop (*Crassadoma gigantea*) along the Pacific coast of North America. Toxicon, 29(7):889-894.

Bricelj V. M., Lee J. H., Cembella A. D. and D.M. Anderson. 1990. Uptake of *Alexandrium fundyense* by *Mytilus edulis* and *Mercenaria mercenaria* under controlled conditions. in "Toxic Marine Phytoplankton", E. Graneli, et al. (eds.), pp. 269-274.

Bricelj V. M., Lee J. H. and A.D. Cembella. 1991. Influence of dinoflagellate cell toxicity on uptake and loss of paralytic shellfish toxins in the northern quahog *Mercenaria mercenaria*. Mar. Ecol. Prog. Ser., 74:33-46.

Bricelj V. M., Lee J. H., Cembella A. D., and D.M. Anderson. 1990. Uptake kinetics of paralytic shellfish toxins from the dinoflagellate *Alexandrium fundyense* in the mussel *Mytilus edulis*. Mar. Ecol. Prog. Ser., 63:177-188.

Cottrell, M.T. and C.A. Suttle. 1991. Wide-spread occurrence and clonal variation in viruses which cause lysis of a cosmopolitan, eukaryotic marine phytoplankter, *Micromonas pusilla*. Mar. Ecol. Prog. Ser. 78:1-9.

Franks P. J. S. and D.M. Anderson. 1992. Along-shore transport of a toxic phytoplankton bloom in a buoyancy current: *Alexandrium tamarense* in the Gulf of Maine. Mar. Biol., 112:153-164.

Franks P. J. S. and D.M. Anderson. 1992. Toxic phytoplankton blooms in the southwestern Gulf of Maine: testing hypotheses of physical control using historical data. Mar. Biol., 112:165-174.

Havens, K.E. 1991. Fish-induced sediment resuspension: Effects on phytoplankton biomass and community structure in a shallow hypereutrophic lake. J. Plank. Res., 13:1163-1176.

Horner R. A., Postel J. R. and J.E. Rensel. 1990. Noxious phytoplankton blooms in western Washington waters: a review. in "Toxic Marine Phytoplankton," E. Graneli et al., (editors), pp. 171-176.

Kleppel, G.S., Holliday, D.V. and R.E. Peiper. 1991. Trophic interactions between copepods and microplankton: A question about the role of diatoms. Limnol. Oceanogr., 36:172-178.

Kvitek R.G., DeGange A.R. and M.K. Beitler. 1991. Paralytic shellfish poisoning toxins mediate feeding behavior of sea otters. Limnol. Oceanogr., 36(2):393-404.

Kvitek R.G. and M.K. Beitler. 1991. Relative insensitivity of butter clam neurons to saxitoxin: a pre-adaptation for sequestering paralytic shellfish poisoning toxins as a chemical defense. Mar.

Ecol. Prog. Ser., 69:47-54.
Lehman, J.T. and C.D. Sandgren. 1990. Trophic dynamics of Lake Michigan: Response of algal production to changes in the zooplankton community. Verh. Internat. Verein. Limnol., 24:397-400.
Madden, C.J. and J.W. Day, Jr. 1992. Induced turbulence in rotating bottles affects phytoplankton productivity measurements in turbid waters. J. Plank. Res., 14:1171-1191.
Martin, J.L., White, A.W. and J.J. Sullivan. 1990. Anatomical distribution of paralytic shellfish toxins in soft-shell clams. in "Toxic Marine Phytoplankton," E. Graneli, et al., (eds.), pp. 379-384.
Nakamura, Y., Umemori, T., Watanabe, M., Kulis, D.M. and D.M. Anderson. 1990. Encystment of *Chattonella antiqua* in laboratory cultures. J. Oceanogr. Soc. Japan, 46(2):35-43.
Paerl, H.W., Rudek, J. and M.A. Mallin. 1990. Stimulation of phytoplankton production in coastal waters by natural rainfall inputs: nutritional and trophic implications. Mar. Biol. 107:247-254.
Richman, S. and P.E. Sager. 1990. Patterns of phytoplankton-zooplankton interaction along a trophic gradient: II. Biomass and size distribution. Verh. Internat. Verein. Limnol., 24:401-405.
Richman, S. Branstrator, D.K. and M. Huber-Villegas. 1990. Impact of zooplankton grazing on phytoplankton along a trophic gradient. in "Large Lakes: Ecological Structure and Function", Tilzer, M.M. and C. Serruya (eds.), Springer-Verlag, Berlin, pp. 592-614.
Sager, P.E. and S. Richman. 1991. Functional interaction of phytoplankton and zooplankton along the trophic gradient in Green Bay, Lake Michigan. Can. J. Fish. Aq. Sci., 48:116-122.
Schwinghamer P., Anderson D. M. and D.M. Kulis. 1991. Separation and concentration of living-dinoflagellate resting cysts from marine sediments via density-gradient centrifugation. Limnol. Oceanogr., 36(3):588-592.
Sellner, K.G. and D.C. Brownlee. 1990. Dinoflagellate-microzooplankton interactions in Chesapeake Bay. in "Toxic Marine Phytoplankton," E. Graneli et al. (eds.), pp. 221-226.
Smayda, T.J. and A.W. White. 1990. Has there been a global expansion of algal blooms? If so, is there a connection with human activities? in "Toxic Marine Phytoplankton," E. Graneli, et al., (eds.), pp. 516-517.
Speirs, R.J. and G.L. Boyer. 1991. Analysis of ^{55}Fe-labeled hydroxamate siderophores by high-performance liquid chromotography. J. Chromotogr., 537:259-267.
Summerson, H.C. and C.H. Peterson. 1990. Recruitment failure of the bay scallop, *Argopecten irradians concentricus*, during the first red tide, *Ptychodiscus brevis*, outbreak recorded in North Carolina. Estuaries, 13:322-331.
Suttle, C.A. and F. Chen. 1992. Mechanisms and rates of decay of marine viruses in seawater. Appl. Environ. Microbiol. 58:3721-3729.
Suttle, C.A., Chan, A.M. and M.T. Cottrell. 1990. Infection of phytoplankton by viruses and reduction of primary productivity. Nature, 347:467-469.
Suttle, C.A., Chan, A.M. and M.T. Cottrell. 1991. Use of ultrafiltration to isolate viruses from seawater which are pathogens of marine phytoplankton. Appl. Environ. Microbiol. 57:721-726.
Taub, F.B. and T. Nosho. 1990. Salmon farming and noxious phytoplankton. Summary of a workshop, Seattle, Washington, February 22-23, 1990. 26 pp.
Tosteson T. R. (ed.). 1990. Proceedings of the third international conference on ciguatera fish poisoning, La Parguera, Puerto Rico, April 30-May 5, 1990. Polyscience Publications, 204 pp.
Wells, M.L. and L.M. Mayer. 1991. The photoconversion of colloidal iron oxyhydroxides in seawater. Deep-Sea Res., 38:1379-1395.
Wells, M.L. and L.M. Mayer. 1991. Variations in the chemical lability of iron in estuarine, coastal and shelf waters and its implications for phytoplankton. Mar. Chem., 32:195-210.
Wells, M.L., Mayer, L.M. and R.R.L. Guillard. 1991. Evaluation of iron as a triggering factor for red tide blooms. Mar. Ecol. Prog. Ser., 69:93-102.
Wells, M.L., Mayer, L.M. and R.R.L. Guillard. 1991. A chemical method for estimating the availability of iron to phytoplankton in seawater. Mar. Chem., 33:23-40.

White, A.W. 1990. International red tide information and assistance service (IRTIAS). in "Toxic Marine Phytoplankton," E. Graneli, et al., (eds.), pp. 509-511.

White Alan W. 1990. Toxic algal blooms: an international directory of experts in toxic and harmful algal blooms and their effects on fisheries and public health. WHOI Sea Grant Program. 216 pp.

Biodiversity

Abbott, I.A. (ed.). 1992. Taxonomy of economic seaweeds: with reference to some Pacific and western Atlantic species. Vol. III. California Sea Grant College Publ. No. T-CSGCP-023. 241 pp.

Bartley, D.M., Gall, G.A.E. and B. Bentley. 1990. Biochemical genetic detection of natural and artificial hybridization of chinook and coho salmon in northern California. Trans. Am. Fish. Soc., 119:431-437.

Cahoon, L.B. and C.R. Tronzo. 1990. New records of amphipods and cumaceans in demersal zooplankton collections from Onslow Bay, North Carolina. 1990. J. Elisha Mitchell Soc., 106:78-84.

Callender, W.R. and E.N. Powell. 1992. Taphonomic signature of petroleum seep assemblages on the Louisiana upper continental slope: Recognition of autochthonous shell beds in the fossil record. Palaios, 7: 388-408.

Callender, W.R., Powell, E.N., Staff, G.M. and D.J. Davies. 1992. Distinguishing autochthony, parautochthony and allochthony using taphofacies analysis: Can cold seep assemblages be discriminated from assemblages of the nearshore and continental shelf? Palaios, 7:409-421.

Carney, D. and R.G. Kvitek. 1991. Assessment of nongame marine invertebrate harvest in Washington, Report to Washington Department of Wildlife. Washington State Sea Grant. 57 pp.

Carpenter, S.R., Frost, T.M., Kitchell, J.F. and T.K. Kratz. 1992. Species dynamics and global environmental change: A perspective from ecosystem experiments. in "Biotic Interactions and Global Change," Kingsolver, J., Kareiva, P. and R. Huey (eds.), pp. 267-279.

Coffroth, M.A., Lasker, H.R., Diamond, M.E., Bruenn, J.A. and E. Bermingham. 1992. DNA fingerprints of a gorgonian coral: A method for detecting clonal structure in a vegetative species. Mar. Biol., 114:317-325.

Garcia, C. 1990. Guia de ecosistemas marinos de Puerto Rico -- Las praderas de *Thalassia* de Puerto Rico [Marine ecosystems of Puerto Rico field guide -- Fields of *Thalassia* of Puerto Rico]. Puerto Rico Sea Grant Publ. No. UPRSG-E2-47. 53 pp.

Haney, J.C., Wunderle, J.M., Jr. and W.J. Arendt. 1991. Some initial effects of Hurricane Hugo on endangered and endemic species of West Indian birds. Am. Birds, 45:234-236.

Hedgecock, D. and F. Sly. 1990. Genetic drift and effective population sizes of hatchery-propagated stocks of the Pacific oyster, *Crassostrea gigas*. Aquaculture, 88:21-38.

Hicks, R.E., Amann, R.I. and D.A. Stahl. 1992. Dual staining of natural bacterioplankton with 4',6-diamidino-2-phenylindole and fluorescent oligonucleotide probes targeting kingdom-level 16S rRNA sequences. Appl. Environ. Microbiol., 58:2158-2163.

Holbrook, S.J., Carr, M.H., Schmitt, R.J. and J.A. Coyer. 1990. Effect of giant kelp on local abundance of reef fishes: The importance of ontogenetic resource requirements. Bull. Mar. Sci., 47:104-114.

Jensen, G.C. and D.A. Armstrong. 1991. Intertidal zonation among congeners: Factors regulating distribution of porcelain crabs *Petrolisthes* spp. (Anomura: Porcellanidae). Mar. Ecol. Prog. Ser., 73:47-60.

Kopczak, C.D., Zimmerman, R.C. and J.N. Kremer. Variation in nitrogen physiology and growth among geographically isolated populations of the giant kelp, *Macrocystis pyrifera* (Phaeophyta). J. Phycol., 27:149-158.

Petersen, C.H. 1991. Intertidal zonation of marine invertebrates in sand and mud. Am. Sci., 79:236-249.

Ramer, B.A. Page, G.W. and M.M. Yoklavich. 1991. Seasonal abundance, habitat use, and diet of shorebirds in Elkhorn Slough, California. Western Birds, 22:157-174.

Short, F.T. (ed.) 1992. The ecology of the Great Bay Estuary, New Hampshire and Maine: An estuarine profile and bibliography. NOAA Coastal Ocean Program Publ. 222 pp.

Snyder, R.A. and M.D. Ohman. 1991. Description of a new species of Strombidinopsidae (Ciliophora: Choreotrichida) from coastal waters of southern California, U.S.A. Trans. Am. Microsc. Soc., 110:237-243.

Stewart, J.G. 1991. Marine algae and seagrasses of San Diego County. California Sea Grant Publ. No. T-CSGCP-020. 197 pp.

Sullivan, M.J. 1990. A light and scanning electron microscope study of the marine epiphytic diatom *Amphora obtusuiscula* Grunow. Ouvrage dédié à H. Germain, Koeltz, 251-258.

Taft, C.E. and C.W. Taft. 1990. The algae of western Lake Erie. Bull. Ohio Biol. Survey, 4:1-189.

Tegner, M.J. and P.K. Dayton. 1991. Sea urchins, El Niños, and the long term stability of Southern California kelp forest communities. Mar. Ecol. Prog. Ser., 77:49-63.

Wicksten, M. 1990. Adaptive coloration in invertebrates. Texas A&M Sea Grant Publ. No. TAMU-SG-90-106. 138 pp.

Yoklavich, M.M., Cailliet, G.M., Barry, J.P., Ambrose, D.A. and B.S. Antrim. 1991. Temporal and spatial patterns in abundance and diversity of fish assemblages in Elkhorn Slough, California. Estuaries, 14:465-480.

Zedler, J.B. 1991. The challenge of protecting endangered species habitat along the southern California coast. Coast. Management, 19:35-53.

Zedler, J.B., C.S. Nordby and B.E. Kus. 1992. The ecology of Tijuana River Estuary, California: A National Estuarine Research Reserve. NOAA Office of Coastal Resource Management, Sanctuaries and Reserves Division, Washington, D.C. 151 pp.

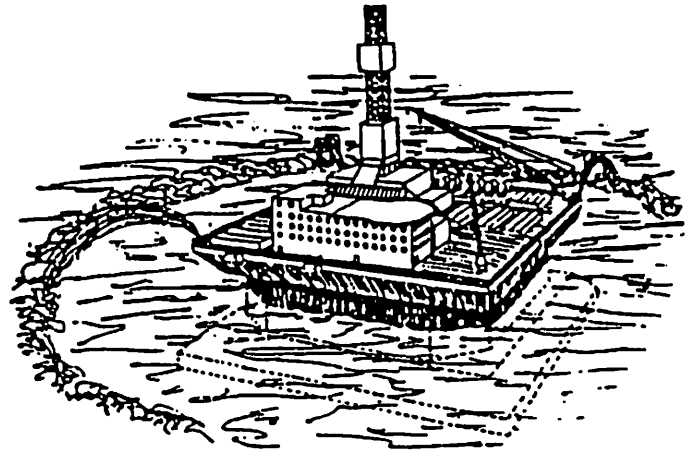
NON-LIVING RESOURCES

CHAPTERS

Non-Living Resources

From FY 1990 through FY 1992, the trend in federal funding for marine geological resources decreased only slightly, but it is less than half the rate for the previous three-year period. An average of 11 projects was funded during the past three years with a steady decrease in the number of projects but only a small decrease in the total level of support to a low of nine projects for $359,455 in FY 1992. The decreasing trend in FY 1990-1992 in total support is due in large part to the phased completion of three studies not related directly to manganese and polymetallic commodities.

From FY 1990 through FY 1992, there has been a downward trend in federal funding for the Sea Grant diving physiology, safety, and technology program. Total funding in 1990 was $497,494; in 1991 it was $351,043; and in 1992 it declined to $281,883. In 1992, only three of the 29 Sea Grant institutions sponsored wet-diving-related research projects. This situation must be improved if Sea Grant is going to uphold its share of the NOAA mandate under the Outer Continental Shelf Lands Act to perform studies that increase diver safety and performance.



Marine Geological Resources

Introduction

The Sea Grant marine geological resources program focuses on research to assess marine mineral resources and to determine the environmental impact of recovering those resources and the technological developments that will increase understanding of the processes responsible for the formation of new resources or the recovery techniques. This report summarizes the research activities of 18 projects for the past three years for two commodities: manganese oxides (crusts and nodules) and polymetallic sulfides. Present activities are summarized for the six projects supported in FY 1992 and recommendations for changes in programmatic themes are identified.

Three-Year Funding Trend

From FY 1990 through FY 1992, the trend in federal funding for marine geological resources has decreased only slightly, but it is less than half the rate for the previous three-year period. An average of 11 projects was funded during the past three years with a steady decrease in the number of projects but only a small decrease in the total level of support to a low of nine projects for $359,455 in FY 1992 (Table 1). The decreasing trend in FY 1990-1992 in total support is due in large part to the phased completion of three studies not related directly to manganese and polymetallic commodities.

Manganese oxide studies support increased in FY 1992, but the increase was only slight compared to the average for the period. Polymetallic sulfide support decreased slightly in FY 1992, but the level of support in FY 1992 is average for the period.

Other than the 50 percent decrease in funding levels for marine geological resources from the previous reporting period (FY 1986-1989), there is no obvious trend during FY 1990-1992. There is, however, a steady decrease in the number of projects supported and in the number of Sea Grant programs (2) supporting this type of research. This is the most worrisome trend in overall support for this research category.

Present Support Levels

In FY 1992, only nine marine geological resource projects were supported with a federal share of $359,455. Matching funds were $197,600 for those nine projects and $358,192 in pass through funds were received for an additional two projects that did not receive Sea Grant funds. All federally-supported projects were conducted at the University of Hawaii except one which was conducted at the University of Washington (Table 2).

In FY 1992, no support went to marine geological resource studies in areas traditionally but infrequently supported by Sea Grant such as: sand and gravel, placers, phosphates, petroleum, and ground water. While other studies supported by Sea Grant may have incorporated aspects of those resources into research projects, those studies were not designed to evaluate or promote exploitation of the resource as a commodity and, therefore, are not included in this report.

Marine Geological Resources
Federal Funding, FY 1990-1992

($x10³/No. of projects)

Commodity	FY 90	FY 91	FY 92
Manganese Oxides	146.7/7	130.3/5	173.4/6
Polymetallic Sulfides	129.3/3	224.8/5	186.1/3
Other	97.1/3	41.1/1	0
Total	373.1/13	396.2/11	359.5/9

Table 1

Summary of Present Activities

Present research supported by Sea Grant addresses the top three research priorities for non-living resources established in FY 1989. The assessment of strategic hard mineral resources and sulfide minerals in the Exclusive Economic Zone (EEZ), the development of *in situ* monitoring devices for studying hydrothermal processes, and refinement of mineral extraction technology are the focus of FY 1992 activities.

Research on the formation, evaluation, recovery, and technology development associated with manganese oxides and polymetallic sulfides is focussed on seamounts and a spreading center in the Pacific Ocean. The investigators and research category for each study are shown in Table 3.

Manganese Oxides

The mechanism for formation of cobalt-rich manganese encrustations is not completely known, but microorganisms are known to play a role in nodule growth. The occurrence of microorganisms in crusts suggests that there is also a biological influence on the geochemical process of crust accumulation. The surface microbial and geochemical activity on cobalt-rich manganese crusts from Cross Seamount southwest of Hawaii is being determined in a multi-year study utilizing trays of various natural particles left on the summit and flanks of the seamount. The study will determine the rates and roles of a variety of microbial and chemical processes on crust formation.

Manganese encrustations form very slowly so that millions of years are necessary to produce a thick crust. During that period, many factors may influence the growth rate. Two projects on crusts from Pacific Ocean seamounts are developing rare earth elemental concentration and radiometric age dating techniques to estimate the growth rates. Once the growth rings are dated, variations in accumulation of manganese will be compared to climate and ocean conditions known to exist at the time of major changes in accumulation rate in order to determine the role of environmental factors on crust growth. Another project is designed to correlate similar growth events recognized in crusts from widely separated seamounts in order to examine the geological and geochemical history of crust formation.

Johnston Seamount southwest of Hawaii may be a prime site for marine mining of cobalt-rich manganese crusts with cobalt concentrations as great as 2 percent. A project to map the crust distribution, determine the engineering properties of the crusts, and produce a geologic map of the seamount is supported. This project will evaluate one of the most promising sites to determine if marine manganese crust mining is viable. Another project involves development and testing of a novel new solution technique for leaching cobalt from manganese oxides on the seafloor. The leachate would be recovered by a processing ship and, therefore, would not require mining of the seafloor deposit.

Polymetallic Sulfides

Seafloor hydrothermal activity produces sulfide deposits in mounds and chimneys on the seafloor in regions of volcanic activity. Two projects at Loihi Seamount south of the big island of Hawaii are designed to determine the geology and geochemistry of the vent fluids and the sedimentary deposits. These studies are fundamental to evaluation of the formation, extent, and processes involved in emplacement and concentration of the sulfide deposits in an active hot spot setting. Vent water samples are obtained with an underwater observatory that is left on the seamount for several months. The observatory also collects geological and geophysical data that is necessary to determine the role of hydrother-

mal activity on the formation of deposits that are concentrated in gold, silver, copper, and zinc. The continued development of the unique seafloor observatory is a technological advancement that will have widespread applications in areas beyond marine geological resource evaluation.

Polymetallic sulfide deposits also occur in areas where diffuse and point source (i.e. smokers) hydrothermal fluids percolate to the seafloor at spreading ridges. Development of state-of-the-art instrumentation to examine the role of these fluids on the transfer of heat from the cooling crust into the ocean is under development. This instrumentation uses electromagnetic induction and thermal sensors to quantify the details of point source vs. diffuse hydrothermal flow that leads to emplacement of mineral deposits.

This instrumentation will also lead to evaluation of hydrothermal systems as a potential geothermal power source.

Future Direction and Plans

Research on marine mineral resources for the last two decades, when tempered with economic and political realities, has led to a lack of U.S. private sector interest in commercial marine mining. Research has identified large mineral deposits but the risks, costs, and long time frame for profitable marine mining development have led to a cessation of plans in the U.S. private sector for near-term exploration or mining. The only remaining interest is within government (state and federal) agencies that continue to fund research and development projects designed to assess a resource that will not be economically viable until well into the 21st century, if at all. It is recognized that the support required to reduce marine mining risks to acceptable levels is greater than governmental agencies will provide. There is, however, a role that Sea Grant can play that may produce important future developments that will keep the U.S. in a position to take advantage of changing economic conditions to foster the development of marine technology that has ramifications beyond the goals of the mineral industry.

Out with the Old

Resource evaluation is the least likely approach to enhance the prospects for marine mining in the 21st century. The extent and concentration of potential ore deposits of manganese oxides and polymetallic sulfides within the U.S. EEZ are now known in considerable detail. The goal is not to find more deposits but to find economical ways for recovery and benefaction of mineral deposits and mitigation of the mining techniques on the marine environment. This does not mean that other marine mineral deposits will not be discovered that will require mapping of that resource as a necessary step before exploitation, but the successful Sea Grant-supported research for manganese oxides and sulfide deposits has identified more commercial grade deposits than can be economically recovered with present technology. The economics of the situation is that an increased supply of marine-based resources would only drive down the com-

Grantee Effort in Marine Geological Resources
Fiscal Year 1992

($x10^3 for Sea Grant and Matching sources)

Grantee Institutions	No. of Projects	Sea Grant	Match	Total
Hawaii	8	240.0	178.4	418.4
Washington	1	119.5	24.1	143.6
Total	9	359.5	202.5	562.0

Table2

Marine Geological Resources
FY 1992 Summary

($x10^3$ for Sea Grant and Matching Sources)

Grantee Institution Principal Investigator	Resource Formation		Resource Evaluation		Resource Recovery		Technology Development	
	Sea Grant	Match	Sea Grant	Match	Sea Grant	Match	Sea Grant	Match
Manganese Oxides								
University of Hawaii								
Cowen	24.8	29.6						
DeCarlo	41.9	27.0						
McMurtry			43.6	33.2				
Malahoff			33.9	10.2				
Malahoff					22.1	22.2		
Wiltshire			7.0	12.0				
Total	66.7	56.6	84.5	55.4	22.1	22.2	0	
Polymetallic Sulfides								
University of Hawaii								
Malahoff	31.3	19.0						
McMurtry	35.3	20.3						
University of Washington								
Schultz							119.5	24.1
Total	66.6	39.3	0	0	0	0	119.5	24.1
Grand Total	133.3	95.9	84.5	55.4	22.1	22.2	119.5	24.1

Table 3

modity price of the deposit and further erode the profitability of marine mining.

In with the New

Sea Grant support of marine geological resources must concentrate on two areas of technological advancement: recovery techniques and seafloor instrumentation. The development of new technology to recover both manganese oxides and polymetallic sulfides by economically attractive means is the next logical step to position the U.S. for a leadership role in future marine mining. Enhancement of the existing leadership position of the U.S. in seafloor instrumentation of sulfide-forming processes will also enhance its position for exploitation of sulfide deposits on analogous pieces of the marine crust that are found where existing mining techniques may be used. Both of these technological developments will have spin-offs in marine research that will go beyond marine mining applications.

New technological advancements in fracturing, drilling, or dissolution of manganese oxide crusts with a concomitant technological development in recovery techniques must be developed. These technological advances could be achieved through development of robotic instruments, automated mining machines, or novel methods of *in situ* benefaction and recovery of the desired minerals in

crusts without the need for recovery of the crust. These technological advances will have spin-offs in robotics and automated undersea vehicles that will find applications in other areas of marine research.

Sulfide deposits are accumulating under the influence of processes that occur and vary on a human time scale at volcanically active seamounts and spreading centers. The existing *in situ* instrumentation used in areas of polymetallic sulfide emplacement in those areas must be further developed to include widespread arrays and linkages to land-based observatories. The presence of accumulation areas within the U.S. EEZ allows an unprecedented opportunity to examine the processes responsible for formation of an ore body. While this ore body may not be economically recoverable in the future, an understanding of the processes controlling formation of the deposit will lead to a better understanding of the analogous ore bodies that are mined at present. The instrumentation of the hydrothermal venting that leads to sulfide emplacement must be extended to subduction margins and sedimented spreading centers where more porous oceanic crust serves as a better host for the mineralized zones.

The enhancement of seafloor instrumentation arrays that can deliver high-resolution, long-term, synoptic measurements of seafloor processes will lead to an understanding of oceanic processes that goes far beyond mineral resource development. Like the new mining technology, this instrumentation will have spin-offs in many other areas of marine research.

Ground Water Research

During the past three years, ground water research received only minimal Sea Grant support in spite of many important problems in coastal regions. Contamination by salt-water injection into aquifers in marine coastal areas and by polluted waters in fresh-water lake areas is a problem that threatens both groundwater sources for human consumption and agricultural use of ground water.

Support for research in halting or slowing groundwater contamination by salt water or pollutants is needed. That research should be directed at better ways of recharging coastal reservoirs, reducing contaminants entering coastal aquifers, and more accurate monitoring or modelling of contaminant flow in affected areas. Especially innovative ideas may be required to assure a continued source for one of the most important geological resources used by humans.

Diving Physiology, Safety, & Technology

Introduction

The priority of the Sea Grant diving safety, physiology, and technology program is to sponsor research that will improve human safety and diver performance. Sea Grant encourages the study of all aspects of diver physiological and psychological restraint, the development of decompression and excursion tables, and the investigation of equipment and protective gear that will improve diver performance during exposure to hostile environments.

Most civilian diving activity by recreational, commercial, scientific, and government organizations is performed by constituents of the states that are served by a Sea Grant institution. Sea Grant is, therefore, uniquely suited through its 29 participating universities (and researchers in neighboring institutions) and their outreach programs to communicate with those performing wet diving activities and to support research that directly benefits their needs.

For the Sea Grant system and its sister NOAA organization, the National Undersea Research Program (NURP), the following research areas have the highest priority:

- Practical operations—procedures, constraints, physical and technological limitations, table development, and topside support requirements.
- Safety—certification/training requirements, epidemiological information on diving-related accidents and fatalities, and diving accident management.
- Medical aspects—treatment of diving-related accidents, hyperbaric equipment, emergency equipment, procedures and protocol, and diving in remote locations.
- Environmental impacts on divers—hazardous materials and pathogens, ambient temperatures, and psychological concerns.
- Fundamental hyperbaric physiological research —all levels from cellular to systemic that address decompression table development.
- New technology development—"tools" to complement the diver's capability systems that enhance underwater abilities and equipment and procedures that increase safety and well-being.

Diving Physiology, Safety, & Technology Research Areas 1990-1992

Research Area	'90	'91	'92
Physiology Research	2	1	1
Practical Operations	1	0	0
Safety/Training	1	1	1
Medical Aspects	1	1	1
Environmental Aspects	0	0	0
Technology	0	0	0
Data Dissemination	0	0	0

Table 1

- Data dissemination—workshops/symposiums, papers, abstracts, bibliographies, and data repositories.

Research results in the above areas will benefit all divers, and will be especially beneficial to civilian divers engaged in diving activities for scientific research, industry, emergency services, and government.

Sea Grant and NURP are sibling organizations under NOAA's Office of Oceanic Research, and the two programs are closely coordinated. NURP, composed of NOAA's Office of Undersea Research and its network of National Undersea Research Centers, is unique among federal funding agencies in its support of shallow submersibles, remotely operated vehicles, surface-supported diving, nitrox diving, and seafloor habitats. The National Sea Grant College Program endorses the application for use of the NURP systems in conducting Sea Grant-supported research in the above or other subject areas. In particular, use of the Aquarius habitat recently installed in the Florida Keys and the nitrox diving capability of the National Undersea Research Center at the University of North Carolina-Wilmington are encouraged in conducting studies to improve diver safety and performance.

Program Statistics

Projects supported by the program in 1990, 1991, and 1992 by research area are shown in Table 1; total support by year is shown in Table 2.

Trends

Only three of the 29 Sea Grant institutions sponsored wet-diving-related research projects in 1992. This is a very poor showing for diving safety and physiology. It must be improved if Sea Grant is going to uphold its share of the NOAA mandate under the Outer Continental Shelf Lands Act to perform studies that increase diver safety and performance.

The downward trend in diving physiology projects can be partially explained by a misunderstanding among some investigators that only researchers at Sea Grant institutions can apply for Sea Grant funding. It must be made clear that this funding is available to all qualified researchers and that all proposals will be given serious consideration. An effort should be made to solicit proposals from outside institutions to reverse this trend.

Progress and Significant Achievements

Physiology Research

A. Applied Physiology of Diving

Lin, Yu-Chon
Hawaii Sea Grant

This research showed that a set of whole body half time equations is appropriate for developing animal (rats, rabbits, dogs, monkeys) decompression tables. A tentative equation has also been produced for extrapolating human decompression tables from animal experiments. The tables resulting from this equation would require less decompression time than currently used tables. While tests cannot be made directly using humans, an indirect study will be performed through cooperation with JAMSTEC scientists.

B. Physiological Reactions to Deep Breath-hold Diving in Humans

Lundgren, Claes E. G.
New York Sea Grant Institute

Respiratory and circulatory adaptations to deep breath-hold diving were studied in expert divers. While diving, the divers exhibited a pronounced dive reflex with slowed peripheral circulation and marked

Diving Physiology, Safety, and Technology Program Funding 1990-1992

	Sea Grant	Matching	Other	Total
90	$251,831	$213,477	$32,186	$497,494
91	$200,059	$150,984	0	$351,043
92	$153,875	$128,008	0	$281,883

Table2

increase in anaerobic metabolism. Dangerously low oxygen levels were reached toward the end of the dives, and throughout the dives there were marked cardiac arrhythmias. Increased knowledge about human breath-hold diving has been gained, and divers should be warned against breath-hold diving, including snorkeling, for persons who have heart problems.

C. Body Fluid Balance During a Seven-Day Nitrox Saturation

Suk Ki Hong
New York Sea Grant Institute

These research results, together with other dives conducted at low chamber pressure (e.g., 4 ATA N_20_2 or 4 ATA He-O_2), suggested that hyperbaric diuresis is gas-density-dependent rather than pressure-dependent and, also, that the critical (or threshold) gas density for the development of a hyperbaric diuresis lies somewhere between 3.2 and 5.0 Kg/m^3

Practical Operations

Decompression Sickness: Pharmacological Control of Inert Gas

Lundgren, Claes E. G.
New York Sea Grant Institute

Human studies of pharmacological effects on nitrogen elimination were performed in an attempt to identify substances that, by enhancing blood circulation, might enhance the nitrogen elimination rate during inhalation of gas mixtures with low nitrogen content. Terbutaline was found to cause a significant (18 percent) increase (compared to non-medicated controls) in the nitrogen eliminated over a two-hour period. In a separate series of experiments, inhalations of 3 and 5 percent carbon dioxide were tried in combination with nitrogen washout procedures. This was done because carbon dioxide retention is a potential problem during diving. No effect of carbon dioxide on nitrogen elimination was evident.

Safety/Training

Factors Governing Stress Responses in Scuba Divers

Morgan, William P.
Wisconsin Sea Grant Institute

A survey of 500 scuba divers revealed that 54 percent have experienced panic or near-panic behavior on one or more occasions. It has been possible to predict panic behavior in beginning scuba divers with 88 percent accuracy using standardized measures of anxiety. Also, preliminary research has revealed that approximately 12 percent of trainees who have completed a formal scuba course experience panic behavior during open water checkout dives. Research on the psychophysiological responses to paced scuba finning has revealed that various stress responses are influenced by personality structure, gender, protective clothing, and water temperature. The validity and reliability of a Body Awareness Scale have been evaluated with 600 male and 300 female volunteers, and this scale is currently being applied in stress response modification research in scuba divers.

Medical Aspects

Decompression and Diver Safety

Lanphier, Edward H.
Wisconsin Sea Grant Institute

This research produced a large animal model of hyperbaric osteonecrosis, a form of bone necrosis that can permanently disable the diver and tunnel worker. In sheep, persistent limb bends, lasting more than four hours, are highly correlated with the later development of bone necrosis in the same limbs. Recompression therapy of limb bends, within four hours, prevented the development of bone necrosis in sheep, and this finding appears consistent with clinical outcomes in recompressed commercial divers.

Other important accomplishments included findings that, with sheep, dive profiles affect the site and manifestation of decompression injury. Although the incidence of serious spinal cord DCS and possible brain injury is small, it is more likely to occur during short deep dives. Limb bends, and resulting potential bone necrosis, are more likely to occur in prolonged shallow dives. These findings appear to be consistent with reports of decompression sickness in divers.

Environmental Aspects

Microbiological Hazard Associated with Diving in Polluted Waters

Colwell, Rita R.
University of Maryland, College Park

Professional and emergency service divers often conduct operations in waters which are chemically and/or microbiologically polluted. This can be hazardous to the diver's health, especially the naive or inexperienced diver. Detection of pathogens in water and of antibody in blood clearly demonstrates the risks for potential bacterial infection, and suggests greater diver protection is required.

As a result of this research, test kits, such as CholeraScreen™ and CholeraSMART™ have been developed for rapid detection of *Vibrio cholerae*. Application of these test kits extends not only to divers but to the hospitals and food processing industries where a patient or food must be tested for the presence of the pathogen.

Future Directions and Plans

Nitrox Diving

The recreational, scientific, commercial, and police search and rescue diving communities are increasing their use of nitrogen-oxygen gas mixes (nitrox) that contain more oxygen than air to increase their time on the bottom. Diving operations are now being performed for which either the current tables have never been proven or no tables/procedures exist.

NOAA/Sea Grant has an opportunity to sponsor the development of safe nitrox diving procedures. This role is consistent with their responsibility for civilian diving procedure and decompression table development.

Sea Grant is encouraging investigators to submit proposals in the seven research priority areas with a special emphasis on purposeful research that will benefit nitrox and shallow water habitat users in the following ways:

- Improvements to diving procedures and decompression tables for all aspects of nitrox diving including:
  - Excursion dives from saturation on nitrogen-oxygen breathing nitrox or helium-oxygen.
  - Long duration surface dives using surface decompression on oxygen and/or air.
  - Repeat surface dives with and without surface decompression.
  - Treatment protocols.
- Clear recommendations on safe practices when using nitrox and training procedures that include recertification requirements.
- To provide and improve the required nitrox procedures, a greater knowledge is required of the extended exposure of humans to oxygen, the effects of cyclic exposure to gas mixes containing nitrogen and helium, and physiological aspects of related decompression sickness and treatment.