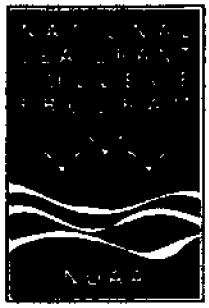

The National Sea Grant College Program

ANNUAL REPORT FY 88

February 1989

SEAFOOD SCIENCE AND TECHNOLOGY

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

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NATIONAL SEA GRANT COLLEGE PROGRAM

SEAFOOD SCIENCE AND TECHNOLOGY

ANNUAL REPORT FOR FISCAL YEAR 1988

FEBRUARY 17, 1989

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SEAFOOD SCIENCE AND TECHNOLOGY

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SEAFOOD SCIENCE AND TECHNOLOGY

Abstract

The National Sea Grant College Program's research in food science is focused on aiding the fishing industry by improving processing technology, products, and methods for assuring safety of seafood, and by developing concepts for new products and by-products. Most importantly, it serves as a hands-on training ground for students who will enter industry with knowledge, skills, and new ideas. The research is relevant to exploiting the potential for expansion of domestic and foreign markets for U.S. seafood.

In fiscal year 1988 the National Sea Grant College Program supported 40 projects in state or regional Sea Grant programs with $1,260,000 in federal funds and $1,164,000 in matching funds. The federal and matching funds invested in seafood science and technology was sharply down from fiscal year 1987. This 16 percent decrease is alarming because it resulted in the support of eight fewer projects at a time when consumption of and interest in seafood is on the increase in the United States, a time when the U.S. trade deficit in seafood is great and many opportunities for upgrading the seafood industry are extant.

The projects supported dealt with a wide range of fishery species. They can be grouped in the following four categories: (1) Engineering and Waste Treatment, (2) Product Development and By-Product Recovery, (3) Microbial and Nutritional Quality, and (4) Handling and Processing. The students and professors conducting the projects produced a lot of useful results that were documented in a variety of publications which are listed in Appendix A of the report. Of particular note were two technical manuals of the Louisiana Sea Grant College Program on design of recirculating systems for producing soft-shell crabs and soft crawfish.

Introduction and Discussion

Academic 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 safety and high quality of seafood. It is especially important to the industry through development of skilled personnel for employment. The research is relevant to expanding domestic and foreign markets for U.S. seafood because successful expansion depends largely on product quality, safety, appearance, and suitability in a wide variety of markets, 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

149,000 metric tons in 1987, imports of edible fishery products still stood at 1.5 million metric tons valued at a record $5.7 billion. Total exports, although up, were valued at only $1.7 billion. Obviously, such a 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 advisory service in seafood technology comprise an important component of the National Sea Grant College Program because it serves an important sector of marine industry, because it trains students for productive careers, and because most processing companies are relatively small and 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 of them 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.

During fiscal year 1988 the National Sea Grant College Program supported 40 research projects in the four categories shown in Table 1 with $1,342,000 in federal funds and $1,213,000 in non-federal matching funds. Table 2 shows the number of projects and funding for research in seafood technology by program. Funding for research in seafood science and technology dropped alarmingly (12%) in fiscal year 1988. This is in part a reflection of a six percent cut in the overall federal budget for Sea Grant, and a ten percent drop in funding for research. The decline in funding would have been far more drastic had not matching funding increased somewhat while federal funding declined 22 percent.

The decline in support for seafood science and technology is of particular concern because it was disproportionate even though the need for research in this field is still great. Consumption of and interest in seafood is on the increase in the United States, the trade deficit in seafood is enormous and many technical facets of the seafood industry need upgrading. In general, proposals in this field to the National Sea Grant Office fare well, so the decline reflects the extremely keen competition among proposals at the state and regional level at a time when the state and regional programs are severely underfunded. On the average they operate at levels for research 40 percent below those of 1981 in constant dollars.

Examples of activities and issues in the four categories are discussed below. Appendix A is a listing of recent Sea Grant publications dealing with seafood technology. Each publication has a name or code designating a program from which reprints can be ordered. Appendix B provides the key to the codes and addresses of the programs. Appendix C is a listing of all Sea Grant research projects in seafood science and technology funded in fiscal year 1988. This listing gives levels of funding and names of the projects' principal investigators with their institutional affiliations.

Engineering and Waste Treatment

The number of projects and level of effort in engineering and waste treatment remained at a low level in 1988. This low level of effort in engineering has been characteristic of Sea Grant's program in seafood technology, but good opportunities and problems for university engineering can be identified. For example, the Mississippi-Alabama Sea Grant and Louisiana Sea Grant have been working in collaboration to upgrade the technology for producing soft-shell crabs and crawfish. Most of the engineering research has been done at Louisiana State University and has resulted in the recent publication by Ronald Malone and Daniel Burden of two excellent technical manuals on design of recirculating systems for commercial production.

Disposal of wastes from processing of seafood is a problem in many areas and in many plants. It is a problem of growing significance as cost of access to landfill sites increase along with restrictions on dumping of wastes in the ocean. In some areas the processing plants' contributions of odoriferous compounds to the atmosphere is a subject of complaint or governmental control. Still, few Sea Grant projects have taken engineering approaches to solving problems of this kind. This may indicate the need to draw engineers, especially chemical engineers, into Sea Grant to deal with these kinds of issues.

TABLE 1
Federal Funding for Projects in Seafood Science and Technology in Fiscal Years 1981-1988
(in thousands of dollars)

	Federal Funding/No. of Projects							
	1981	1982	1983	1984	1985	1986	1987	1988
Engineering and Waste Treatment	58/4	56/2	19/1	144/4	76/2	101/6	56/2	84/3
Product Development & By-Product Recovery	444/13	335/13	406/14	444/14	403/14	324/11	545/14	572/16
Microbiological & Nutritional Quality	427/16	556/21	610/19	646/17	829/22	923/24	818/22	444/17
Handling & Processing	371/14	396/14	376/12	411/13	271/9	261/7	308/10	242/8
TOTALS	1300/47	1343/50	1411/46	1645/48	1579/47	1609/48	1727/48	1342*/44

*Non-federal matching funds were $1,212,701 in FY 1988; total funding was $2,545,000. Total funding in FY 1987 was $2,902,000.

TABLE 2
Number Projects and Funding for Seafood Science and Technology by Institution in Fiscal Year 1988

INSTITUTION	PROJECTS	$ FEDERAL	$ MATCH
ALASKA SEA GRANT	2	$ 68,200	$ 15,000
CALIFORNIA SEA GRANT	3	$ 78,345	$ 78,809
DELAWARE SEA GRANT	1	$ 12,266	$ 49,529
FLORIDA SEA GRANT	2	$ 58,930	$ 89,094
GEORGIA SEA GRANT	2	$ 51,200	$ 21,300
LOUISIANA SEA GRANT	1	$ 37,421	$ 24,974
MAINE/NEW HAMPSHIRE SEA GRANT	1	$ 35,514	$ 22,490
MARYLAND SEA GRANT	1	$ 28,200	$ 23,100
MISSISSIPPI/ALABAMA SEA GRANT	1	$ 21,903	$ 10,952
MIT SEA GRANT	1	$ 40,000	$ 28,567
MICHIGAN SEA GRANT	1	$ —	$ 44,015
NEW JERSEY SEA GRANT	1	$ 10,000	$ 126,100
NEW YORK SEA GRANT	5	$ 125,683	$ 130,958
NORTH CAROLINA SEA GRANT	4	$ 78,481	$ 78,216
OREGON SEA GRANT	3	$ 165,900	$ 122,400
RHODE ISLAND SEA GRANT	2	$ 48,397	$ 71,988
TEXAS A&M SEA GRANT	1	$ 45,696	$ 38,583
VIRGINIA SEA GRANT	4	$ 124,546	$ 85,116
WASHINGTON SEA GRANT	5	$ 209,703	$ 107,000
WISCONSIN SEA GRANT	1	$ 17,216	$ 10,448
WOODS HOLE SEA GRANT	2	$ 84,800	$ 35,014
GRAND TOTAL	44	$1,342,401	$1,212,701

Product Development and By-Product Recovery

By-product recovery is another approach to dealing with wastes from processing of seafood and a number of Sea Grant projects in fiscal year 1988 took this approach. For example, J. P. Fontenot, George Flick, Brice Bainbridge and Paul Graham in the Virginia Sea Grant College Program continued their efforts to develop procedures for **using wastes from processing** of blue crabs in cattle feed. Their preliminary calculations indicated that the value of the crab waste would be higher in ensiled cattle feed than as a dehydrated crab meal for rations of other domestic animals. They expect the nutritional value of the ensiled product to be high. In North Carolina Donald Hamann and Tyre Lanier focused on identifying components of leachwater from production of surimi that would be suitable as food ingredients. These components constitute a valuable potential resource because only 15 to 20 of whole fish are recovered in the primary surimi product.

Seafood specialist, Brian Perkins, working in the Alambama Sea Grant Extension Program, looked at the issue of **recycling wastes from processing of shrimp**. Perkins worked with materials normally washed away during mechanical heading and peeling of shrimp and produced a pinkish product similar in texture to deviled ham. This year he expects to have enough product for distribution to industry in frozen five-pound blocks with a report on the method of its production. Perkins already reports a lot of industrial interest in his work.

In terms of development of primary products, the entire effort was on various aspects of **surimi production** with four projects--in Alaska, North Carolina, and Oregon. Alaskan pollock, Atlantic croaker and red hake, menhaden, and Pacific whiting were the primary species of study.

Microbial, Chemical and Nutritional Quality

Microbiological research is a major focus of the program in seafood science because it bears on human health and the perishability of seafood products. For example, shellfishing grounds are opened and closed on the basis of concentrations of coliform bacteria, but exactly how or if this measure of quality relates to the number of all human pathogens in shellfish has not been established. In some cases the differences and relationships between virulent and avirulent strains of bacteria and their natural occurrence in coastal waters are unknown. Also, there is a need to improve some of the methods used in enumerating microorganisms in seafood and the marine environment so that decisions in management of resources can be made efficiently and with greater certainty and specificity.

In November of 1986 the Alaska Sea Grant College Program sponsored a major international **symposium on determination of seafood quality.** The symposium brought researchers and representatives of industry together in a forum to discuss what constitutes quality in seafood, how quality can be measured, and what standards are available for fishery products. The emphasis of the discussions and papers was on standards that can be used internationally and the measurements available to make the standards usable. The participants also addressed nutritional aspects of seafood products as well as public health concerns. The proceedings of the symposium have been published by Elsevier Science Publishers in a large, handsome, and informative volume edited by Donald E. Kramer of the University of Alaska and John Liston of the University of Washington.

David Cook and Angela Ruple of the Mississippi-Alabama Sea Grant College Program recently completed studies on modification of **microflora in temperature abused shellstock oysters.** They drew the following conclusions from their work:

- Storage temperatures of 10^{o} prevents fecal coliform bacteria from reproducing in oysters. At temperatures of $22^{o}C$ and above, fecal coliforms may reproduce, but, temperature and time did not appear to be the only factors which controlled their reproduction. The normal commerical practices used in handling oysters permit fecal coliform bacteria to multiply in oysters.

- Vibrio parahaemoliticus, Vibrio vulnificus, Vibrio cholerae, Vibrio mimicus, and Aeromonas hydrophlia multiplied in oysters under normal commercial transport and in oysters stored at $22^{o}C$ and $30^{o}C$. Only A. hydrophila was capable of multiplying at a temperature of $10^{o}C$, a temperature at which the fecal coliforms could not multiply.

- The vibrios and A. hydrophila increased in number in the same samples in which the fecal coliforms increased, but these potential pathogens increased in some samples when the fecal coliforms failed to multiply. It thus appears that no correlation exists between the multiplication of the fecal coliforms and the potential pathogens studied in shellstock oysters.

In Florida Steve Otwell and other specialists and agents have assisted the Southeastern Fisheries Association in developing a manual that can be used in meeting **codes for product quality.** The

purpose is to improve the reputation of seafood from the Southeast for quality and value. The specifications in the code have drawn national recognition. Otwell and his collaborators expect the National Food Marketing Institute to incorporate them into its new quality awards program. So far they have developed codes for only a few species, but hope to continue until all major species have been addressed.

Handling and Processing

Research in this category ranges over a variety of approaches to improving quality of seafood and the efficiency of its production--in some ways the bread and butter issues in Sea Grant because the results are frequently useful to agents and specialists in the Sea Grant Extension Programs. Some of the recent research has dealt with oxidation of seafood products. For example, John Kinsella and his associates at Cornell University have been studying the **mechanisms of oxidation** of unsaturated fish oils with the intent of developing better methods for its control. Their research deomonstrated the ability of lipoxygenase in gills to initiate oxidation of fatty acids to hydroperoxides in fish tissue. They suggest that under postharvest conditions the release of tissue lipoxygenases could generate significant quantities of reactive lipid hydroperoxides. In the presence of metal ions the hydroperoxides could serve as sources of free-radical species that in turn further catalyze autoxidation and generate off-flavors and reactive products that further degrade flavor and color of fish products. Proper postharvest methods, such as low-temperature storage on ice or at $0^{o}C$, avoidance of bruising or injury, mild heating (blanching), and control of pH may be employed to control or retard oxidations initiated by lipoxygenase.

Robert Linday and C. Karahadian at the University of Wisconsin studied the mechanism of dilauryl thiodipropionate's antioxidant activity with the intent of improving **methods for preserving fish oils.** They found thiodipropionates to be ineffective decomposers of lipid hydroperoxide at levels allowed in foods (200ppm), but found them to terminate peracid oxidations of aldehydes and epoxidation of olefins. Use of thiodipropionates with currently employed antioxidant systems should provide increased quality and flavor stability, especially in foods containing sensitive aldehydic flavor compounds, unsaturated nutrients, and compounds that are oxidized to potentially harmful substances.

Craig Hoesley and Dean Martin at the University of South Florida reported on their efforts to sterilize **seawater for depuration** through photodynamic action. They used Vibrio vulnificus as a test organism and conducted experiments to determine the bactericidal effects of two sensitizers, rose bengal and eosin yellow. Rose bengal, which works by producing singlet oxygen, was effective at micromolar concentrations. Their studies also

showed that rose bengal was not absorbed intact by the clam Mercenaria mercenaria. Their results indicate that photosensitization may be exploited to improve depuration practices, but studies with other edible shellfish are needed before practical procedures can be recommended.

Opportunities and Needs for the Future

The National Sea Grant College Program's modest investment in seafood science and technology pays off very well with fundamental advancements in food science, results important in improving practice in seafood processing, and training of competent new professionals for the workforce. The research, education, and service in this field are important in helping the U. S. seafood industry improve its position in international markets.

The disportionate decline in research in seafood technology during fiscal year 1988, the many pressing problems and opportunites extant in seafood processing, and the sharply increasing public interest in seafood and its beneficial effects on health strongly suggest the need for seafood scientists and advisory specialists to persuasively outline a framework for a cohesive, national program of research, service, and education in this field for the next few years. Such a framework or discussion of the most important issues in this field could be used to delineate the role of academe, government, and industry in this field, to define areas where collaboration between or among these parties would be especially beneficial, to enhance esprit de corps in the field, and to set guidelines that would improve the chances of approval of proposals in this field at a time when competition for funding is extremely keen.

The U.S. General Accounting Office's report of August, 1988, **Seafood Safety: Seriousness of Problems and Efforts to Protect Consumers**, noted that "seafood was a notable contributor to food-borne illness" and "accounted for about 10 percent of all the reported food-borne illness outbreaks ..." from 1978 trhough 1984 according to data of the Centers for Disease Control, but observes that "there does not appear to be a compelling case at this time for implementing a comprehensive, mandatory federal seafood inspection program similar to inspections used for meat and poultry." The report noted that many officials and experts acknowledge problem areas and opportunities where programs and services should be improved or where additional effort is needed and that the problem areas are well known in government, industry, and universities. It further noted that most of the suggestions for change would require greater commitment of resources. Some areas of concern, relating to research and extension, included in the report are the following:

- the need to develop better tests to measure microbiological contamination in shellfish-growing waters and in shellfish stock,

- the need for a better indicator of viral contamination in shellfish,

- the need to create a greater public awareness of the potential health risks associated with consuming raw or undercooked molluskan shellfish,

- the need for more consumer education in general about seafood handling and preparation, (Mishandling of seafood and improper cooking are regarded as major causes of seafood-borne illness.) and

- the need for more research to better understand chemical contamination in seafood and its implications for human health.

Natural toxins such as ciguatoxin, scombrotoxin, paralytical shellfish poison, and diarrhetic shellfish poison, continue to be principal contributors to seafood-borne illness. The source and distribution of ciguatoxin remains poorly defined and no quick and reliable methods for its 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. A multi-disciplinary approach including biological, chemical, physical and social scientists plus modelers is urgently needed to provide a predictive capability for toxic blooms.

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. In November and December of that year it made 153 persons ill in Canada; 93 experienced gastrointestinal distress only and 58 reported, in addition, neurological symptoms, including confusion, loss of short-term memory, seizures and coma. ASP directly and indirectly killed five persons. ASP was traced to the diatom Nitschia pungens. The effect of this toxin on humans is still being studied. ASP is present in U. S. waters and Maine has closed two harvest areas because of it. Obviously, ASP and the biological oceanography of Nitschia are topics of very high priority for research.

APPENDIX A

RECENT SEA GRANT PUBLICATIONS
IN
SEAFOOD SCIENCE AND TECHNOLOGY

Advisory Bulletins, Booklets, and General Publications

Davis, N. Ed, 1987. Fatty Fish Utilization: Upgrading from Feed to Food, **Proceedings of a National Technical Conference**, Raleigh, North Carolina, December 10-11, 1987, NCU-W-87-001.

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Harbell, S., 1988. Controlling Seafood Spoilage, **Seafood Retailing Series**, Washington Sea Grant, 7pp.

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Anonymous, 1988. Vitamins & Minerals in Florida Seafood: The Story from A to Zinc, **Sea Net**, Issue III (Summer), Florida Sea Grant Program, 4pp.

Averill, P. H., 1988. Composting Seafood By-Products, **Fisheries Information Series No.** 6, Maine/New Hampshire Sea Grant College Program, 4pp.

Anonymous, 1988. Controlling Food Contamination through Sanitation Programs, **Seafood Current**, Vol.2, No. 2 (Spring), North Carolina Sea Grant.

Anonymous, 1988. Tips on Tuna Handling, Woods Hole Oceanographic Institution, 2pp.

Harbell, S., 1988. Receiving Seafood, Seafood Retailing Series, Washington Sea Grant, 5pp.

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Peters, J. B., 1988. Listeria monocytogenes: A Bacterium of Increasing Concern, **Seafood Processing Series**, Washington Sea Grant, 4pp.

Doyle, J. P. and C. Jensen, 1988. Handbook on White Fish Handling Aboard Fishing Vessels, **Marine Advisory Bulletin No.** 36, Alaska Sea Grant College Program, 75pp.

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Hegen, A. R., 1987. Over the Coals with Texas Seafood, **TAMU-G-87-001**, 2pp.

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Anonymous, 1987. Royal Red Shrimp, **MASGC-G-870-005**, 2pp.

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Price, R., 1987. Sanitizers for Food Processing Plants, **CUIMR-G-87-002**, 5pp.

Price, R., 1987. Cleaning Compounds for Food Processing Plants, **CUIMR-G-87-001**, 7pp.

Perkins, B., 1987. Saving Your Catch: A Guide to Handling and Preserving Seafood from the Water to the Table, **MASGC-G-87-006**, 2pp.

Anonymous, 1987. Eating Great Lakes Fish. **MICHU-G-87-001**, 7pp.

Bray, P. and S. Harbell, 1987. Coming to Grips with a Crab, **WASHU-G-87-001**, 5pp.

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Swanson, J. E. M. Black and J. E. Kinsella, 1987. Dietary n-3 Polyunsaturated Fatty Acids: Rate and Extent of Modification of Fatty Acyl Composition of Lipid Classes of Mouse Lung and Kidney, **Lipids**, pp.824-832 (NYSGI-R-87-006)

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Kinsella, J. E., 1988. Fish and Seafoods: Nutritional Implications and Quality Issues, **Food Technology**, 42(5):146-150 & 160. (NYSGI)

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APPENDIX B

SEA GRANT PROGRAMS AND AFFILIATES

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APPENDIX C

SEAFOOD SCIENCE AND TECHNOLOGY PROJECTS

TITLE/INVES./INST		FED FUNDS	MATCHING FUNDS
I. ENGINEERING AND WASTE TREATMENT			
ENERGY USE ASSESSMENT IN ALASKAN SEAFOOD PROCESSING PLANTS J. C. NASH UNIVERSITY OF ALASKA, FAIRBANKS	(35)	$ 29,100	$ 8,900
BIOLOGICAL FILTER DESIGN FOR CRAB SHEDDING AND AQUACULTURE WHEATON, FREDRICK W. UNIVERSITY OF MARYLAND, COLLEGE PARK	(1)	$ 28,200	$ 23,100
THERMAL PROPERTY EVALUATION FOR SEAFOODS KOLBE, EDWARD R. OREGON STATE UNIVERSITY, CORVALLIS	(35)	$ 27,000	$ 39,400
TOTAL ----------		$ 84,300	$ 71,400
II. PRODUCT DEVELOPMENT AND BY-PRODUCT RECOVERY			
CONTROL OF SURIMI FUNCTIONALITY THROUGH MODIFICATION OF PROTEIN COMPOSITION J. S. FRENCH UNIVERSITY OF ALASKA, FAIRBANKS	(35)	$ 39,100	$ 6,100
COLLAGENOLYTIC ACTIVITY IN THE SKELETAL MUSCLE OF FISH NORMAN F. HAARD UNIVERSITY OF CALIFORNIA, DAVIS	(35)	$ 31,080	$ 34,828
DEVELOPMENT OF A POTENTIAL ANTI-TUMOR DRUG FROM MARINE WASTE BY-PRODUCT: ANGIOGENESIS INHIBITOR FROM CARTILAGE OF ELASMOBRANCH KIN-PING WONG CALIFORNIA STATE UNIVERSITY, FRESNO	(12)	$ 39,441	$ 24,528
USE OF CHITOSAN FOR PLANT BIOTECHNOLOGY PROCESSES DIETRICH W. KNORR DELAWARE SEA GRANT COLLEGE PROGRAM	(1)	$ 12,266	$ 49,529

TITLE/INVES./INST	FED FUNDS	MATCHING FUNDS
IMPROVING QUALITY AND UTILIZATION OF BLUE CRAB MINCED MEAT RECOVERED FROM PROCESSING BY-PRODUCTS KEITH W. GATES (35) GEORGIA SEA GRANT COLLEGE PROGRAM	$ 34,800	$ 21,300
MENHADEN OIL AS A SUPPRESSOR OF THE GENETIC TRAIT FOR DIABETES AND HEART DISEASE CAROLYN D. BERDANIER (12) GEORGIA SEA GRANT COLLEGE PROGRAM	$ 16,400	$ 0
CHARACTERIZATION OF VOLATILE ODOR COMPONENTS OF MENHADEN FISH OIL THOMAS C. HSIEH (35) LOUISIANA STATE UNIVERSITY	$ 37,421	$ 24,974
PREPARATION AND ELUCIDATION OF BENEFICIAL BIOLOGICAL EFFECTS OF N-3 POLYUNSATURATED FATTY ACIDS FROM MARINE SOURCES JOHN E. KINSELLA (12) CORNELL UNIVERSITY	$ 39,620	$ 65,010
FISH MYOFIBRILLAR PROTEIN AS A FOOD INGREDIENT D. HAMANN (35) NORTH CAROLINA STATE UNIVERSITY	$ 5,145	$ 40,962
FUNCTIONAL CHARACTERIZATION OF SURIMI WASTE STREAM PROTEINS T. LANIER (35) NORTH CAROLINA STATE UNIVERSITY	$ 55,696	$ 5,936
PRODUCTION OF WASHED FLESH FROM PACIFIC WHITING CRAWFORD, DAVID L. (35) OREGON SEA GRANT COLLEGE PROGRAM	$ 95,000	$ 66,800
DEVELOPMENT OF COASTAL FISH OIL RESOURCES FOR POTENTIAL U. S. HEALTH INDUSTRY TURCOTTE, J. G. (13) UNIVERSITY OF RHODE ISLAND	$ 9,000	$ 48,968
UTILIZATION OF CRAB PROCESSING WASTE FOR FEEDING CATTLE FONTENOT, J.P. (35) VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY	$ 22,625	$ 22,557

TITLE/INVES./INST		FED FUNDS	MATCHING FUNDS
COLD-ACTIVE TRYPSIN PROTEASES FROM COD (GADUS MORHUA) FOX, JAY W. UNIVERSITY OF VIRGINIA, CHARLOTTESVILLE	(11)	$ 45,342	$ 24,944
CHITIN-CHITOSAN COATED FIBERS G.G. ALLAN UNIVERSITY OF WASHINGTON, SEATTLE	(13)	$ 40,300	$ 28,700
CRAB SHELL CHITOSAN, ITS MODE OF GENE ACTIVATION LEE A. HADWIGER WASHINGTON STATE UNIVERSITY	(13)	$ 48,581	$ 17,600
TOTAL ----------		$ 571,817	$ 482,526
III. MICROBIAL AND NUTRITIONAL QUALITY			
IRON AS A TRIGGERING FACTOR OF RED TIDE BLOOMS MAYER, LAWRENCE M. UNIVERSITY OF MAINE	(6)	$ 35,514	$ 22,490
IMMUNOLOGICAL DETECTION OF THE BROWN TIDE ANDERSON, DONALD M. WOODS HOLE OCEANOGRAPHIC INSTITUTION	(7)	$ 25,300	$ 15,672
HYDROGRAPHIC LOCALIZATION OF TOXIC DINOFLAGELLATE BLOOMS IN COASTAL WATERS ANDERSON, DONALD M. WOODS HOLE OCEANOGRAPHIC INSTITUTION	(7)	$ 59,500	$ 19,342
IMMUNE RESPONSE IN GREAT LAKES FISHEATERS MARYFRAN SOWERS UNIVERSITY OF MICHIGAN, ANN ARBOR	(45)	$ 0	$ 44,015
ROLE OF SUSPENDED SOLIDS IN THE SURVIVAL AND TRANSPORT OF ENTERIC VIRUSES IN THE ESTUARINE ENVIRONMENT ELLENDER, R. D. UNIVERSITY OF SOUTHERN MISSISSIPPI	(40)	$ 21,903	$ 10,952
CHEMICO-BIOLOGICAL INTERACTIONS BETWEEN FISH AND TREATED MUNICIPAL WASTEWATER PEDDRICK WEIS NEW JERSEY MEDICAL SCHOOL--COLLEGE OF MEDICINE AND DENTISTRY	(45)	$ 10,000	$ 126,100

TITLE/INVES./INST		FED FUNDS	MATCHING FUNDS
PUBLIC HEALTH ADVISORIES: THE ROLE OF THE FEDERAL GOVERNMENT IN HUMAN HEALTH CONCERNS REGARDING SEAFOOD CONSUMPTION ROBERT E. MALOUF NEW YORK SEA GRANT INSTITUTE	(35)	$ 0 *$ 11,886	$ 0
RISK PERCEPTION AND COMMUNICATION REGARDING CHEMICALLY CONTAMINATED FISH IN LAKE ONTARIO FISHERIES BARBARA A. KNUTH CORNELL UNIVERSITY	(29)	$ 9,487	$ 14,110
MICROBIAL INDICATORS OF FECAL CONTAMINATION IN COASTAL WATERS, SEDIMENTS AND SHELLFISH M.D. SOBSEY UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL	(8)	$ 9,890	$ 22,350
EVALUATION OF PLASMID PROFILES AS A METHOD TO DETERMINE THE SOURCE OF FECAL POLLUTION IN AN ESTUARY R.K. SIZEMORE UNIVERSITY OF NORTH CAROLINA, WRIGHTSVILLE	(8)	$ 7,750	$ 8,968
CARDIOVASCULAR DISEASE RISK REDUCTION BY DIETARY FISH WNDER, ROSEMARY C. OREGON STATE UNIVERSITY, CORVALLIS	(12)	$ 43,900	$ 16,200
CAUSAL MECHANISMS OF PTYCHODISCUS BREVIS RED TIDES ON THE TEXAS COAST COX, ELENOR M. TEXAS A&M UNIVERSITY, COLLEGE STATION	(40)	$ 45,696	$ 38,583
GROWTH AND SURVIVAL OF CLOSTRIDIUM BOTULINUM IN PASTEURIZED OYSTERS HACKNEY, CAMERON VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY	(35)	$ 25,397	$ 13,880
EFFECTS OF FISH OIL FEEDING AND EPA OR DHA IN HYPERLIPIDEMIA ROBERT H. KNOPP UNIVERSITY OF WASHINGTON, SEATTLE	(13)	$ 50,747	$ 27,000

TITLE/INVES./INST		FED FUNDS	MATCHING FUNDS
CELLULAR LOCALIZATION AND MOLECULAR BIOLOGY OF DINOFLAGELLATE TOXINS BARBARA A. BOCZAR UNIVERSITY OF WASHINGTON, SEATTLE	(8)	$ 40,700	$ 14,100
STUDIES OF PSP TOXINS IN PROTOGONYAULAX JOHN LISTON UNIVERSITY OF WASHINGTON, SEATTLE	(8)	$ 29,375	$ 19,600
GREAT LAKES FOOD FISH CONTAMINANTS AND HUMAN REPRODUCTIVE OUTCOMES KANAREK, MARTY UNIVERSITY OF WISCONSIN, MADISON	(45)	$ 17,216	$ 10,448
TOTAL		$ 444,261	$ 423,810
SEA GRANT FUNDS:	$ 432,375		
*PASS-THROUGH FUNDS:	$ 11,886		
IV. HANDLING AND PROCESSING			
EXTENDING PRIME QUALITY MARKET LIFE OF SEAFOODS NORMAN F. HAARD UNIVERSITY OF CALIFORNIA, DAVIS	(35)	$ 7,824	$ 19,453
DEVELOPING CONTROLS FOR MELANOSIS IN CRUSTACEANS THROUGH ENZYMATIC MECHANISMS M. R. MARSHALL UNIVERSITY OF FLORIDA, GAINESVILLE	(35)	$ 39,050	$ 32,403
OZONE-ASSISTED DEPURATION OF RED TIDE CONTAMINATED SHELLFISH AND SEAWATER G. E. RODRICK UNIVERSITY OF FLORIDA, GAINESVILLE	(35)	$ 19,880	$ 56,691
DEVELOPMENT AND CONTROL OF LIPID OXIDATION IN MINCED MENHADEN MUSCLE HERBERT O. HULTIN	(6)	$ 40,000	$ 28,567
METHODS FOR IMPROVING THE EFFICIENCY OF SUPERCRITICAL EXTRACTION FOR THE FRACTIONATION OF FATTY ACIDS FROM MARINE OILS SYED S.H. RIZVI CORNELL UNIVERSITY	(35)	$ 9,750	$ 18,680

TITLE/INVES./INST	FED FUNDS	MATCHING FUNDS
UPTAKE AND DEPURATION OF RED TIDE PARALYTIC SHELLFISH POISONING TOXINS IN EAST COAST BIVALVE MOLLUSCS V. MONICA BRICELJ (6) STATE UNIVERSITY OF NEW YORK AT STONY BROOK	$ 54,940	$ 33,158
FURTHER STUDIES ON A BIOTECHNOLOGICAL APPLICATION OF PSEUDOMONAS SYRINAGE FOR ENERGY SAVINGS & IMPROVED QUALITY FREEZING SEAFOOD LEE, T. C. (35) UNIVERSITY OF RHODE ISLAND	$ 39,397	$ 23,230
DETERMINATION OF AUTOLYTIC DECOMPOSITION RATES IN SELECTED MID-ATLANTIC FISH SPECIES STORED UNDER ICED AND SUPER-CHILLING TEMPERATURES FLICK, GEORGE J. (35) VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY	$ 31,182	$ 23,735
TOTAL ----------	$ 242,023	$ 235,917
GRAND TOTAL	$ 1,342,401	$ 1,213,653

TOTAL SEA GRANT FUNDS: $ 1,330,515

*TOTAL PASS-THROUGH FUNDS: $ 11,886

TITLE/INVES./INST	FED FUNDS	MATCHING FUNDS
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