# PROGRESS REPORT

## June 1, 1979 to May 31, 1983

UNIVERSITY OF HAWAII SEA GRANT COLLEGE PROGRAM

## CONTENTS



**COVER:** Fishermen catching aku (skipjack tuna) using pole-and-line method. This method, while environmentally sound, is not the most efficient for catching this fish. Aku is the principal commercial fishery in Hawaii.




This report describes research and other activities conducted by the University of Hawaii Sea Grant College Program under Institutional Grant Nos. NA79AA-D-00085 and NA81AA-D-00070 from NOAA Office of Sea Grant, Department of Commerce. Additional support was provided by the Hawaii Legislature, the University of Hawaii, the Hawaii Department of Land and Natural Resources, the Hawaii Department of Planning and Economic Development, the National Marine Fisheries Service Honolulu Laboratory, and the University of Guam, as well as from public and private individuals and organizations.

A Report on the Activities of the University of Hawaii Sea Grant College Program: Years 12 to 15

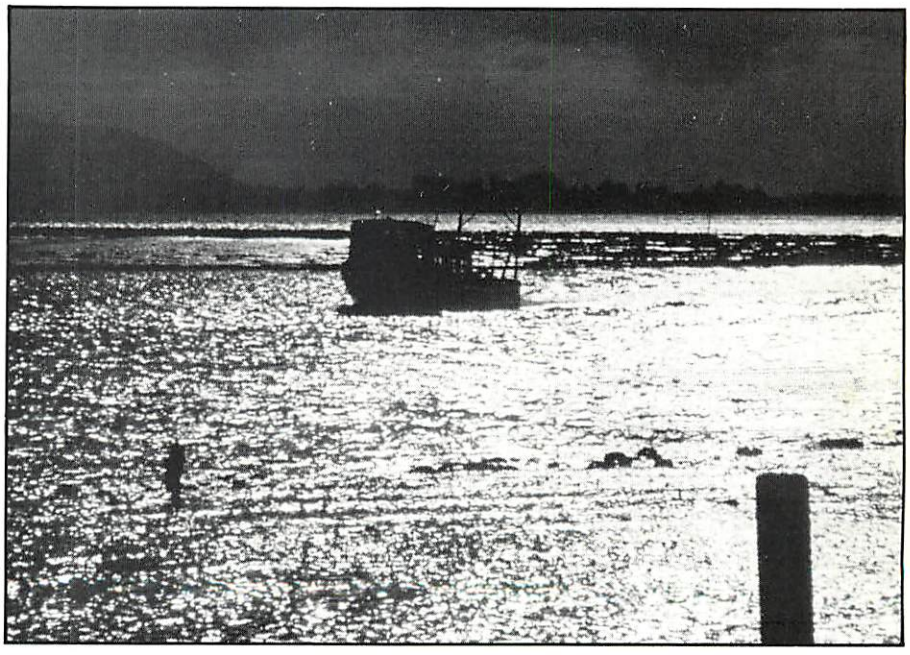
University of Hawaii Sea Grant College Program

# PROGRESS REPORT

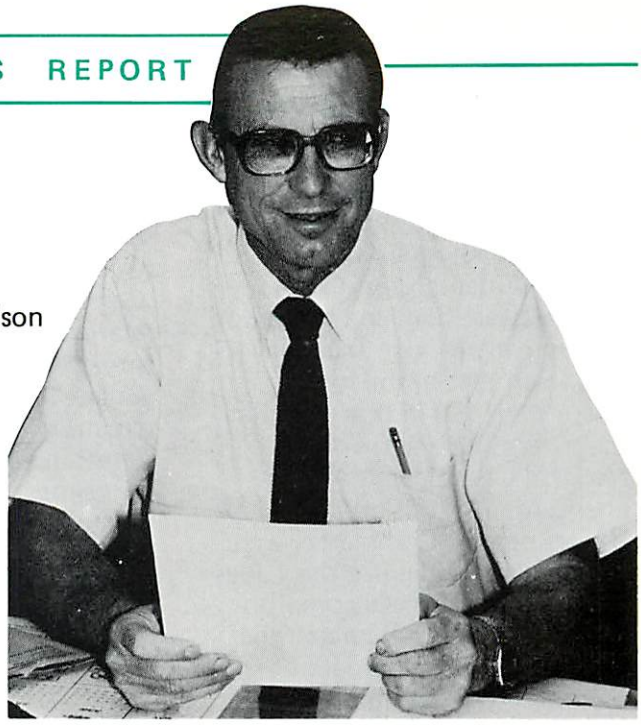
## June 1, 1979 to May 31, 1983

Sea Grant Miscellaneous Report
**UNIHI-SEAGRANT-MR-85-01**

April 1985



# THE DIRECTOR'S REPORT



Jack R. Davidson

The National Sea Grant Program and the University of Hawaii Sea Grant Program were initiated in 1968 in an era of commitment to wise use and management of marine resources. The Stratton Commission report, *Our Nation and the Sea,* provided a set of national goals and a framework for action programs to accomplish these goals. The state of Hawaii responded with a parallel examination of its marine concerns and opportunities. It then set forth its goals and recommendations in *Hawaii and the Sea.*

By 1972, the national situation had changed. The executive branch's interest in the oceans was on the ebb and many of the new programs were faltering. Thus, the 1972-76 period saw the development and management of the nation's ocean resources relegated to a relatively low priority level by the federal administration. Due to strong congressional interest and support, however, Sea Grant continued to grow at a modest rate during this period. Meanwhile, Hawaii maintained its support and success ratio for marine-related ventures at the same or even slightly increased levels. The economic and social benefits provided by Sea Grant in the early years demonstrate the impact this unique federal-state program can make. Examples include the development of a viable coral jewelry industry and the emergence of a fledgling but growing aquaculture industry. In another area, the Quality of Coastal Waters Program produced the information needed to support the development of special water quality standards for Hawaii's nearshore waters. This permitted saving many millions of dollars in capital and operational costs for sewage disposal. Innovative marine educational efforts at all appropriate levels facilitated local marine educational program development and projected participating personnel into regional and national advisory roles.

The significant portion of early Sea Grant-supported research efforts was geared to seeking early results and solutions utilizing the resources available within close proximity to the main Hawaiian islands. However, even before the close of the first decade, the international community had also reaped a bountiful harvest from UH Sea Grant efforts. Notable examples are the development of *Eucheuma* farming in the Philippines and Asia and the initial impetus given to Japan's man-in-the-sea program through a cooperative program of diving research. The Law of the Sea Institute was accorded international recognition as an influential forum on the law of the sea. In other areas, programs designed for solving national problems were adopted by the international community. Most significant was the floating city concept which influenced Japan's commercial development of the semi-submerged platform ferry and industrial applications of stable platforms, as well as the evident transfer of the latter technology to Europe for use in the Condeep designs.

By 1979, the Nation again appeared to be moving towards a commitment to a viable national ocean program. The Fishery Conservation and Management Act of 1976 had extended the nation's fisheries jurisdiction out to 200 miles. Developments in international law of the sea negotiations and a westward shift of trade had focused new attention on the Pacific rim and Pacific island nations. A new report of the National Advisory Committee on Oceans and Atmosphere indicated the importance of the ocean to the national economy and international strength. Successful testing of the Mini-OTEC (ocean thermal energy conversion) concept made ocean energy and ancillary use of the cold deep ocean water major topics and ancillary use of the cold deep ocean water major topics of interest. A significant role was projected for deep ocean manganese resources in meeting future metal needs.

## THE SECOND DECADE: PROSPECTS FOR BROADENING PROGRAM SCOPE

The second decade for the nation's Sea Grant programs opened on a hopeful note. Congressional interest in the programs was high and there was reason to expect continued favorable treatment in the future. There were also indications that the parent institutions, the National Oceanic and Atmospheric Administration and the Department of Commerce, were beginning to recognize the values stemming from the accomplishments of each program and the unique access each program offered to the nation's university systems.

The 1979-81 UH Sea Grant College Program's biennial proposal reflected these perceptions with the scope of interest broadened to include marine resources development opportunities and concerns throughout the Hawaiian Archipelago and the western and southern Pacific. The areas of emphasis included fisheries development and associated environmental impacts, especially in the Northwestern Hawaiian Islands; aquaculture, including culture of coldwater species in deep ocean water upwelled onto the OTEC platform; and the development of legal regimes for ocean resource development and use in the Pacific basin. Other areas of interest included diving physiology and the potential environmental impact of manganese nodule processing and OTEC development off the island of Hawaii.

The marine education component, which continued to include the highly successful Marine Option Program, rounded out its accomplishments in curricula development with a marine science unit for Hawaii's intermediate schools. Teacher training was extended to the American Trust Territory of the Pacific Islands.

The advisory service unit had grown with the research program, with agents in each of Hawaii's counties and in addition had extended the Sea Grant information network to the western Pacific region with agents in Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands. A joint University of Hawaii/University of Guam Sea Grant Program was formed to further develop research, extension, and educational programs to serve the western Pacific. An international Sea Grant Program was designed and implemented to permit transfer of knowledge and skills to the 11 island nations served by the University of the South Pacific.

However, major setbacks to the program occurred with the presidential and congressional elections of 1980. Preoccupation with balancing the federal budget led to a recommendation to eliminate the National Sea Grant College Program. This was in spite of the recommendations of the conservative Heritage Foundation in its post-election assessment of the federal programs for the new administration:

> *The Sea Grant Program has an impressive record of success, primarily because it is based largely on local priorities and needs. It operates in partnership with State and local governments, private industry, universities, organizations and individuals concerned with or affected by ocean and coastal resources. The Congress makes regular requests of Sea Grant for information.*
>
> *A key element of Sea Grant is its outreach mechanism whereby results of research are provided to users in industry, government agencies and the general public.*
>
> *Sea Grant funding should be increased by 10 percent per year in real terms for the next five years.*

Once again the program depended on the Congress for support and, in this instance, for survival. Even with congressional interest and support, heavy pressure to cut spending resulted in pared down budgets and curtailed programs. As a result, many of the programs and projects proposed for the 1981-83 biennium were dropped, the international program was scheduled for phasing out, and efforts to expand or even maintain the services which had been extended to the American communities in the western Pacific were severely curtailed.

In face of these cuts, special efforts were made to protect the commitments to the state of Hawaii to keep up the momentum in the prawn aquaculture research and extension program and to the tripartite agencies to continue working together on the NWHI fisheries investigations. It was evident by this time that the NWHI studies were important to the eventual development and management of archipelagic resources. Moreover, the timing and focus of these studies made them and the participating scientists major sources of data and expertise for the development of fisheries management plans mandated under the Fishery Conservation and Management Act of 1976.

The period between 1981 and 1983 also saw a narrowing of programmatic scope as shown in the guidelines issued by the National Sea Grant College Program. These guidelines generally directed less emphasis on marine environmental concerns and more focus on marine resources development. They dictated more attention to projects and programs of national consequence and less on serving state needs. At the same time the guidelines and directives called for improved scientific quality of proposals and, paradoxically, early results and applications. The guidelines mandated a less comprehensive

focus on marine education in contrast to the emerging activities in the Sea Grant system. The partnership aspects of the program appeared to be given less credence and less consideration in the evolving review processes. This was in spite of the increasing state and regional commitments to the program as manifested by the program's matching support.

In this atmosphere of narrowing scope — declining real dollars and increasing control of programmatic content — difficulties in program planning to maintain momentum, to attract matching monies, and to make a significant impact on regional problems increased. Plans to expand the focus on Pacific basin policy issues were delayed; involvement with the emerging ocean thermal energy conversion program was kept to a minimum; the long-term diving physiology program was reduced in scope; and the end of the international program was foreshadowed. In addition, the western Pacific program, with the exception of the extension project which became part of the Guam program, was cut back; work with manganese nodules was prepared for phasing out; environmental programs were cut drastically; and plans to implement a substantial program in marine corrosion in the following biennium were dropped.

Despite the many set-backs during the quadrennium, the UH Sea Grant College Program was responsible for a major increase in marine awareness in the state and region. The program initiated research efforts which have resulted in the development of new knowledge to facilitate policy formulation and decisions, foster economic development, and manage marine resources. In addition, the program was a significant contributor in the development of the state's and nation's scientific talent and expertise in marine fields.

## THE UH SEA GRANT 1979-83 PROGRAM

The UH Sea Grant 1979-83 quadrennial program consisted of a tripartite of research, advisory, and educational programs as proscribed for a Sea Grant College. The quadrennial program consisted of 54 research projects under four general topic areas and the University of Guam component:

1. Marine resources development (30)
2. Pacific basin policy studies (4)
3. Marine technology research and development (6)
4. Marine environmental research (10)
5. University of Guam (4)

These programs and projects were undertaken at a cost of $6,953,700.

The 30 resource development projects included two major multidisciplinary programs: the Hawaiian Prawn Aquaculture program with six subprojects focusing on basic production and management issues; and the Northwestern Hawaiian Islands Fisheries Investigations. The latter consisted of 13 projects designed to complement the federal-state tripartite goals for development and management of the area resources. Other research areas included projects on baitfish, ciguatera poisoning, and deep ocean manganese nodules.

The five marine educational projects and programs represented a sharp reduction of effort in this area compared with previous years. The Extension program operated a statewide network of field agents and support staff in each of the counties of the state. The 1979-83 period was the beginning of a shift in each of the counties of the state. This period saw the Sea Grant Extension staff shift from generalists to specialists. County advisory committees were formed and the appropriate county programs developed. Extension programs for Samoa, the Marianas, and Guam were developed. The latter effort was curtailed as budgets contracted, however.

The projects and programs of the quadrennium are listed in Table 1 and a general budget summary by activity is provided in Table 2.

During the quadrennium, 312 undergraduate students and 123 graduate students were involved in one or more of the projects funded under Sea Grant (Table 3). The research and education functions merge in the training of graduate students, who earn baccalaureate, masters, or doctoral degrees while participating in and contributing to the research progress. The educational process continues in the research associate relationship where postdoctorates and other postgraduates join with faculty in research endeavors on a more nearly peer basis.

Table 4 summarizes the degrees earned by students who participated in Sea Grant programs and projects. On the average, undergraduates would not be as heavily involved in a Sea Grant project or program as graduate students. Graduate student funding, work commitments, and degree of involvement in a project are much higher. As shown in Table 4, 50 of the students who earned degrees in the 1979-83 quadrennium secured employment in private firms and 70 in academic or public institutions.

To facilitate advanced planning and to meet short-range opportunities and needs, the Sea Grant director manages a small amount of funds for planning, proposal development, and "rapid response" grants. These projects are listed on Table 5. Although the sought-for results are often grounds for a more comprehensive research proposal, a number of publications and reports arose from these projects.

TABLE 1. PROJECT STATUS AND RESULTS OF RESEARCH

| Project Title | Investigator(s) | Status 12 | 13 | 14 | 15 | Product(s) |
|---|---|---|---|---|---|---|
| MARINE RESOURCES DEVELOPMENT | | | | | | |
| Primary and Secondary Plankton Productivity and Potential Fishery Yields in the Hawaiian Archipelago | J. Hirota | C | | | | CP |
| Reef and Shelf Benthic Ecology of the Hawaiian Archipelago | R.W. Grigg | O | C | | | CP |
| Trophic Analysis of Shallow-water Fish Communities in the Northwestern Hawaiian Islands: Effects of Natural and Human Predation | J.D. Parrish, L.R. Taylor, Jr. | N | O | O | C | CP |
| Survey and Assessment of the Green Sea Turtle Resource of the Northwestern Hawaiian Islands | G.H. Balazs | C | | | | Papers |
| Population Biology of Spiny Lobsters Throughout the Hawaiian Archipelago | C.D. MacDonald, J.S. Stimson | C | | | | 10 JCs and TPs (published); 5 JCs (in prep.); thesis; CP |
| Development of a Biological Basis for Managing the Handline Fishery for Snapper and Grouper Populations in the Hawaiian Archipelago | P. Helfrich | O | C | | | CP |
| Genetic Aspects of Population Structure of Four Species in the Northwestern Hawaiian Islands | J.B. Shaklee | O | C | | | CP |
| Economics of Fisheries Development in the Hawaiian Archipelago | J.R. Davidson, S. Comitini | O | O | C | | CP |
| Laboratory and Field Test Studies in Ciguatoxigenic Dinoflagellates in the Hawaiian Archipelago | A.H. Banner | N | O | O | C | CP |
| Hydrography, Primany Productivity, and Inshore Planktivorous Fish Production at French Frigate Shoals and Kawaihae Bay, Hawaii | J. Hirota | | N | C | | CP |
| Benthic Primary Productivity at French Frigate Shoals | R.W. Grigg | | | N | C | 2 CPs |
| Hawaiian Seabird Bioenergetics: The Impact of Seabirds on Marine Food Resources | G.C. Whittow | | | N | C | 2 papers |
| Institutional Policymaking on the Management of the Northwestern Hawaiian Islands | R.T. Pfund | | | N | C | Article; proceedings paper; dissertation; CP |
| Hawaiian Prawn Aquaculture Program — Biological Bases of Production | D.M. Karl, E.A. Laws, S.R. Malecha, R.M. Nakamura, S.E. Olbrich, J.B. Peebles III, J.J. Polovina | N | O | O | C | CP |
| Low Temperature Storage of Freshwater Prawn, *Macrobrachium rosenbergii* | W.K. Nip | | | N | C | |
| Feeds and Supplements for Optimum Prawn Pond Production | R.W. Stanley | | | N | O | |
| Technology Transfer of *Eucheuma* Farming Information to Ponape* | M.S. Doty | | | O | C | |
| Analysis of Potential Organic and Inorganic Toxicants in Hawaiian Shrimp and Prawn Aquaculture Systems | H. Zeitlin | | | N | C | |
| OTEC-Aquaculture Macroalgae Experiments† | P. Helfrich | | | O | C | |
| OTEC Coldwater Fish Culture† | P. Helfrich | | | O | O | |
| Aquacultural Engineering for Prawn Farming | J.K. Wang | | | N | C | Roller size grader |
| Culture of Baitfish | W.J. Baldwin | C | | | | |
| Hydrometallurgical Separation of Metals from Ferromanganese Nodules | H. Zeitlin | O | C | | | 4 students from the University Hawaii (2) and Arizona (2) have or will receive degrees based on their research on manganese nodules. |
| A Study of the Potential Enhancement and Aggregation of Fishery Resources Due to Floating Objects | T.A. Clark | | N | C | | |

*Began in Year 11; not funded in Year 12; continued in Year 13 as "*Eucheuma* Farming in Ponape"; retitled in Year 14 as "Technology Transfer of *Eucheuma* Farming Information to Ponape"

†Began in Year 13 as "OTEC-Cold-Water Aquaculture Experiments"; continued in Year 14 as two separate projects, "OTEC-Aquaculture Macroalgae Experiments" and "OTEC Coldwater Fish Culture"

Note: C = completed, O = ongoing, N = new; CP = conference paper, JC = journal contribution, TP = technical paper

TABLE 1. PROJECT STATUS AND RESULTS OF RESEARCH (continued)

| Project Title | Investigator(s) | Status 12 | 13 | 14 | 15 | Product(s) |
|---|---|---|---|---|---|---|
| Determination of Prey Odor Components to Increase the Effectiveness of Fish Aggregation Buoys and Live Bait | P. Helfrich | | | N | C | |
| An Experimental Study of the Effect of Predation by Muraenid Eels on Reef Fish Population Density, Size Distributions, and Species Composition in Hawaii | J.S. Stimson | N/C | | | | |
| *Eucheuma* Farming in Ponape* | M.S. Doty | | O | | | |
| OTEC-Cold-Water Aquaculture Experiments† | J. Caperon | | N | | | |
| Marine Metabolites as Potential Pest Control Agents | P.J. Scheuer | | | N | O | |
| Pelagic Fish Migration Monitoring | R.E. Brock | | | | | |
| PACIFIC BASIN POLICY STUDIES | | | | | | |
| Law of the Sea Institute | J.P. Craven | O | O | O | O | |
| An Investigation of the Legal Issues and Jurisdictional Disputes in the Pacific | J.M. Van Dyke | N/C | | | | |
| Law of the Sea Issues Affecting the Pacific Nations | J.M. Van Dyke | | N/C | | | 2 papers |
| Issues of International Environmental Law Affecting the Ocean Resources of the Pacific Basin: Dumping and Storage of Nuclear Wastes | J.M. Van Dyke | | | N | C | JCs; Legal Constraints on Ocean Disposal of Nuclear Wastes is being brought to completion. An Executive Summary will be circulated to the leaders of the Pacific island communities. |
| MARINE TECHNOLOGY RESEARCH AND DEVELOPMENT | | | | | | |
| Exogenous Gas Bubble Disease: Physical Factors in the Etiology, Detection, and Prevention | D.E. Yount | O | O | C | | |
| Inert Gas Elimination and Thresholds for Decompression-Induced Venous Gas Emboli | Y.C. Lin | O | O | O | C | |
| Investigation of Methods to Improve the Treatment of Decompression Sickness Based Upon the Physics of Dissolution of Gas Bubbles in Gelatin | E.L. Beckman | | N | C | | |
| The Physics of Gas Bubbles: Medical Applications | D.E. Yount | | | N | O | |
| The Effect of Terrain Roughness on Tsunami Run-up and Inundation | C.L. Bretschneider | O | C | | | Paper; users guide |
| A Slanted Look at Ocean Wave Forces on Pipes | R.A. Grace | C | | | | |
| MARINE ENVIRONMENTAL RESEARCH | | | | | | |
| Pathogenic Human Enteric Viruses in Hawaiian Ocean Waters: Role and Effects of Antiviral Agent(s) | P.C. Loh, L.S. Lau | C | | | | |
| Microbiological Indicator for Ascertaining Fecal Contamination of Marine Recreational Waters | R.S. Fujioka | C | | | | |
| Marine Mollusks as Indicator Organisms in Benthic Communities | E.A. Kay | C | | | | |
| The Significance of the Bactericidal Effect of Sunlight on Indicator and Pathogenic Bacteria in Marine Waters on Measurements and Interpretations of Water Quality | R.S. Fujioka | N | C | | | |
| Distribution, Isolation, and Characterization of the Natural Marine Antiviral Agents (MAVAs) from Hawaiian Ocean Waters and Other Pacific Regions | P.C. Loh | N | O | C | | 2 articles |
| Response of the Benthic Ecosystem to the Sand Island Sewage Outfall: A Community Metabolism Approach | S.V. Smith | | | N | C | |
| A Geological and Geochemical Assessment of Proposed Manganese Tailings Ocean Dumping Sites in the Puna Canyon and Kawaihae Basin | J.E. Andrews | | | N | C | Dissertation |

TABLE 1. PROJECT STATUS AND RESULTS OF RESEARCH (continued)

| Project Title | Investigator(s) | Status 12 | 13 | 14 | 15 | Product(s) |
|---|---|---|---|---|---|---|
| Ocean Dumping of Manganese Nodule Processing Plant Tailings: A Preliminary Assessment of Environmental Concerns | K.E. Chave | | | N | C | |
| Hydrology, Chemistry, and Microbiology of Geothermal Systems on the Submarine Rift Zones of Kilauea, Mauna Loa, and Haleakala Volcanoes | G.M. McMurtry | | | N | O | Paper |
| Bacteria in Marine Fouling and Corrosion of Copper-Nickle Alloy CA706 | L.R. Berger | | | N | C | |
| MARINE EDUCATION AND TRAINING | | | | | | |
| Marine Option Program | J.J. McMahon | O | O | O | O | |
| Hawaiian Backyard Aquaculture Program | J.W. Hunt | | | N | C | |
| Ho'i Ana Ike Kai — Return to the Sea | R.T. Pfund | O | C | | | 2 teaching units |
| Development of a New Course in Underwater Technology | E.K. Noda | C | | | | 9 students trained |
| Development and Pilot Testing of Fishing and Related Instructional Materials | M.E. Naughton | N/C | | | | 2 courses |
| ADVISORY SERVICES | | | | | | |
| Marine Advisory Program | P.A. Pratte | O | O | O | O | |
| Western Pacific Marine Advisory Program | P.A. Pratte | N | C | | | |
| Development of Freshwater Prawn (*Macrobrachium rosenbergii*) Advisory Services | J.R. Davidson | | N | O | C | |
| Marine Education at the Waikiki Aquarium: A Guide to the Living Exhibits | L.R. Taylor, Jr. | | | N | C | Guidebook |
| Cooperative Extension Service/Marine Advisory Program for Maui County | G.M. Nakasato | | | N/C | | Reports; workshops |
| PROGRAM DEVELOPMENT, MANAGEMENT, AND ADMINISTRATION | | | | | | |
| Program Development, Management, and Administration | J.R. Davidson | O | O | O | O | |
| The Publications Program | K.Y. Tanoue | O | O | O | O | |
| UNIVERSITY OF HAWAII/UNIVERSITY OF GUAM SEA GRANT PROGRAM | | | | | | |
| University of Guam: Marine Advisory Program | P.A. Pratte | | | N | O | Workshop |
| Evaluation of the Potential of Two Species of *Gracilaria* (Rhodophyta) for Mariculture in the Mariana Islands | J.R. Davidson | | N | O | C | 2 theses |
| Importance of Residence Time of Water to the Productivity, Biomass, and Structure of Planktonic and Benthic Marine Nearshore Communities | C.E. Birkeland | | | N/C | | |
| Preservation of Rare Coral Species by Transplantation and Examination of Their Recruitment and Growth | R.H. Randall | | | N/C | | |
| Assessment of Resource Stocks in Three Marine Ecosystems in the Marianas Archipelago: Patterns of Variation and Interaction | S.S. Amesbury | | | | N/C | |

TABLE 2. GENERAL BUDGET SUMMARY: YEARS 12 TO 15

| | Year 12 | | Year 13 | | Year 14 | | Year 15 | |
|---|---|---|---|---|---|---|---|---|
| | NOAA Grant Funds | Matching Funds | NOAA Grant Funds | Matching Funds | NOAA Grant Funds | Matching Funds | NOAA Grant Funds | Matching Funds |
| **MARINE RESOURCES DEVELOPMENT** | | | | | | | | |
| Aquaculture | $ 210,896 | $ 281,604 | $ 251,817 | $ 275,354 | $ 169,500 | $ 273,147 | $ 190,403 | $ 248,883 |
| Living Resources (non-aquaculture) | 331,695 | 245,700 | 352,368 | 210,189 | 271,186 | 155,365 | 214,210 | 119,162 |
| Mineral Resources | 45,445 | 20,263 | 44,177 | 19,241 | | | | |
| Marine Biomedicinals and Extracts | | | | | 40,303 | 26,615 | 38,077 | 32,323 |
| **PACIFIC BASIN POLICY STUDIES** | | | | | | | | |
| Ocean Law | 52,436 | 63,605 | 81,560 | 51,960 | 72,000 | 82,227 | 69,755 | 113,726 |
| Socio-Political Studies | | | | | 8,981 | 4,956 | 11,092 | 5,218 |
| **MARINE TECHNOLOGY RESEARCH AND DEVELOPMENT** | | | | | | | | |
| Ocean Engineering | 45,372 | 18,160 | 38,794 | 18,217 | 10,392 | 34,839 | 12,305 | 39,430 |
| Resources Recovery and Utilization | 114,934 | 59,666 | 151,809 | 84,667 | 111,594 | 74,914 | 92,073 | 75,517 |
| **MARINE ENVIRONMENTAL RESEARCH** | | | | | | | | |
| Ecosystems Research | | | 14,634 | 7,772 | 80,931 | 139,468 | 53,038 | 80,051 |
| Pollution Studies | 88,842 | 69,637 | 57,000 | 56,031 | 46,122 | 49,614 | 7,956 | 16,504 |
| Environmental Models | | | | | 96,879 | 63,425 | 127,018 | 69,551 |
| **MARINE EDUCATION AND TRAINING** | | | | | | | | |
| College Level | 17,956 | 13,133 | | | | | | |
| Vocational Marine Technician Training | 7,500 | 18,851 | | | | | | |
| Other Education | 62,617 | 66,067 | 57,475 | 88,316 | 51,111 | 114,378 | 53,048 | 115,710 |
| **ADVISORY SERVICES** | | | | | | | | |
| Extension Programs | 399,714 | 88,477 | 524,341 | 194,506 | 435,602 | 213,666 | 469,426 | 281,737 |
| Other Advisory Services | 101,221 | 27,021 | 115,678 | 7,898 | 107,562 | 18,079 | 132,498 | 9,519 |
| **PROGRAM MANAGEMENT AND DEVELOPMENT** | | | | | | | | |
| Program Administration | 173,072 | 59,935 | 197,347 | 85,189 | 202,837 | 89,611 | 239,101 | 123,844 |
| TOTAL | $1,651,700 | $1,031,119 | $1,887,000 | $1,099,340 | $1,705,000 | $1,340,304 | $1,710,000 | $1,331,175 |

TABLE 3. NUMBER OF STUDENTS INVOLVED IN SEA GRANT PROJECTS: YEARS 12 TO 15

| Discipline | Year 12 | | Year 13 | | Year 14 | | Year 15 | |
|---|---|---|---|---|---|---|---|---|
| | UG | G | UG | G | UG | G | UG | G |
| Agriculture | | | | | 1 | | 1 | |
| Agricultural Engineering | | | | | | 2 | | 1 |
| Animal Science | 1 | | 2 | 1 | | | 2 | |
| Anthropology | | | | | | | 1 | |
| Aquaculture | | | | | 1 | | | 5 |
| Art | | | | | 1 | | | |
| Asian Studies | 1 | | | | | | | |
| Biological Oceanography | | | | 2 | | 2 | | |
| Biology | 2 | | 12 | 1 | 10 | | 6 | |
| Biology/Chemistry | | | | | 2 | | | |
| Botany | | | | | | | 2 | |
| Business | | | | 1 | 4 | | 4 | |
| Business Economics | 1 | | | | | | | |
| Chemistry | | 5 | 3 | 2 | 2 | 6 | | 3 |
| Chinese | | | | | 1 | | | |
| Civil Engineering | | | 1 | | 1 | | | |
| Communications | | | | | 1 | | | |
| Computer Science | 1 | 1 | | | | | | |
| Economics | | | 1 | | | | | |
| Education | | | | | | | 2 | |
| Engineering | | | | | 1 | | | |
| English | | | | | 1 | | | |
| English as a Second Language | | | | | | | | 1 |
| Environmental Studies | | | | 1 | | | 2 | |
| Fisheries | | 1 | | 1 | | | | |
| Food Science | | | 1 | | | 2 | | 2 |
| French | 1 | | | | | | | |
| General Agriculture | 2 | | | | | | | |
| Geography | | | | | | | 4 | |
| Geology | | 1 | 1 | | | | 4 | |
| Health, Physical Education, and Recreation | | | 1 | | 2 | | | |
| Horticulture | 1 | | | | | | | |
| Japanese | | | | | | | 1 | |
| Law | | 3 | | | | 5 | | 4 |
| Liberal Arts | | | 20 | | 28 | | 18 | |
| Liberal Arts/Marine Science | | 1 | | | | | | |
| Liberal Studies | 9 | | | | 1 | | | |
| Management | | | | | 1 | | | |
| Marine Biology | | | 1 | 1 | 1 | | | |
| Marine Technology | | | | | 3 | | 1 | |
| Marketing | | | | | | | 1 | |
| Mathematics | | | 1 | | | | | |
| Mechanical Engineering | | | | | 1 | | 1 | |
| Medical Technology | 1 | | 1 | | 1 | | | |
| Microbiology | | | | | 1 | | 1 | |
| Music | | | | | | | 1 | |
| Nursing | | | | 1 | | 1 | | |
| Ocean Engineering | | 4 | | 1 | | 1 | | 1 |
| Oceanography | | 12 | 1 | 4 | 1 | | | 5 |
| Ocean Studies | | | | | | | 1 | |
| Pacific Marine Studies | | | | | | | 1 | |
| Physics | | | 2 | | 1 | 1 | 2 | 1 |
| Physiology | | | | | 1 | | | 2 |
| Political Science | | | | | | | | 1 |
| Pre-Medicine | | | 1 | 2 | | | | |
| Psychobiology | | | 1 | | | | | |
| Psychology | | | 2 | 3 | | | 2 | |
| Psychology/Chinese | | | | | | | 1 | |
| Public Health | | 1 | | | | | | |
| Science Education | | | | 1 | | | | |
| Toxicology | | | | | | 1 | | |
| Travel Industry Management | | | | | | | 1 | |
| Tropical Agriculture | | | 3 | | 2 | | | |
| Tropical Crop | | | | | | | 1 | |
| Zoology | 13 | 1 | 24 | 9 | 23 | 9 | 19 | 6 |
| Other (High School) | | | | | | | 1 | |
| Unknown | 3 | 2 | 6 | 3 | 5 | | 5 | 2 |
| TOTAL | 36 | 32 | 85 | 33 | 99 | 29 | 92 | 29 |

Note: UG = undergraduate, G = graduate

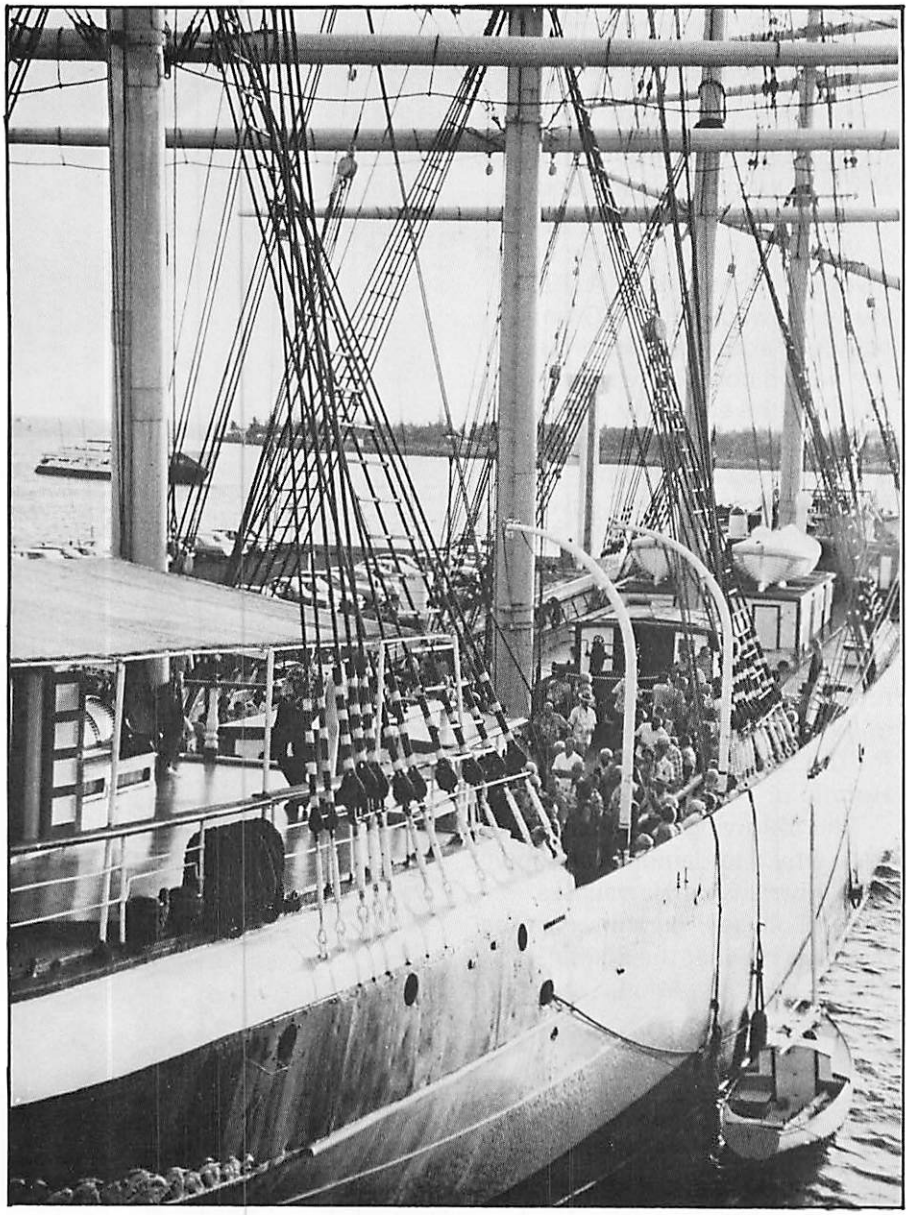
TABLE 4. EMPLOYMENT STATUS OF STUDENTS INVOLVED IN SEA GRANT PROJECTS: YEARS 12 TO 15

| Discipline | Degree Earned/to be Earned: Years 12 to 15 | | | | | | | | Employer: Years 12 to 15 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AA | AS | BA | BS | MS | JD | PhD | Unknown | Academic Institution | Private Firm | Public Service | Unknown |
| Agricultural Engineering | | | | | 1 | | | | 1 | | | |
| Animal Science | | | | | | | | 1 | | | | 1 |
| Art | | | 1 | | | | | | | | 1 | |
| Biology | | | | 3 | | | 1 | 4 | 5 | 3 | | |
| Biological Oceanography | | | | | | | 2 | | | 2 | | |
| Chemistry | | | | 3 | 6 | | 7 | 1 | 7 | 7 | 2 | 1 |
| Chinese | | | | | | | | 1 | | | | |
| Chinese/Psychology | | | 1 | | | | | | | 1 | | |
| Computer Science | | | 1 | | | | | | | 1 | | |
| Electrical Engineering | | | | 1 | | | | 1 | | 1 | 1 | |
| Engineering | | | | | | | | 1 | | 1 | | |
| Environmental Studies | | | 1 | | | | | | | 1 | | |
| Food and Nutritional Sciences | | | | | 2 | | | | 2 | | | |
| Geography | | | 1 | | | | | 1 | | 2 | | |
| Geology/Geophysics | | | | | | | | 1 | | 2 | | |
| Health, Physical Education, and Recreation | | | | 1 | | | | | | | 1 | |
| Journalism | | | 2 | | | | | | | 1 | 1 | |
| Law | | | | | | 3 | | | | 2 | 1 | |
| Liberal Arts | 8 | | | | | | | 3 | 3 | 6 | 2 | |
| Liberal Studies | | | 6 | | | | | 3 | 5 | 4 | | |
| Marine Tech | | 2 | | | | | | | 1 | 1 | | |
| Microbiology | | | | | | | | 1 | 1 | | | |
| Ocean Engineering | | | | | 1 | | 1 | | | 1 | 1 | |
| Oceanography | | | | | 4 | | 4 | | 3 | 3 | 2 | |
| Ocean Studies | | | 1 | | | | | | | 1 | | |
| Physics | | | | | | | 2 | | 1 | 1 | | |
| Physiology | | | | | | | 2 | | 2 | | | |
| Political Science | | | | | | | | 2 | 2 | | | |
| Respiratory Therapy | | | | 1 | | | | | | 1 | | |
| Tropical Agriculture | | | | | | | | 2 | | 1 | 1 | |
| Zoology | | | 10 | 1 | 8 | | 3 | 9 | 16 | 9 | 6 | |
| TOTAL | 8 | 2 | 24 | 10 | 21 | 3 | 22 | 31 | 49 | 50 | 21 | 2 |

Note: AA = Associate of Arts, AS = Arts and Sciences, BA = Bachelor of Art, BS = Bachelor of Science, MS = Master of Science, JD = Juris Doctor, PhD = Doctor of Philosophy

TABLE 5. PROGRAM MANAGEMENT RAPID RESPONSE PROJECTS: YEARS 12 TO 15

| Project | Investigator(s) | Amount |
|---|---|---|
| **YEAR 12** | | |
| Sea Grant Association Slide Show | R. Pfund | $ 680 |
| Dissemination of High School Marine Science Studies Curriculum (HMSS) | F. Sullivan | 1,200 |
| Bubble Dissolution Physics in Gelatin | E. Beckman | 3,661 |
| Sea Trek Hawaii Teachers' Guide | D. Pendleton | 2,712 |
| Feasibility of Bullfrog Culture in Hawaii | B. Culley | 588 |
| Freshwater Prawn Farming Workshop | J. Wiltshire | 1,460 |
| DUMAND Symposium | V. Peterson | 2,000 |
| Ciguatoxin Studies | A. Banner | 2,100 |
| NWHI Bird Research | S. Conant | 1,350 |
| Coastal Geology | J. Kraft | 3,500 |
| Control of the Mud Blister Worm, *Polydora websteri*, in Hawaiian Oyster Culture | J. Brock | 3,883 |
| Computer Correlations of Reef Fish Abundance with Habitat Characteristics | K. Carpenter | 3,728 |
| Olfactory Response to Amino Acids and Natural Prey Odors in Pelagic Marine Fishes | R. Brill | 1,161 |
| OTEC Implementation in the US Pacific Islands | J. Craven | 2,783 |
| Ponape *Eucheuma* Farming Project | M. Doty | 3,988 |
| Professional Correspondence | J. Craven | 17,840 |
| Palau Marine Education Workshops | E. Chave, C. McCord | 2,611 |
| Travel to Giant Prawn Conference in Bangkok | Y. Shang | 500 |
| Updating the Economic Study of the Development of Prawn Farming in Hawaii | Y. Shang | 1,873 |
| Examination of Marine Zooplankton Biomass from Hawaii to Alaska (Oceanic Training for Two High School Students) | K. Hunt | 1,000 |
| Manganese Nodule Research | J. Wiltshire | 3,699 |
| Baitfish Project Overrun | W. Baldwin | 400 |
| Microfiche Readers for Two Hawaii DOE Districts | J. McMahon | 389 |
| NWHI Site Reviewer | J. Magnuson | 900 |
| Northwestern Hawaiian Islands Resource Investigations Symposium | R. Grigg | 1,124 |
| OTEC Aquaculture Experiments | J. Caperon | 2,991 |
| Additional Support for Study of Snappers and Groupers in NWHI | P. Helfrich | 1,935 |
| Environmental Survey Techniques for Coastal Water Assessment Conference | R. Fujioka | 3,000 |
| Completion of Acrylic Aquarium | R. Knapp | 720 |
| **YEAR 13** | | |
| Additional Funds for "Hydrography, Primary Productivity, and Inshore Planktivorous Fish Production at French Frigate Shoals and Kawaihae Bay, Hawaii" | J. Hirota | 8,500 |
| Backyard Aquaculture Program | J. Hunt | 5,500 |
| Graduate Student Support for Eel Study Project | J. Stimson | 2,508 |
| Mokauea Island Fishpond Project and Supplies | S. Maynard | 11,463 |
| Technician for Spiny Lobster Research at French Frigate Shoals | C. MacDonald | 6,950 |
| Administrative Assistant and Research Assistant for Northwestern Hawaiian Island Fisheries Investigations | R. Grigg | 8,458 |
| Marine Education at Waikiki Aquarium: A Guide to Living Exhibits | L. Taylor | 6,000 |
| Hyperbaric Facility Studies | J. Craven | 2,000 |
| Pelagic Fish Monitoring | R. Brock | 1,900 |
| Hawaii Ciguatera Workshop | R. Shomura | 1,229 |
| Continuation of Control of Mud Blister Worm Study | J. Bailey-Brock | 650 |
| Marine Careers Consultant | A. Pratte | 1,300 |
| Longline Fishing Project | J. Harris | 3,000 |
| MOP Bishop Museum Invertebrate Zoology Training | S. Maynard | 1,700 |
| An Evaluation of the Seabed Troika Photos (Manganese Nodule Research) | J. Wiltshire | 3,699 |
| Travel for Two Graduate Students to Attend Sea Grant Awards Banquet in Washington, D.C. | H. Zeitlin | 600 |
| **YEAR 14** | | |
| Adsorbing Colloids Floatation Methodology | H. Zeitlin | 6,399 |
| Predation by Eels | J. Stimson | 3,589 |
| Design of Ocean Sports Education Program | S. Maynard | 3,951 |
| Preliminary Study of Vibrio Bacteria in Marine and Brackish Water Environments in Hawaii | R. Fujioka | 4,735 |
| Adaption of Large Tank Larval Techniques for Mahimahi to Small Tanks | L. Taylor | 3,978 |
| Low Energy Water Circulation in Prawn Ponds | A. Fast | 3,978 |
| Larval Parasites in the Musculature and Viscira of Commercially Important Fishes in the Waters Offshore from Hawaii | T. Deardorff | 4,677 |
| Zooplankton Populations and Water Chemistry of the Surface and Deep Pumped Water Discharge Pipes of Natural Energy Lab at Keahole, HI | J. Miller | 7,672 |
| Examination of Ancient Deepwater Outcrops in Mamala Bay, Oahu and Associated Flashlight Fishes, Rhyncocynetid and Heterocarpid Shrimps | E. Chave | 2,493 |
| **YEAR 15** | | |
| Efficient Fishing at Pala Lagoon | F. Gerritsen | 4,273 |
| Colloid Adsorption | H. Zeitlin | 4,970 |
| Bio-economic Model for Prawn Production | Y. Shang | 4,411 |
| Orientation of the Green Turtle, *Chelona mydas*, in Response to Altered Magnetic Field Conditions | R. Young, A. Perry | 3,320 |
| Development and Comparison of Clinical Profiles of Healthy and Heavily Parasitized Tilapia (*Arotherodon mossamibicus*) | P. Helfrich, J. Kaneko | 6,047 |
| Age Determination and Confirmation in Large Pelagic Fishes (Sharks and Billfish) From California and Hawaiian Waters | R. Radtke | 16,698 |
| Humpback Whales in Hawaii – 1983 | L. Herman, G. Bauer | 4,776 |
| Survey of Hilo Fishing Grounds | R. Young | 4,452 |
| Summer Marine Science Program | P. Helfrich | 4,997 |
| The Use of the Hormones, Triiodothyronine and Testosterone, as Promoters in the Aquaculture of Tilapia | G. Grau | 4,998 |



"Rapid response" projects take several forms. Some capitalize on an opportunity to facilitate the completion of a high-quality marine effort appropriate to the Sea Grant role; e.g., when a scientist has developed a concept to a certain point with his own initiative or other funding and requires only limited funding for completion. The project duration is usually less than 1 year and the research is usually at a critical stage where delay would result in loss of personnel or continuity in observations. Others address a vital need for information for decision-making, usually for a state abency or marine industry. In some instances, a limited amount of extra funds is required to complete a Sea Grant project where the approved budget did not account for an unusual cost or an unexpected delay.

A summary of publications produced during the quadrennium is given below:

| Type of Publication | Number |
|---|---|
| Technical Reports | 3 |
| Advisory Reports | 1 |
| Miscellaneous Reports | 12 |
| Journal Contributions | 73 |
| Cooperative Reports | 17 |
| Miscellaneous Brochures | 1 |
| Working Papers | 14 |
| Miscellaneous Contributions | 4 |
| Conference Papers | 36 |
| Advisory Brochures | 12 |
| Newsletters | |
| Sea Grant Quarterly | 14 |
| Kahu O Ke Kai | 8 |
| Makai | 48 |
| Publication Lists | 3 |

A detailed listing of these publications appears in the "Publications" section of this report.

Jack R. Davidson
Director

# INTRODUCTION

"What is Sea Grant?" is an often asked question. The University of Hawaii Sea Grant College Program, one of the oldest and strongest Sea Grant programs in the nation, carries out research, educational, and advisory activities in the development and management of marine resources in Hawaii and the western Pacific.

It is part of the National Sea Grant College Program, which was established in 1966 by Congress. The national program was organized so that the results of research being done on a problem in one part of the country would be available to solve similar problems elsewhere. At the same time, the university-based Sea Grant programs serve the needs of their local and regional constituents.

Since its establishment in 1968, the University of Hawaii Sea Grant College Program has joined in partnership with government and private industry to work for the sound economic development and wise use of local marine and coastal resources. During Sea Grant Years 12 to 15 (June 1979 to May 1983), the accomplishment of this mission was focused upon the following program areas: marine resources development, Pacific basin policy studies, marine environmental research, marine technology research and development, marine education and training, and marine advisory services.

This report serves both to fulfill federal reporting requirements and to show our "stockholders" — the general public — how their tax dollars were spent. Over the last 4 years, the University of Hawaii Sea Grant College Program spent more than $6 million to support several dozen research projects, its Sea Grant Extension, the Marine Option Program, and other activities.

What are the returns on dollars invested in Sea Grant? A 1981 study showed that Sea Grant activities at universities around the nation contribute nearly as much to the economy each year — $217 million — as the total amount — $270 million — invested by the federal government from 1966 until the beginning of the 1980s. In Hawaii, research in just one area — pollution of coastal waters — has contributed to savings of $120 million in capital costs and $13 million in annual operating costs for the City and County of Honolulu.

The following sections illustrate why and demonstrate how the University of Hawaii Sea Grant College Program serves the needs of Hawaii, the Pacific region, and the nation.

## INVESTIGATORS HELP IN ASSESSMENT OF STANDING STOCK LEVELS IN NWHI

Diversification of its revenue base has been a long-standing thrust of Hawaii's economic development efforts. Since the 1970s, ocean resources have often been cited as future sources of revenues by the state's leaders. Although fishery resources have topped the list of exploitable ocean resources, such rhetoric was based mostly on intuition rather than scientific evidence.

With the enactment of the Magnuson Fishery Conservation and Management Act in 1976, the need for data to develop fishery management plans for the resources of the undeveloped Northwestern Hawaiian Islands (NWHI) became urgent. To meet this need, the resources of federal and state sectors and the university were combined to assess the levels of the standing stocks of commercially valuable species in the Northwestern Hawaiian Islands. Sea Grant funds enabled university scientists to join a tripartite group of state and federal agencies to launch a comprehensive 5-year resource assessment program.

The tripartite group was composed of the Hawaii Division of Aquatic Resources, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service.

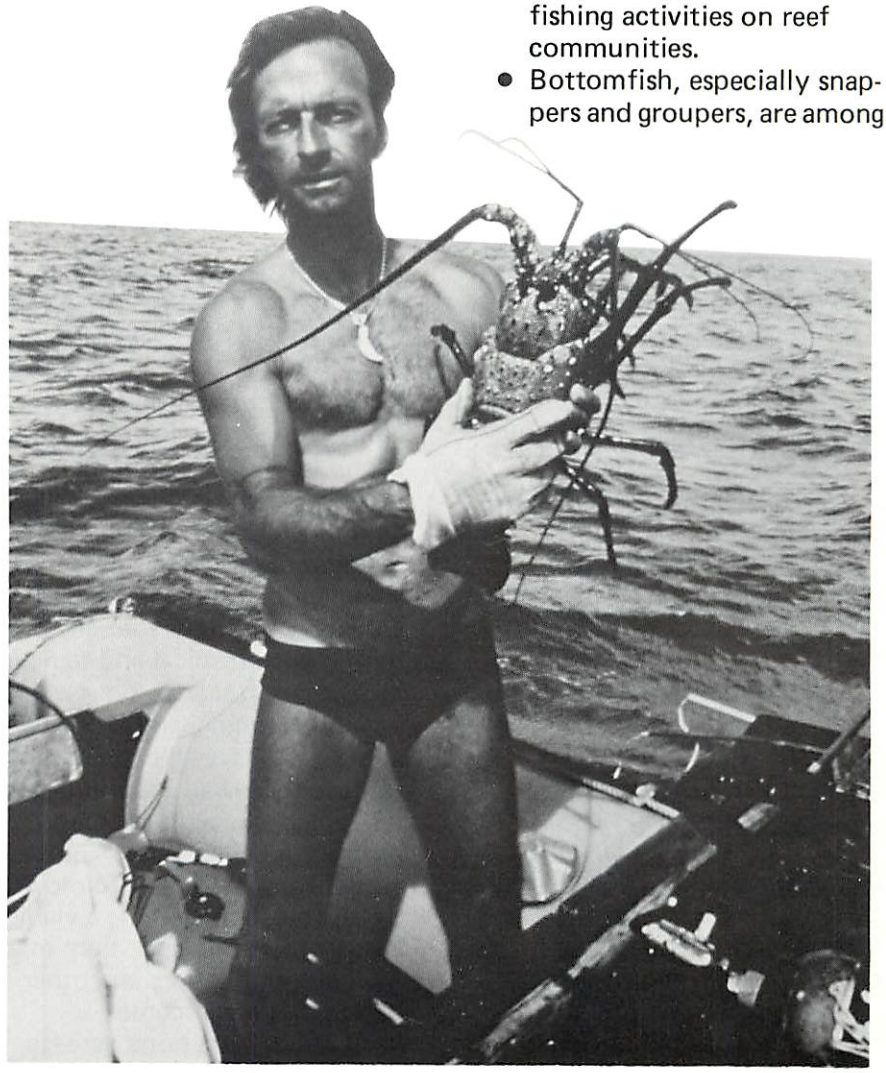
The Sea Grant effort included resource assessment as well as ecological, economic, and policy-making studies. Richard W. Grigg was the program manager. The research activities culminated in a symposium held on May 25-27, 1983.

The major goal of Sea Grant's NWHI fisheries investigations was to determine the potential of the fisheries of this area for economic development which is compatible with the needs of the wildlife. Questions related to the potential productivity of the Hawaiian Archipelago as a system or set of systems were considered through the multidisciplinary study.

The researchers estimated that the potential fishery yield in Hawaiian waters is two to four times (9,000 to 18,000 metric tons) greater than the annual catch (4,500 metric tons) of tuna in the last two decades. If these estimates are correct, researchers believe that tunas and other commercially important species may be harvested at much higher yields than present levels indicate. The increase in landings requires exploiting new fishing grounds offshore or off the Northwestern Hawaiian Islands, or using new fishing technologies such as fish aggregation buoys or school-locating gear.

Other major findings are listed below:

- A "top down" look at the food web helped scientists and resource managers to estimate fisheries yields of targeted species and to gauge the effects of man's fishing activities on reef communities.
- Bottomfish, especially snappers and groupers, are among



Among the species assessed during the study period was the commercially important spiny lobster, *Penaeus marginatus*.

the most valuable commercial fish species in Hawaii. From multispecies analyses, researchers determined that the deepsea handline fishery for bottomfish is probably producing close to maximum levels off the main islands. In spite of historically heavy fishing pressure, this fishery has remained stable, but the researchers conclude that management of bottomfish resources may be required to ensure continued stability.

- Researchers estimate that seabirds consume 350 metric tons of fish and other seafood daily.
- Spiny lobsters found throughout the Hawaiian Archipelago are genetically homogeneous; hence, they should be managed as a unit stock.
- At a point – dubbed the "Darwin Point" – somewhere just north of Kure Atoll (latitude 29°N), the rate of coral growth is insufficient to prevent islands from "drowning." Were it not for colder water and less intense sunlight, the Hawaiian Archipelago might stretch all the way to the Siberian shores of the Soviet Union.

Together with other data, the results of the fisheries investigations create an ecological storehouse of information and data on the Hawaiian Archipelago, particularly on the Northwestern Hawaiian Islands. This mosaic of information has already been used by state and federal agencies in fish and wildlife management planning and policymaking and by fishermen to determine the profitability of expanding their operations into the NWHI.

The tripartite-Sea Grant research completed during this quadrennium culminates a 5-year $5-million survey and assessment of the marine resources of the NWHI. Total Sea Grant and matching funds commited to the research during the 5-year period exceeded $1.5 million. Matching funds were provided by the Office of the Marine Affairs Coordinator (now functioning as the Ocean Resources Branch of the Hawaii Department of Planning and Economic Development). The investigations constitute one of the largest multidisciplinary ecological studies ever undertaken, involving several hundred researchers and scores of undergraduate and graduate assistants and requiring the intimate cooperation of state, federal, and university organizations and agencies.

A final measure of the tripartite-Sea Grant investigations will be the degree to which wildlife preservation and commercial and recreational fishing opportunities are compatible in the development of the NWHI fishery resources.

## RESEARCHERS FOCUS ON AQUACULTURE OF PRAWNS; ALSO NORI AND SALMON

Aquaculture in Hawaii has come a long way. From research begun in 1965 on Malaysian prawns and mullet, it has become an important, though still small, segment of the state's diversified agriculture. Year-round climatic conditions that allow for raising both tropical and temperate species, research, policymaking and planning, and farm experience have all contributed to making Hawaii a world leader in tropical aquaculture. Currently in a "shakedown" phase, aquaculture continues to move closer toward becoming a viable industry, as biological, farm management, marketing, and other obstacles are overcome.

In 1983, total pond acreage for aquaculture amounted to 508; farm pond production – including prawns, oysters, tilapia, and trout – reached 423,000 pounds; and the wholesale value of harvests topped $1.6 million.

### FRESHWATER PRAWN

The freshwater prawn, *Macrobrachium rosenbergii*, remains the dominant production species, with its commercial potentials slowly beginning to be realized. By the beginning of the quadrennium, the prawn industry had shown rapid growth in pond acreage and number of farms. From 1976 to 1978, for example, the number of prawn farms more than tripled from 6 to 20 and pond acreage more than quadrupled from 26.6 to 117 acres. In the same period, production rose from 41,480 to 175,000 pounds, with a corresponding rise in wholesale value of from $145,180 to $616,000.

At about this same time, prawn research had reached a new stage in its progress where a change in priorities seemed warranted. Hence, in the first half of this quadrennium, researchers focused on the biological bases of prawn production to better understand the various components of pond ecology related to feeds and feed management, crises management (of low oxygen levels in ponds, for example), stress and disease, growth patterns, genetic performance, and alternate management systems. All prawn aquacultural projects were consolidated into a single, interdisciplinary program because of the difficulty of determining where the possible influence of one discipline begins and another ends, especially regarding the production setting. Much of the research continued into the second half of the quadrennium. The addition of projects on other prawn-related studies and other species broadened the aquacultural program.

*Feed Studies* – Feed studies during this quadrennium yielded a number of findings important both for potential farm profit-

ability and for further prawn research. In one study, researchers found that feed may not have to be formed into pellets – a possible cost savings for farmers – for prawns to eat it, and that feed ingredients can include cheap agricultural by-products such as corn silage, surgarcane bagasse, and pineapple green chop. Using the knowledge that prawns are detrital feeders, it was demonstrated in swine-manure-enriched polycultural systems with fish that prawns are able to obtain their energy needs from "natural" food sources. In another study, radioactively tagged "artificial detritus" in pellet form was found to be a useful technique for further research of prawn ecology and digestive physiology.

*Oxygen Depletion Studies* – Like any farm operation, aquafarms have their share of crises. In Hawaii, almost all pond management crises result from depletion of dissolved oxygen, especially on the pond bottom where prawns reside. Between January 1977 and September 1978, for example, 30 prawn kills were reported. Losses in each pond ranged from 4.5 to 1,100 pounds of prawn. This is an ongoing problem which researchers continue to address.

More clearly understanding the processes causing oxygen depletion is essential for the development of effective management strategies, both for short-term "prophylactic" management on small farms and long-term "self-management" of ponds on large-scale farms of 300 or more acres. Reducing or more effectively managing phytoplankton and bacteria in ponds is a first step in controlling oxygen demands. The increase in the biomass of these organisms in ponds is thought to be partly caused by the large amounts of feed introduced into ponds and the inefficient use of this feed by the prawns themselves. This "extra" feed may be a nutrient bonanza to phytoplankton and bacteria.

*Pond Health Studies* – Among the achievements during this quadrennium was the application of a theoretical model to experimental data to predict phytoplankton respiratorial and productive rates as a function of average levels of light in ponds. This means, for example, that, accounting for other factors, concentrations of phytoplankton may indicate degree of health of ponds.

ATP (adenosine triphosphate) measurements may be another valuable tool for assessing pond health. Researchers found strong correlations between concentrations of ATP and rates of oxygen consumption in the water column and on the pond bottom. ATP measurements may also prove useful for estimating bottom microbial biomass and rates of production.

Polyculture was tested as a means of controlling phytoplankton abundance. Over a 6-month period, average concentrations of chlorophyll *a* were more than 10 times smaller in tanks stocked with silver carp than in tanks with no fish. Test results suggest that stocking commercial prawn ponds with silver carp may prove to be an effective means of controlling the abundance of phytoplankton.

*Intraspecific Traits Studies* – Also during this quadrennium, research was carried out to evaluate economically important intraspecific traits of several ecotypes, or races, of prawns. At present, commercially farmed prawns in many countries are from a stock known as the "Anuenue" strain. Because of the large geographic range of wildstocks of *M. rosenbergii*, it is possible that there are populations that are physiologically, developmentally, and behaviorally better suited for domestication than the Anuenue strain.

Some desirable traits which researchers studied in various stocks were reduced larval development time, improved larval survival, larval tolerance to poor quality water, and postlarval tolerance to low temperatures.

In general, researchers found little economically useful variations within the prawn stocks studied. Furthermore, it appears that the Anuenue strain has changed little under culture from its wild relatives.

*Harvesting Systems Design and Testing* – The prevailing "Continuous Stocking and Harvesting System" takes advantage of the fact that small prawns "grow into" larger size classes as large prawns are culled for marketing. While this method is simple to practice and has other advantages, it has significant drawbacks, including harvest efficiency, high postlarval mortality, and impossibility of managing sex-specific performance characteristics.

A "Multi-Rotational Stocking and Harvesting System," designed and tested by UH researchers, holds promise for overcoming major drawbacks of the former system. The new system more directly manipulates production through variable density culture, stock division, and size grading.

*Growth Capability Studies* – Tank-level studies demonstrated that age and size are not indicators of the growth capability of prawns: a "runted" prawn can undergo considerable compensatory growth when moved from a population of larger prawns to one of similar-sized prawns. In addition, field trials indicated that size grading greatly enhances compensatory growth capability. Yields in size-graded populations compared favorably with those of control populations. Furthermore, more large, size-graded prawns reached market size faster than comparable animals in control ponds.

*Engineering Research* – In addition to biological research, applied engineering research was begun to improve labor productivity and operational efficiency

on commercial prawn farms. During this quadrennium, efforts focused upon improving harvesting as well as size grading technologies.

Two measures of a harvesting system's performance are the labor requirement (number of people and time consumed) and harvesting efficiency (percentage of market-sized prawns that are harvested). The former can be calculated from stopwatch time and motion studies, and the latter from the percentage of marked market-sized prawns taken during a harvest. The prawns are "marked" by placing colored rubberbands that are non-injurious around the abdomens of the animals.

The researchers measured the harvesting efficiency and labor requirements of three harvesting systems used on local commercial farms. The data gathered in the study indicate that labor productivity (unit of labor per unit of prawns harvested) could be increased with an adequately designed mechanized harvesting seine which would increase harvesting efficiency and decrease the labor required.

Size grading of prawns is a labor-intensive operation. Researchers built an experimental roller size-grader that could size grade prawns for market with up to 90 percent accuracy. Although the machine's design offers one solution for size grading, the researchers concluded that a different design concept may be better.

## NORI AND SALMON

Two other aquaculture projects carried out in this quadrennium focused on nori and salmon as species of study.

In 1980, a study was begun to demonstrate the biological feasibility of cold-water aquaculture, using cold, deep water available through an ocean thermal energy conversion (OTEC) system. OTEC aquaculture offers the potential for large-scale, high-density production. Nori (*Porphyra tenera*), an edible seaweed, was selected as the sample organism.

During the project, researchers were able, in the short term, to grow the seaweed at rates equal to those for rapidly growing seaweeds in similar culture systems. The experiments also demonstrated the feasibility of growing cold-water species in the subtropics by using mixed surface and deep waters from an OTEC facility.

The nori cultured using water from the experimental OTEC system at the Natural Energy Laboratory of Hawaii, located at Keahole Point on the island of Hawaii, was taken to Japan for processing into nori sheets, an important food item for the Japanese. The sheets made from the nori were judged to be low in quality and worth two and a half cents, if saleable at all. Japanese experts, noting the difficulty of producing high quality nori, said that the Hawaiian nori was quite good for a "first try."

In a second project, researchers studied the suitability of using OTEC cold water for growing salmon. In addition, researchers conducted smoltification tests on coho salmon in which a tropical photoperiod and high salinity seawater were used. Smoltification is the transformation of body form, physiology, and behavior that permits salmon to migrate from freshwater into seawater.

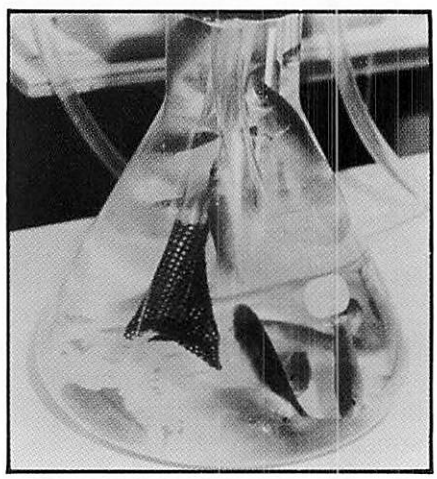
Initial findings from this research, scheduled to continue until mid-1984, clearly show that salmon can grow and thrive in waters discharged from OTEC facilities. In addition, it is probable that growth period to smoltification can be shortened by manipulating water temperature and photoperiods which would shorten the salmon's rearing time in freshwater, a very limited resource in Hawaii.

## ALTERNATIVE BAITFISH CULTURED SUCCESSFULLY

A key constraint on the development of the aku fishery has been inadequate supplies of nehu (Hawaiian anchovy) for baitfish. Perhaps because it is the baitfish of choice among aku fishermen, wild stock of this fragile fish is decreasing. And, unfortunately, it is not easy to culture.

In an effort to solve the baitfish problem, researchers evaluated several alternate species for mass culture, finally settling on topminnows as the candidate baitfish. Topminnows are hardy enough for culturing and survival in baitwells. Prototypes of a culture system capable of producing large amounts of this baitfish have been developed.

More important, sea tests demonstrated that topminnows could be an effective baitfish for pole-and-line fishing. In addition, innovative fishermen discovered that topminnows are especially effective around fish aggregation devices (FADs). However, it is likely to be some time before traditional baitfish preferences among Hawaii's fishermen are overcome so that new baitfish alternatives such as the topminnows are accepted.



Mexican mollies, *Poecilia mexicana*, during group oxygen consumption tests at Hawaii Institute of Marine Biology.

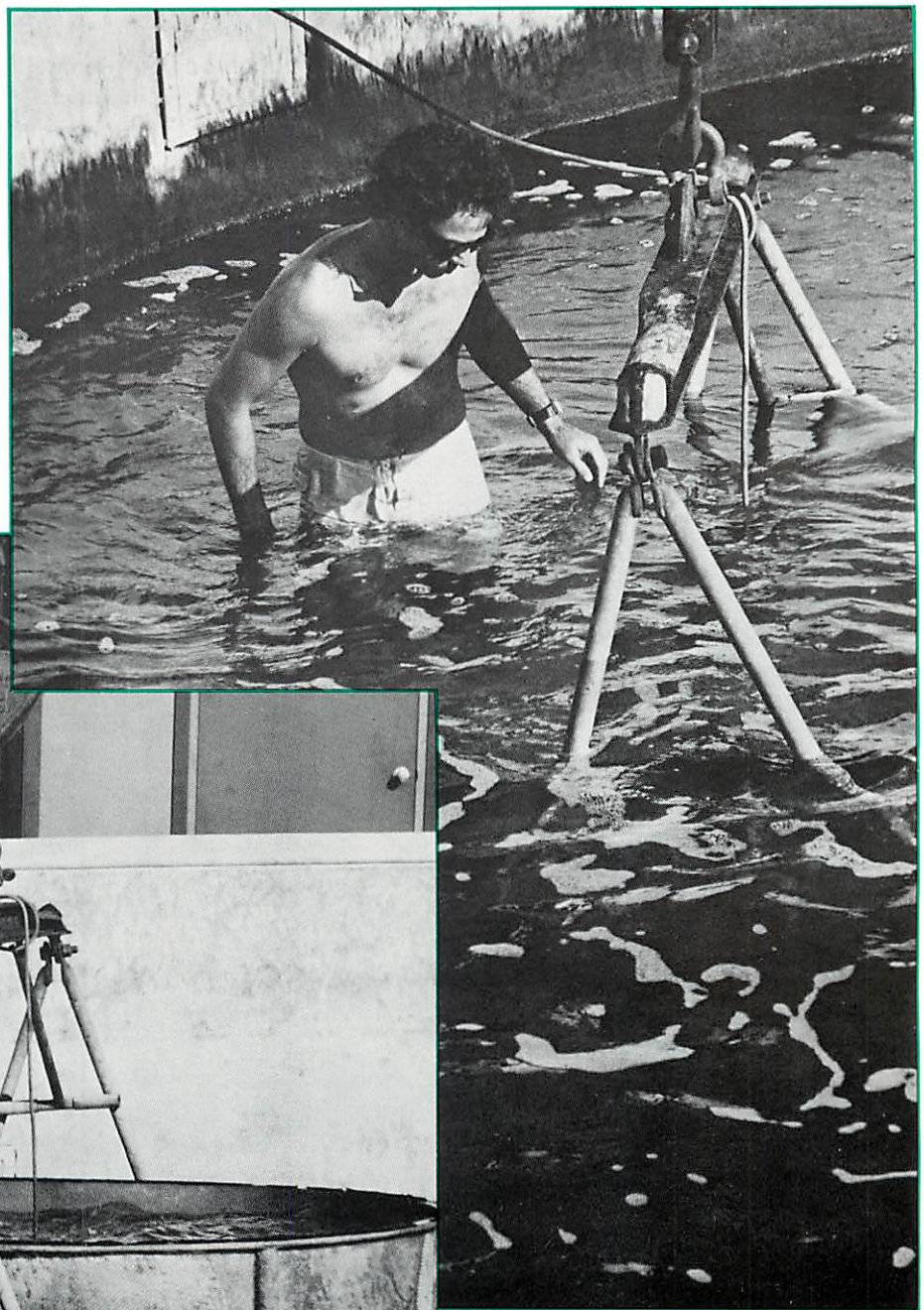
## FISH AGGREGATION DEVICES RESEARCH AIMS AT ENHANCING FISHING PRODUCTIVITY

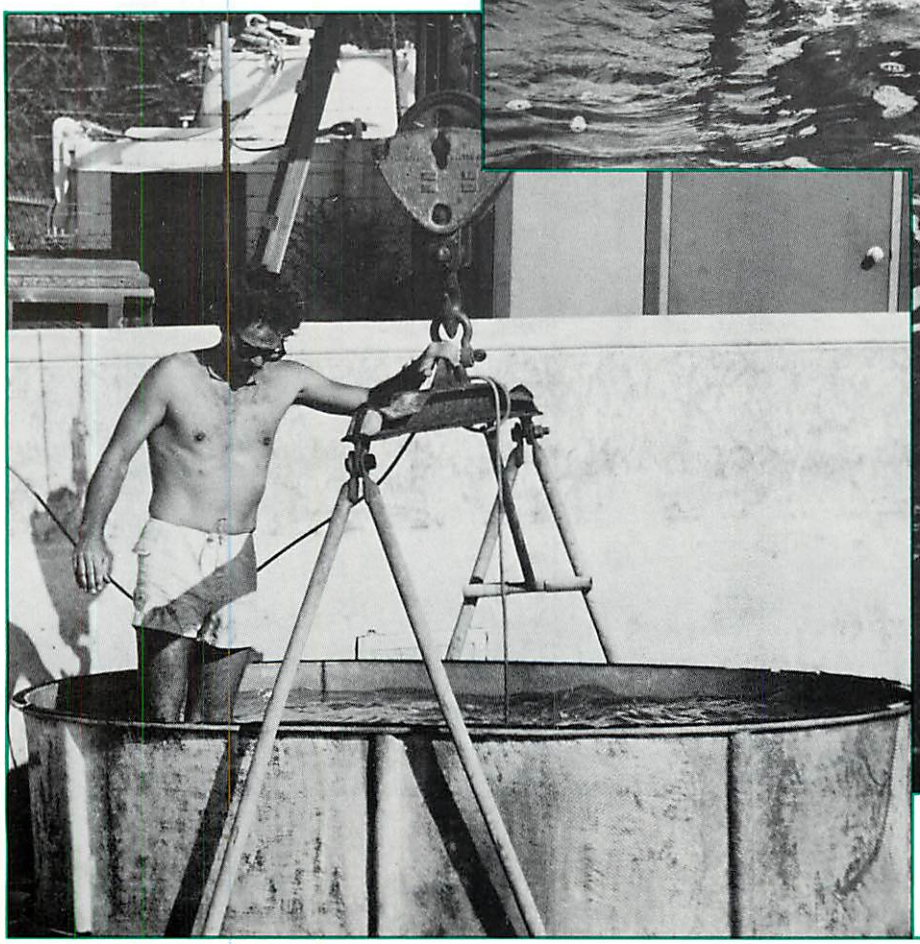
*Recruitment Studies* — Understanding why fish are attracted to FADs and other floating objects is crucial to improving their effectiveness. In one project, researchers moved closer to such understanding by gathering data on recruitment of fish to FADs and rates of colonization. The data gathered provide a picture of the species attracted to FADs, including both prey and predators, and suggest that fish aggregate around FADs for the prospect of food and perhaps use the devices for navigation and orientation.

*Prey Odor Studies* — Researchers tested prey odors that might be used together with precious live bait, particularly in the tuna fisheries. If prey odors can eventually be manufactured in commercial preparations, they may improve fishing efforts around FADs, as well as in the open ocean.

First, laboratory trials indicated that tunas do show feeding behaviors when the rinses of various prey are released into the water. And, like most animals, they have their favorites. High on their preference list are opelu (mackerel scad) and squid rinses. Interestingly, nehu was the least effective odor in stimulating feeding behavior. Similar results were obtained in open-ocean trials.

If prey odor preparations prove to be commercially feasible, chemical "chumming" may play an important role in enhancing fishing operations in Hawaii and elsewhere.





Prey odor trials were first conducted in tanks at the Hawaii Institute of Marine Biology and then in the open ocean where similar results were obtained.

## MANGANESE NODULES MAY BE GOLD MINES FOR VALUABLE METALS

The United States currently spends $1.5 billion a year on imported nickel and cobalt, and this figure is expected to rise to $6 billion a year in the next 25 years. Ferromanganese nodules, which contain these and other metals, is viewed, in the long term, by many as an important alternate resource that may become profitable to mine from the ocean floor.

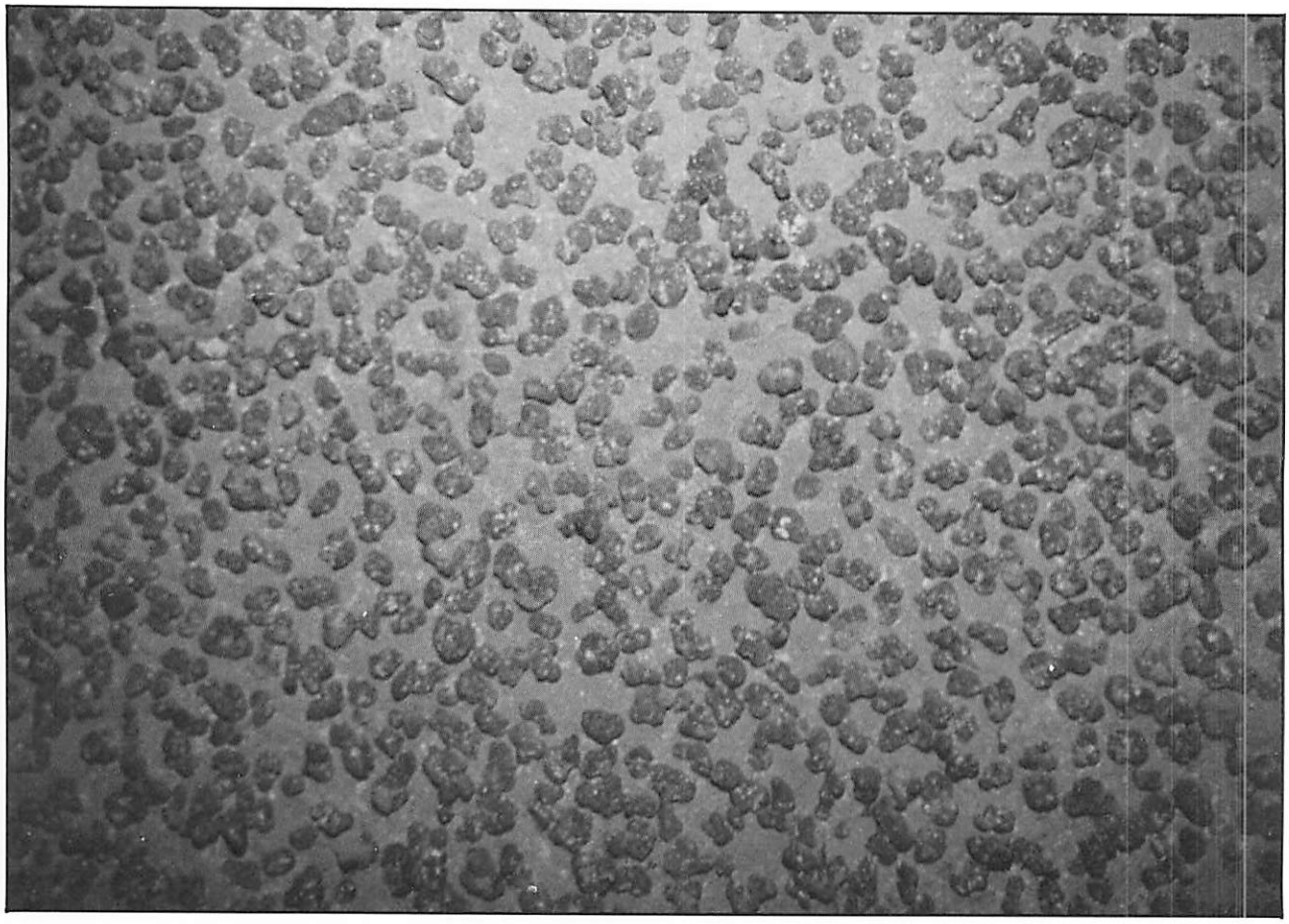
An estimated 1.5 trillion tons of these nodules are located within a two-million-square-mile area of the Pacific, extending from about 600 miles southwest of Hawaii to about 600 miles from the coast of Mexico. Because of the proximity of this resource to Hawaii, the prospects for a local mining industry appear favorable.

The Hawaii Department of Planning and Economic Development has worked with industrial representatives on the feasibility of establishing a ferromanganese nodule industry in the islands. Developing nodule processing technologies that are clean and have minimal environmental consequences is essential.

Researchers have completed a 4-year study of the chemical interrelationships of the metals within the complex nodule structure and the chemical reactions related to hydrometallurgical processing technologies for the recovery of selected metals such as cobalt, copper, manganese, molybdenum, and nickel.

One aspect of the research dealt with a recovery process called sulfation. In this process the water-soluble metallic oxides contained in the nodules are transformed into water-soluble sulfates by treatment with sulfur dioxide and oxygen. The metals can then be recovered from the sulfate compounds through further chemical processing. This research may suggest important ways of maximizing yield efficiency per unit of energy consumed.

For their contributions to this research, two graduate students from the University of Hawaii received awards from the National Sea Grant Association.



The decade of the 1980s will see the emergence of a new regime of ocean law. We face the prospect that treaty law will govern the oceans more comprehensively than ever before in the history of humankind. International society has entered upon a complex process of challenge and response, in which both the adversary process and common national interests will result in new legal principles, new definitions, and new authority over the oceans and their resources. Many of these new rules will be regional in their origin, but, of these, many can be expected to serve as global precedents.

## LSI CONTINUES TO PROVIDE FORUMS FOR FRANK EXCHANGES OF VIEWS

The formulation of new ocean law has been steadily and increasingly influenced by the Law of the Sea Institute, located at the University of Hawaii. Since its inception in 1965, the institute has been able to encourage research; elicit important views, ideas, and information; and provide essential international communications on international law of the sea.

Originally located in Rhode Island, the institute in its early years focused chiefly on law-of-the-sea matters in the Atlantic. Upon its transfer to the University of Hawaii in 1977, the institute's focus was expanded to include the Indo-Pacific, with its unique regional problems and its importance as the possible locale for exploitation of the deep seabed.

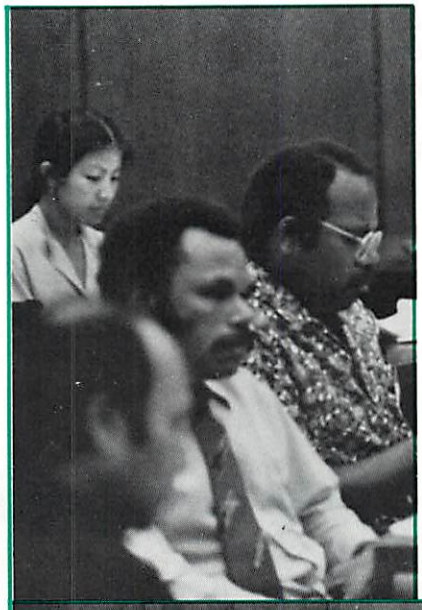
The institute's purposes are to create opportunities for interactions of specialists in the law of the sea at the highest levels of scholarship and to disseminate the results of these interactions to scholars, practitioners, and others concerned with rules for the use of the world's oceans.

With Sea Grant and other support, the Law of the Sea Institute accomplishes these purposes largely through interdisciplinary conferences, workshops, and other meetings. Participants speak as individuals rather than as members of governments; hence, frank exchanges of views are encouraged that might not be expressed under the pressure of official negotiations.

The major meeting — and the institute's major activity — is its annual conference. During this quadrennium, the thirteenth through sixteenth annual conferences were held. As a matter of policy, the location of the annual conference is changed each year to better serve a global constituency.

The thirteenth conference, held in October 1979 in Mexico City, was the first to be held in a developing country. The theme, "State Practice in Zones of Special Jurisdiction," was especially appropriate for this site because Latin American states have been active in promoting these zones, both diplomatically and through national legislation.

"The Law of the Sea in the 80s and Beyond" was the theme of the fourteenth annual conference, which was held in Kiel, Germany. Its agenda anticipated the final phases of the Third United Nations Conference on the Law of the Sea and covered the changes that will occur in state



LSI workshop participants, like the conference participants, are made up of a global constituency.

practice, in international organizations, in the new international bodies that are to be created by the proposed agreement, in marine research, and in enclosed and semi-closed seas such as the Baltic Sea.

The fifteenth conference, held in Honolulu, focused on "The Law of the Sea and Economic Development in the Pacific Basin." Fisheries, seabed mining, energy, and industrialization, marine transportation, ocean boundaries, and marine scientific cooperation in the Pacific were the major topics addressed.

The sixteenth conference was held in Halifax, with the theme, "The Law of the Sea and Ocean Industry: New Opportunities and Restraints." It focused on ocean policy issues in a region not covered in recent years. It also assessed the outcomes of the Third United Nations Conference on the Law of the Sea, held in 1982 in the city of New York.

## NUCLEAR WASTE DUMPING ISSUES: A CONCERN FOR COMMUNITY LEADERS IN THE PACIFIC BASIN

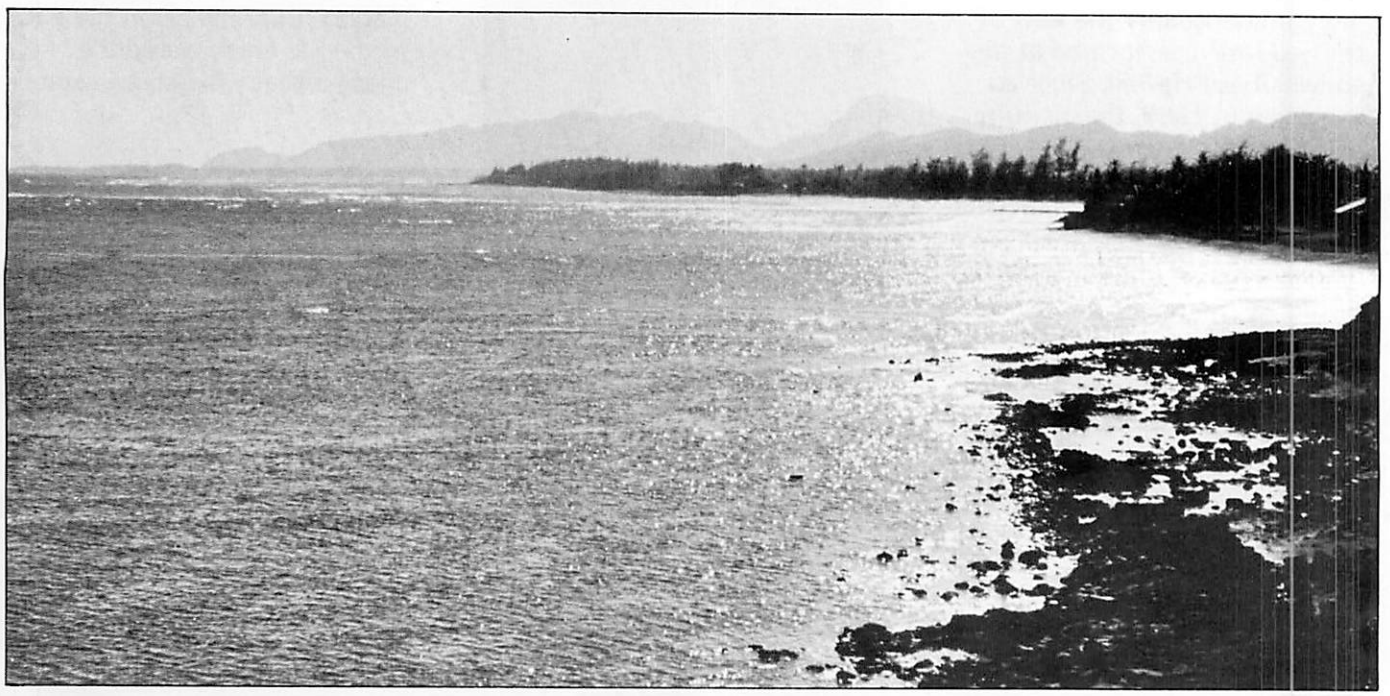
For probably as long as humans have been on earth, they have used the oceans to discard the waste products of human activities, including garbage, sewage, and junked automobiles. With the rise in the use of nuclear energy, the oceans once again are candidates for waste — nuclear waste.

For example, the Japanese have been eyeing an ocean site located between Japan and the Northern Marianas to dump 10,000 barrels of nuclear waste. Because it is small, densely populated, and earthquake prone, Japan will continue to look to the Pacific Ocean as a potential dumping site for its nuclear waste.

Another potential danger is the possible burial at sea of old nuclear submarines. The U.S. Navy is considering this alternative because many of its nuclear submarines are outmoded. One such submarine would add half as much radioactivity to the oceans as all the steel drums previously dumped.

A 2-year research project examined and analyzed legal issues, the adequacy of international environmental requirements, and specific legal strategies and procedures for challenging pollution of the environment associated with nuclear waste dumping.

The results of this project have been disseminated to leaders of potential dump sites in the Pacific. These leaders should now be better able to evaluate the options of forming regional organizations and in deciding whether to use the ocean as a dumping site for nuclear and other wastes and whether to oppose its similar use by others.



## RESEARCHERS MAKE SIGNIFICANT ADVANCES IN THE TREATMENT AND PREVENTION OF DECOMPRESSION SICKNESS

Bubbles effervescing from a glass of soda may whet one's appetite and soap bubbles dancing in the breeze may capture one's spirit, but bubbles forming in the blood of a scuba diver in a high-pressure environment spells trouble – potentially life-threatening trouble. Decompression sickness, or exogenous gas bubble disease, is the condition in which bubbles form in the blood or bodily tissues, usually after a reduction in surrounding air or water pressure. Hawaii's scuba divers have one of the highest rates of decompression sickness in the world.

Since Year 01 (1968-69) UH Sea Grant has supported research to further understand the effects of high-pressure, or hyperbaric, environments on human beings. Over the years significant advances have been made in revealing the physical laws governing bubble formation in watery fluids.

In this quadrennium, a 5-year project, continuing earlier work on the physics of bubble formation in watery fluids, was concluded. The most important accomplishments of this research were the development of a physical model – called the nucleation model – to describe bubble formation and the application of the model to the causes, detection, and prevention of decompression sickness.

Reseachers used the model to calculate several decompression tables for humans in the mid-1970s. The tables are based on data of bubble formation in gelatin. By 1981, model predictions had been compared with decompression data on salmon, rats, and humans. The present work developed a new theory of decompression sickness that can be verified without reference to gelatin data.

What is important is that the researchers developed diving tables based on physical laws, rather than on ad hoc and often faulty assumptions.

From field experience with the Nippon Salvage Company, Sea Grant researchers recommended changes in diving and decompression sickness to 10 percent of that obtained with modified U.S. Navy diving tables. In addition, reseachers were able to resolve a long-standing paradox concerning the ability of Hawaiian diving fishermen to surface from dives with minimal decompression in a series of repetitive dives.

Research to date suggests that besides limiting bubble formation two additional factors should be accounted for in applying the nucleation theory to decompression sickness. The first is the regeneration of gas nuclei in the blood or bodily tissues; the second, the dependence of the safety of a decompression table upon the total bubble volume of gas released, rather than upon the mere presence or absence of bubbles.

In a related project, researchers developed a mathematical theory of bubble dissolution, which suggests that common treatments for decompression sickness may be only marginally effective and that, in many cases, existing techniques and facilities cannot adequately dissolve the bubbles causing the sickness. The theory and experience also suggest that while common treatments may be successful in relieving pain in cases of simple decompression sickness, they may not be as successful in cases when it afflicts the central nervous system.

From this research, a new in-water treatment of decompression sickness was developed for use by Hawaiian diving fishermen when they are more than one hour's travel time away from a decompression treatment facility. The treatment involves administering oxygen and then recompressing the victim in water at the 30-foot depth for up to three hours. The treatment has been taught to Hawaiian fishermen and is now required for use by University of Hawaii divers.

Other groups that have benefited from research in this area include the Undersea Medical Society, the U.S. Navy, and the civilian diving community.

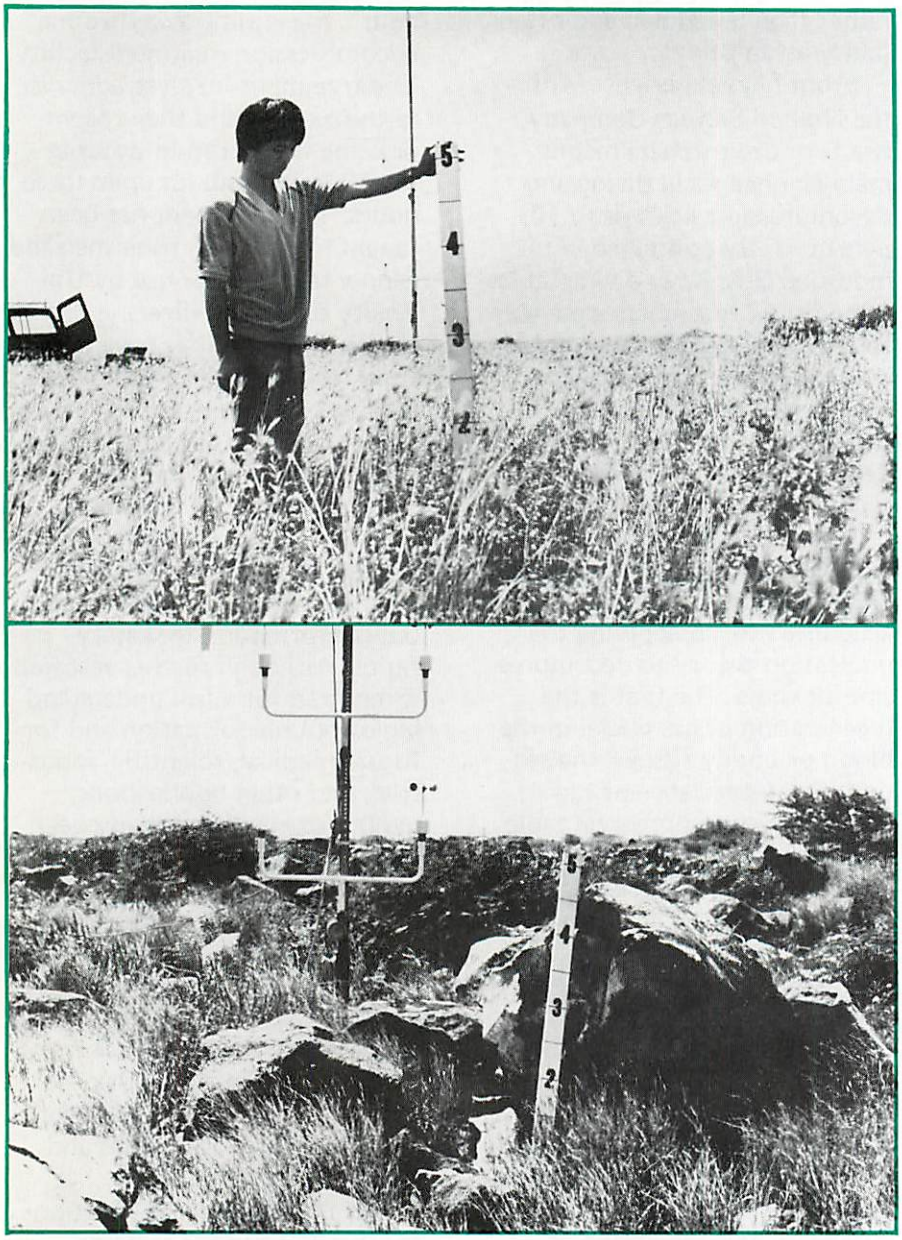
After 300 years, scientists, through the results of Sea Grant-sponsored research, have begun to understand the mechanism of bubble formation in watery fluids. Although further research is required for a full understanding of bubble formation and for future medical, scientific, industrial, and other applications, much progress has already been made. The projects carried out during this quadrennium, building on the accomplishments of earlier Sea Grant research, have resulted in significant advances not only in the treatment and prevention of decompression sickness, but also in the solution of problems in hydraulic engineering, acoustics, and surface and membrane chemistry.

But the foremost motivation for this and further research remains improved treatment and, ultimately, the prevention of decompression sickness.

## RESEARCHERS DEAL WITH WAVE FORCES ON LAND AND IN THE OCEAN

Certain coastal regions in Hawaii, having more or less straight or concave shorelines, are prime locations for urban and industrial development. These same coastal regions are also among the ones most likely to be subjected to tsunami inundation, a phenomenon that is always a potential threat to life and property.

Little attention has been given to the flooding problems that occur when a tsunami transforms into a flood wave at the top of a beach or coastline and washes inland over a dry bed or coastal terrain. Knowledge of how the consequences of tsunami inundation are affected by terrain roughness, especially natural terrain changed during urban or industrial development, might prove valuable in trying to reduce the destructive potential of tsunamis.



Wind profile measurements for "typical" Hawaiian terrain types were carried out by Sea Grant researchers to better understand the effects of terrain roughness on potential tsunami inundation. Examples of "typical" terrains represented here are thick grass (top) and boulders and grass (bottom).

To better understand the effects of terrain roughness on potential tsunami inundation, Sea Grant researchers carried out wind profile measurements for 15 "typical" Hawaiian terrain types, as well as for 15 other types. The wind measurements were found to be an excellent alternative method for studying friction and other roughness factors that cannot be investigated in hydraulic laboratories. The wind studies proved to correlate well with both theory and hydraulic experiments obtained from the literature.

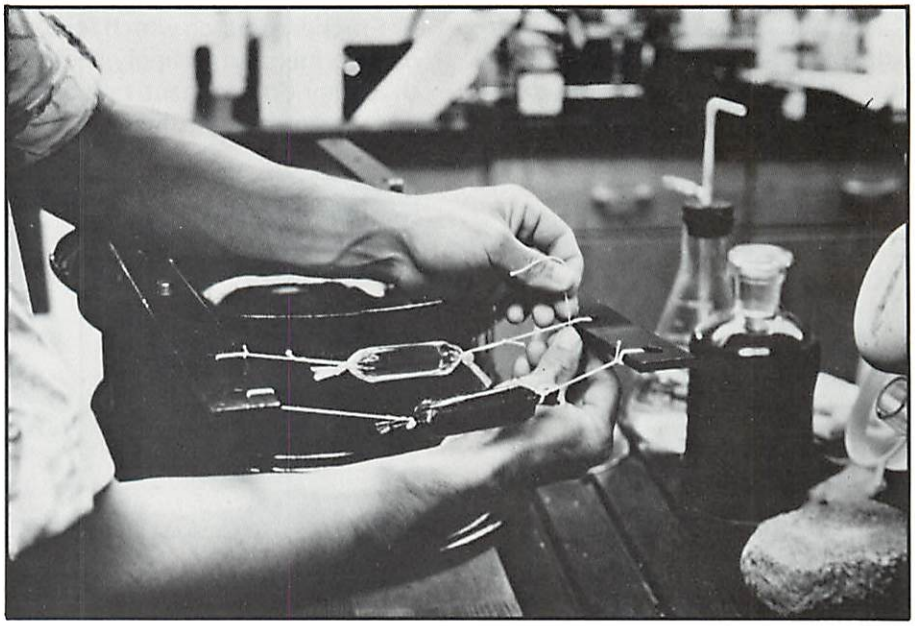
The data collected during this research formed the basis for the publication of a user's guide to help engineers calculate run-up criteria for tsunami inundations and design channels and canals.

The second project focused on wave forces and their effect on sewer outfalls, cooling water intakes, hydraulic dredge lines, and gas pipelines — all of which are examples of pipelines laid on the seafloor. Those pipes or portions of pipelines laid in shallow, exposed waters are subject to strong wave forces that at times cause pipe damage. To meet the need for more wave-pipe interaction data to improve pipe design to withstand the stern forces of shallow ocean environments, field tests were carried out.

At a test location offshore from Kewalo Basin in Honolulu, Sea Grant researchers studied wave forces on a 40-inch diameter pipe that was variously positioned at angles of 15, 35, and 52 degrees to the wave front.

The data gathered during the project were processed to indicate how the data themselves vary in relation to the angle of wave attack and other factors such as wave period. This data should be useful to designers and installers of submarine pipelines.

## WATER QUALITY INVESTIGATIONS VALIDATE POLLUTION INDICATORS, IDENTIFY POLLUTION CONTROLS, AND DETERMINE THE FATE AND EFFECTS OF SEWAGE EFFLUENT



Scientist preparing bacterial samples in laboratory to be placed in ocean for testing

In Hawaii, as in many other coastal areas around the world, sewage is discharged into the ocean. From the island of Oahu, where about 80 percent of the state's one million people reside, more than 120 million gallons of sewage are discharged into the ocean every day. Of this amount nearly 50 percent is discharged within a few miles of one of the world's premiere tourist playgrounds, Waikiki.

Until recent years, discharging sewage into the world's oceans did not attract much attention. Sewage discharged into seawater, which is not used for drinking, usually becomes greatly diluted. But, increasing fecal pollution of offshore waters and increasing demand for the use of these same waters for recreational purposes have raised concerns. The spread of disease by fecally polluted seawater, especially to swimmers, is now a definite reality. Where such mixed use of ocean waters occurs, the monitoring of water quality and evaluating health risks to humans are essential.

*FC:FS Ratio* — For about 60 years, the presence of coliform bacteria in all types of water has been the accepted indicator of fecal pollution; it has been used as a measurement of water quality and of the potential for transmitting human diseases. Another indicator, validated by University of Hawaii researchers in the 1970s, is the ratio of fecal coliform to fecal streptococci (FC:FS). Its advantage over the coliform bacteria indicator is that it enables water quality monitors to determine the source of fecal pollution, i.e., human or animal. Both indicators had been validated in freshwater, but not in seawater.

*Fecal Streptococci Superior* — In this quadrennium, Sea Grant research on the FC:FS relationship showed that sunlight in the visible light spectrum has a strong and rapid bactericidal effect on both fecal coliform and fecal streptococci in seawater down to 30 feet. Fecal coliform are so much more sensitive to sunlight than fecal streptococci that the FC:FS ratio established in freshwater is not applicable in seawater. Because of their greater stability, fecal streptococci appear superior to fecal coliform as an indicator for the presence of disease-causing organisms in sewage discharged into the ocean.

*Lethal Effect of Sunlight* — The lethal effect of sunlight to fecal coliform and other intestinal bacteria in seawater, but not in freshwater, was the topic for another research project concluded in this quadrennium. Although how sunlight kills off bacteria, such as fecal coliform and fecal streptococci, is still not known, data gathered by researchers suggest that in seawater the organisms die from a photosensitive reaction. The sunlight's lethal effect is dramatically lessened in fresh stream water, possibly because of products of plant decay — pigments perhaps. These may absorb some wavelengths of light and thereby preserve bacterial life.

This study further demonstrated that the effect of sunlight on fecal coliform and fecal streptococci is lethal and rapid. Thus, this factor needs to be considered by water quality monitors in selecting sampling times and sites, as well as in the interpretation of data.

*Marine Antiviral Agents* — On a related front, Sea Grant researchers concluded a major study begun in 1975 on the survivability in seawater of human intestinal viruses and the role and effects of marine antiviral agents

(MAVAs). Project goals included the determination of the distribution and manner of distribution of these viruses in the ocean; the effectiveness of the Sand Island sewage outfall (newly installed in 1976); and determination of the health risk, if any, the outfall posed to users of the ocean waters, especially near Waikiki.

The results indicate that although ocean currents and winds are primarily responsible for the movement of human intestinal viruses, their maximum dispersion is probably dependent on their survival time in the ocean. Also, some antiviral agent is present in both clean and sewage-polluted waters. Researchers suspected that some marine microorganisms might have some antiviral capabilities.

Perhaps the best news for governmental authorities is that the new Sand Island outfall installation is helping to keep neighboring ocean waters free of disease-causing viruses. Researchers were unable to find traces of human intestinal viruses even in the zone of mixing near the outfall. However, they caution that because the health hazard potential of human intestinal viruses in ocean water is not known, some kind of precaution must be exercised in the disposal of sewage — especially new sewage — into the ocean.

Working on the assumption that marine antiviral agents are marine microorganisms, Sea Grant researchers collected 100 different kinds of bacteria and tested their antiviral qualities. Of these, two bacteria — labeled "clumpers" and "swarmers" — showed antiviral qualities.

MAVAs may have the potential to control biologically viral contamination and the spread of viral diseases in sewage-polluted waters. They may also be used in chemotherapy of viral diseases. The intestines of infected people probably harbor more than 100 types of viruses, including poliovirus and infectious hepatitis. The clumpers and swarmers were the only bacteria in the group of 100 that inactivated poliovirus.

Further research which focused on swarmers surprisingly showed that they do not inactivate other viruses similar to poliovirus, nor

Swarmers have been found to inactivate poliovirus.

do they inactivate a broad spectrum of viruses. The researchers attributed these findings to a number of possible reasons: swarmers are broad spectrum MAVAs that somehow lose their capacity in laboratory conditions; the specificity of swarmers to inactivate only poliovirus is unique; swarmers in the ocean only inactivate poliovirus, while other bacteria inactivate other viruses; or swarmers do not play an important role in inactivating viruses in their natural environment.

These and other data suggest that other methods need to be tried for possibly finding bacteria that do have broader spectrum antiviral activity. In addition, the restricted antiviral activity of the swarmer bacteria is unique and needs to be studied further to determine if this is a natural phenomenon for all MAVAs.

*Micromollusks* — The results of a study of micromollusks that are less than 10 mm in diameter showed that they are useful indicators of the conditions of ocean bottom-dwelling communities of organisms and of short-term environmental changes such as water quality. The remains of micromollusks persist in sediments for long periods of time, and they occur in large enough numbers to permit statistical analyses of their assemblages.

The distribution patterns of micromollusks in Hawaiian waters can be used for interpreting the condition of bottom communities. These patterns are useful in monitoring not only human effects on the marine environment, but also other conditions in nonpolluted waters. For example, relatively high proportions of parasitic mollusks indicate high nurtient content in the water column or in the bottom sediment.

The data base established by this project has been in continuous use by the City and County of Honolulu in its monitoring program of offshore sewer outfalls. The city has also used it in its application for waiver of certain Environmental Protection Agency requirements at such outfalls.

*Sewage Effluent Dispersal* — Another water quality project carried out in this quadrennium focused on the metabolic processes of ocean-bottom dwellers near the Sand Island sewage outfall in Honolulu. The major effect of sewage disposal is the addition of nutrients, as measured by the presence of nitrates and phosphates, to an ecosystem. Measuring the rates of the metabolic processes that cycle nutrients from the outfall provides a means to gauge the fate and effect of sewage within the local marine ecosystem.

The results of this study show that 98.5 percent, and perhaps more, of the sewage is dispersed in the water column under the influence of normal tides and currents. It appears that the particles of sewage discharged are small enough not to normally settle on the bottom. For these

and other reasons, the present levels of treatment and sewerage discharge appear to be having little or no effect on bottom and pelagic communities of marine organisms.

However, the results do show that bottom communities, as indicated by metabolic measurements, are very sensitive to introduced nutrients. Although the structure of these communities was not affected, it is highly possible that sewage treatments producing larger particles that more readily settle on the bottom could cause some structural changes. This knowledge can be used to predict ecosystem responses in similar situations and help in fashioning more effective management and policy decisions.

## MANGANESE NODULE TAILINGS DISPOSAL IN OCEAN ASSESSED

Marine environmental research also focused on the effect of manganese nodule tailing disposal in waters off the island of Hawaii. Rich fields of manganese nodules, which contain such strategically important metals as cobalt and nickel, lie in waters south of Hawaii. The processing of these nodules has been viewed as a possible new industry of major economic importance for Hawaii. Kawaihae and the district of Puna, both located on the island of Hawaii, have been seriously considered as sites for a manganese nodule processing plant.

Industry representatives estimate that a plant of the size to be profitable will create as much as 3 million tons of sludge and waste liquid, called tailings, a year. Since a large amount of waste may contain a significant quantity of hazardous elements, disposal of tailings is a major concern of industry, government, and the public.

Ocean dumping is one of the favored methods for disposing of tailings. For a plant in Puna, the proposed disposal of tailings would be through a slurry pipe into the Puna Canyon. At Kawaihae, the tailings would be dumped from barges into the Kawaihae basin.

Two Sea Grant projects were undertaken in this quadrennium to study proposed dumping sites and to make a preliminary assessment of related environmental concerns.

Puna Canyon, one of the largest and youngest submarine canyons in the world, lies within 0.5 mile off the east coast of the Big Island. It extends 75 km seaward and reaches depths of up to 5,400 m. The canyon is now relatively sediment-free and has a stable water column with weak bottom currents. Volcanic sediments that are both geochemically and in grain size distribution compatible with tailings and the predictable pathways of sediment transport make the canyon an ideal disposal site.

The fine-grained size of manganese nodule tailings makes them a major environmental pollutant in surface waters. Disposing the tailings in deep water along known sediment pathways in the canyon would eliminate this hazard. A 2-km-long, 50-cm-diameter pipe would allow a saltwater slurry of tailings to enter the canyon's head at a depth of 350 m.

Researchers in the second project carried out laboratory analyses of sample tailing slurries provided by Ocean Minerals Company. Unfortunately, a planned 5,000-kg pilot-scale dumping of tailings could not be carried out. Nevertheless, the laboratory data gathered yielded some valuable information about the potential effects of ocean dumping.

Cadmium, copper, nickel, and lead are among the metals in manganese nodule tailings that are known to be toxic to marine life. Consequently, one effect of ocean dumping may be an increase in both the suspension of tailing particles in the dump site's plume and the concentration of toxic metals associated with these solid components of the tailings. The extent of the effect depends on a number of factors such as amount of tailings dumped, methods of release, settling characteristics, and the activities of filter-feeding zooplankters as an entry point of toxic metals into the food chain.

Other tests indicate, however, that discharging tailings into the open ocean will not significantly raise the dissolved concentration of potentially toxic elements, except that of manganese. Furthermore, researchers predict that elements in the solid components of the tailing slurry will remain as particles and not dissolve. Although all proposed activities could not be carried out, enough data have been gathered to make reasonable predictions about the potential effects of ocean dumping on Hawaiian waters.

## EVIDENCE SUGGESTS THAT HYDROTHERMAL SYSTEMS EXIST UNDER THE BIG ISLAND

Project Pele, begun in Year 14 (1981-82), is a multi-year study to determine whether the Hawaiian island chain has hydrothermal systems similar to those found along the world rift system, which produce mineral deposits and support unique life forms. The Hawaiian chain, an isolated oceanic "hot spot," sits thousands of miles away from the nearest part of the world rift system, the East Pacific Rise.

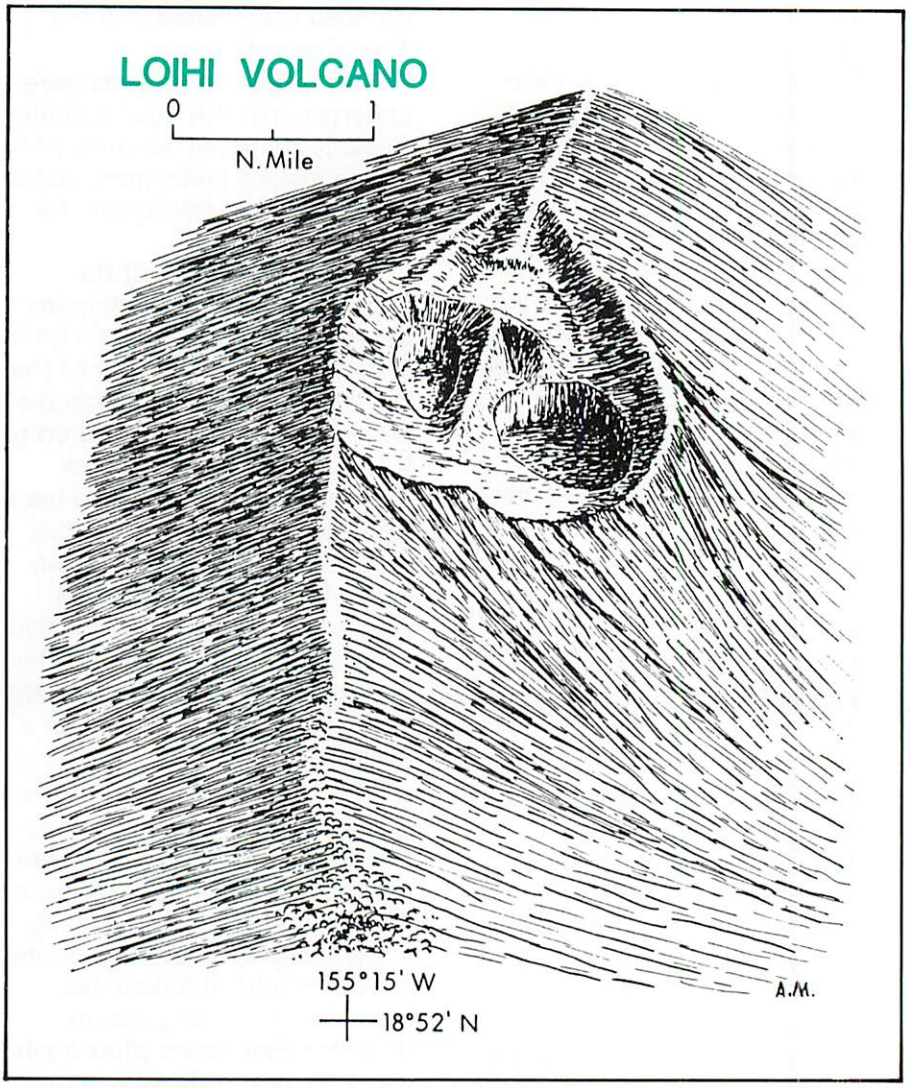
Although the rift zones of Mauna Loa on the island of Hawaii and Haleakala on the island of Maui were planned targets of study, major efforts during this quadrennium were

focused on the submarine portion of the east rift zone of Kilauea on the Big Island, which has been erupting periodically since January 1983.

The submarine portion of the east rift zone extends 50 km from Cape Kumukahi. To date, hydrothermal systems have not been discovered on the upper submarine portion (down to 400 m) of the east rift zone, but ample evidence suggests that such systems exist under the Big Island. The use of deeper-diving submersibles and unmanned remotely operated vehicles is expected to increase the chances of detecting submarine hydrothermal systems.

Researchers, however, have discovered hydrothermal systems in the Hawaiian chain that are similar in many respects to those found along the world rift system. These known submarine systems are located on the summit crater of Loihi Seamount, an active submarine volcano situated about 50 km south of the Big Island. Specialized life forms and massive sulfide systems similar to those in the world rift system have not yet been discovered. Data gathered suggest that sulfide deposits probably occur within basaltic piles of the volcano, and bottom photographs reveal sulfide-like stacks or pinnacles.

As this project continues into the next quadrennium, information will be sought to characterize the groundwater system of the east rift zone and to determine how it influences the geothermal energy resource of that area, the chemical composition of submarine hydrothermal vent waters, and the life forms that may be found associated with submarine hydrothermal vents.




Perspective physiographic drawing of the summit of Loihi submarine volcano, looking north. Principal features are the south rift (foreground), the summit crater, and the north rift (background).

—A. Malahoff drawing (modified)

"From the cradle to 'pau hana' (retirement)" is the oft quoted goal for marine education in Hawaii.

Sea Grant initiatives have contributed significantly to the identification and formalizing of marine education in Hawaii's educational institutions as a programmatic focus. In doing so, Sea Grant educators focused the attention of students and teachers from the primary grade levels to graduate programs on the riches and richness of the ocean. In marine education programs, the medium (the ocean) is truly the message.

## HO'I ANA I KE KAI USES THE OCEAN AS A LIVING LABORATORY

"Marine education" is generally construed to mean giving learners opportunities to gain knowledge and understanding of the ocean and its wonders. In at least one special case "marine education" means something much different: it means using important ocean-based values of the learner's culture to build an alternative educational program to help the learner come to see formal education as an important element of his or her personal and career development.

*Ho'i Ana I Ke Kai* ("Return to the Sea") was begun in 1978 to reach elementary- and secondary-level students living along the rural Waianae coast of Oahu. Many of the students, reared in a "Hawaiian lifestyle," often perform poorly in school. The project took advantage of the positive aspects of these children's culture to enhance both cognitive and affective learning, using an enjoyed and valued setting — the ocean — as the focus for instructional materials.

A 2-year marine studies program for alienated students at Waianae High School offered such ocean-focused content and activities as commercial fishing methods and marketing, seafood preparation, and marine careers. These were interspersed with necessary language arts, math, science, and social science skills and concepts.

During the first year, 23 of the 24 students, all previously identified as alienated and poor achievers, successfully completed the high school program. The turnaround in terms of academic objectives, attendance, and post-high school educational aspirations was, according to the students themselves, directly attributable to this program. Lowered rates of absenteeism and statistically significant cognitive gains by the students indicate that this culture-based program has the potential to help those who do not adapt readily to "mainstream" classrooms.

Similar sorts of results were obtained in the elementary-level part of *Ho'i Ana I Ke Kai.*

## UNDERGRADUATE MARINE PROGRAM SERVES DIVERSITY OF STUDENTS

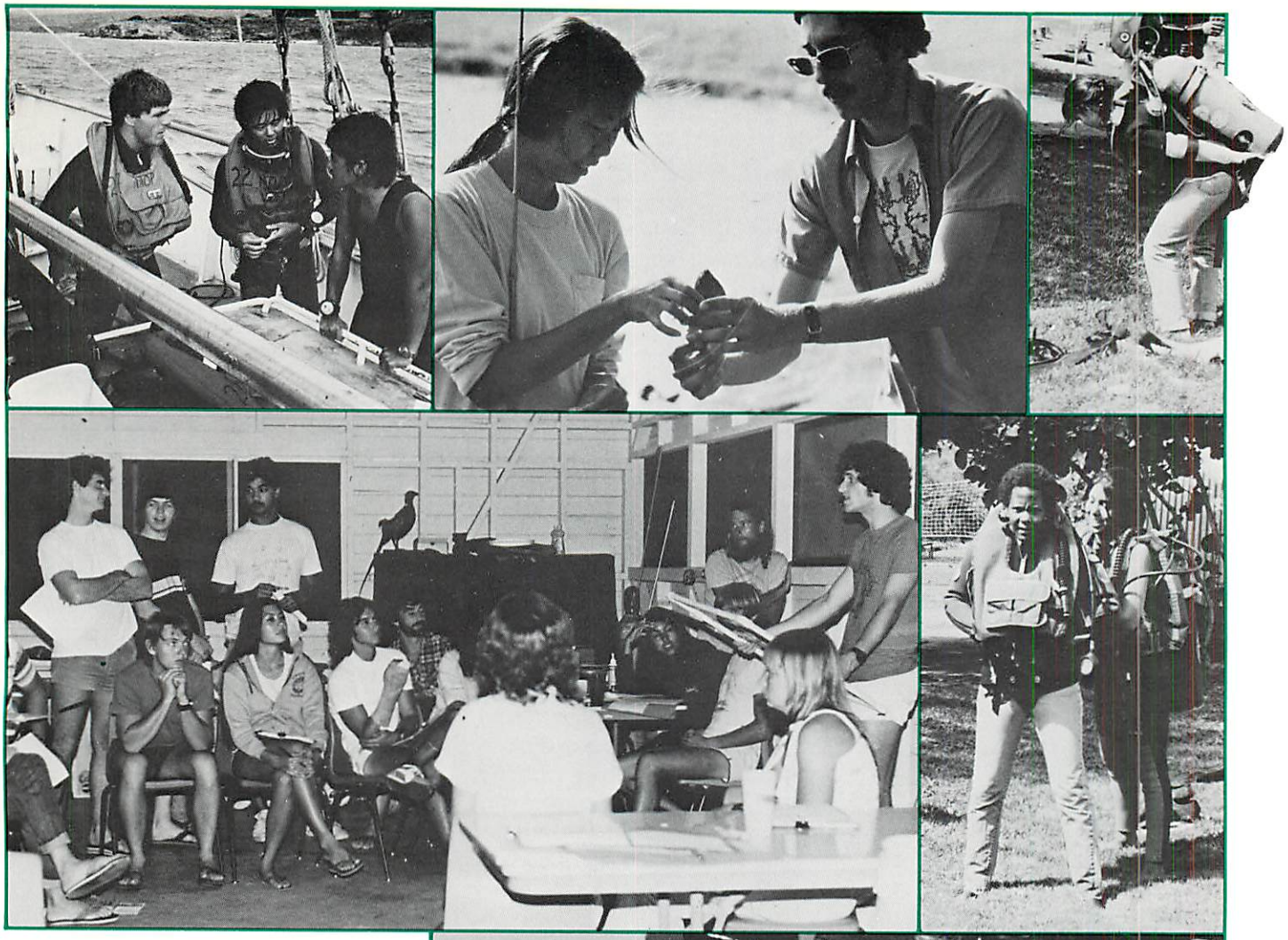
At the college level, the University of Hawaii Marine Option Program remains as one of the unique programs of undergraduate marine education in our nation's colleges and universities.

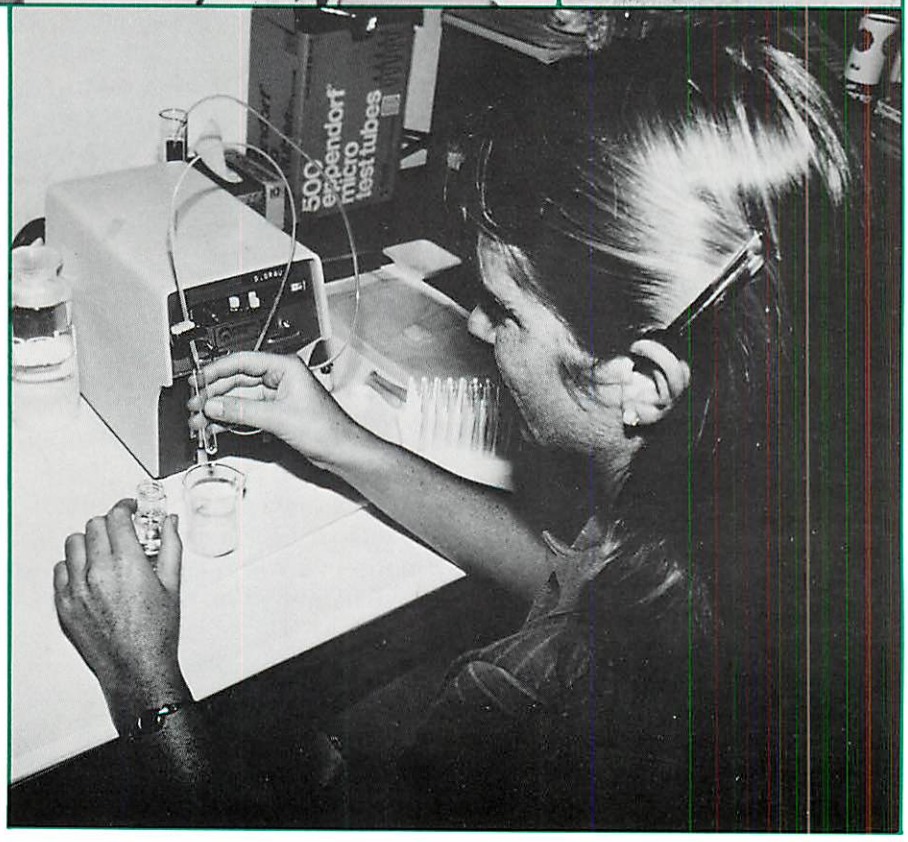
Established in 1971, this Sea Grant-supported program of marine studies offers a wide range of opportunities to undergraduate students for career preparation and enhancement of liberal arts studies. Thus, MOP students not only have "marine" majors, but majors from many other disciplines. This program operates on several campuses of the University of Hawaii system.

The program's approach is "experiential," that is, a student's major field of study is supplemented with coursework in marine studies and with "hands-on" skill projects or internships in varied settings outside the classroom. The disciplines (e.g., journalism, business administration, biochemistry, and oceanography) and the subject areas of skill projects (e.g., ecological baseline surveys, photography, surfing safety, dolphin language, and whale migrations) are evidence of the diversity of the students' backgrounds and interests.

A program goal, through such studies and activities, is to help participating students to become responsive and responsible citizens and decisionmakers relative

Student skill projects or internships take place in varied settings outside the classroom. Scuba diving, underwater photography, and ecological baseline surveys are among the skills projects conducted in the marine environment.






to marine issues and problems. During the last 4 years, nearly 600 students were enrolled in the Marine Option Program, with 91 earning a certificate offered by the program. The certificate signifies that a student has a unique set of credentials, which, for some, have proven to be instrumental in creating job and graduate educational opportunities. For most students, however, the opportunity to enhance their college education with marine studies through the Marine Option Program is reason enough.

In addition to its formal program, the Marine Option Program has, over the years, sponsored public events such as the annual Ocean Fair and seminars, workshops, and field trips presented by students, graduates, and professionals.

## STUDENTS INVESTIGATE "HOW TO" ASPECTS OF BACKYARD AQUACULTURE

At Windward Community College in Kaneohe, Oahu, Marine Option Program students were heavily involved in the Hawaiian Backyard Aquaculture Program. The Sea Grant-supported program was started in 1981 to develop and to disseminate techniques of small-scale, or "backyard," aquaculture to interested residents of Hawaii. The intent was to provide residents with "how to" information on constructing and maintaining subsistence and avocational ponds on house lots and other small land areas.

During the last 2 years of this quadrennium, the Hawaiian Backyard Aquaculture Program concentrated on transferring the research and practices of commercial-sized aquaculture systems to small-scale ones. In this period, the 31 students participating in the program adapted and developed about 80 percent of the practices needed for backyard aquaculture.

The information originating from this program has been disseminated through workshops, conferences, Sea Grant and other publications, news items in the media, and other means. This work in small-scale aquaculture complements that done locally for commercial aquaculture and further establishes Hawaii as a world leader in this field.

## NEW EDUCATIONAL DEVELOPMENT PROJECTS FOCUS ON TECHNOLOGY AND TECHNIQUES

Instructional materials on fishing gear and techniques were developed and pilot-tested and added to the Marine Technician Training Program at Leeward Community College. These materials are used to teach two new courses: "Fishing Gear and Techniques" and "Trap Fishing Gear and Techniques." Forty-eight students were enrolled in these courses. An indirect result of the project was the development of a third course at the community college, "Boat Maintenance and Repair."

A new course in underwater technology in the Department of Ocean Engineering at the University of Hawaii-Manoa provides graduate students with sufficient knowledge to recognize design and operational criteria related to problems and applications below the ocean's surface.

"Boat Maintenance and Repair" course provides each student opportunities for "hands-on" learning.

## EXTENSION SERVICE NARROWS ACTIVITY FOCUS FOR GREATER EFFECTIVENESS

The mission of the UH Sea Grant Extension Service is to carry out programs of extension and education that will help marine resource users (including the general public) and managers to arrive at wise decisions regarding the development and conservation of marine resources in Hawaii and elsewhere in the Pacific. To this end the Extension Service seeks to help identify priority ocean and coastal problems, implement problem-solving programs, develop and maintain cooperative relationships with other agencies and groups, influence the direction of Sea Grant research to meet marine users' needs, and increase staff proficiency in serving Sea Grant clientele.

During Years 12 through 15, the Extension Service's outreach efforts addressed a wide range of needs, reflecting local, regional, and national concerns. Having since its formation expanded in size of staff and scope of its activities, the Extension Service began to narrow the focus of both individual and program efforts for even greater effectiveness, a hallmark of the last 4 years. Client-related problems were addressed in the following areas: aquaculture, community resources development, fisheries, marine resources development, seafood education, and youth education.

The following examples of extension activities in fisheries exemplify the efforts and results achieved throughout the program.

Most of the 13 million pounds of fish landed in Hawaii come from its nearshore fishery. More than half of the catch is comprised of aku (skipjack tuna), with the remainder consisting of such commercially important species as ahi (yellowfin and bigeye tunas), opakapaka (pink snapper), and ono (wahoo). In this quadrennium, as in previous years, the retention of a vigorous nearshore fishery continued to be a major priority of the Extension Service.

Howard Takata, East Hawaii agent, helped Elaine and Richard Dollnig get started in trout aquaculture on the island of Hawaii. They harvested their first commercial crops in 1982.

The extension staff sought to extend new fisheries knowledge and technology to current and prospective fishermen, stimulate adoption of more advanced marketing and handling techniques, and help consumers recognize new opportunities for nutritious low-cost food, especially under-

used seafood species.

Ika-shibi (deep handlining) for ahi is well established on the island of Hawaii, but little practiced elsewhere in the state. Early in the quadrennium, workshops on the island of Kauai stimulated numerous fishermen to adopt this technique. Encouraged by this success, training sessions held on the island of Lanai resulted in several more fishermen adopting this technique within a year.

On the island of Hawaii, ika-shibi fishermen sometimes lose up to 75 percent of an ahi's value because of ahi "burn," a deterioration of the flesh. Working with Sea Grant, the National Marine Fisheries Service, and local fishermen, a gathering of Hawaii County leaders committed themselves to support a University of Hawaii veterinarian to seek better means of identifying affected ahi and to determine what causes burn. Workshops were held on the Big Island to bring fishermen and county leaders up to date on research progress.

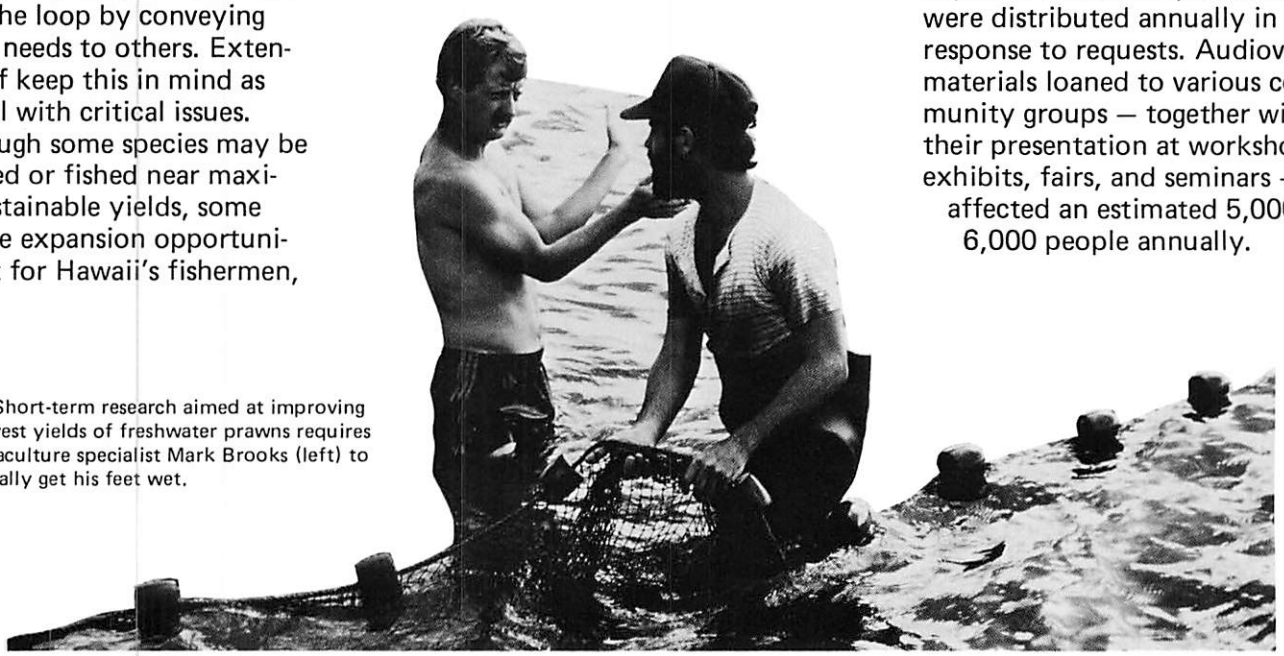
This is one instance of the Extension Service's role of not only taking information to users and stimulating its adoption where appropriate, but also completing the loop by conveying research needs to others. Extension staff keep this in mind as they deal with critical issues.

Although some species may be overfished or fished near maximum sustainable yields, some nearshore expansion opportunities exist for Hawaii's fishermen, notably for the harvest of underused species such as taape (blue-lined snapper), shark, and deepwater shrimp. Sharks, for example, are usually discarded when caught incidentally. If fishermen could be stimulated to harvest them and consumers to eat them, a now wasted resource could become a valuable one.

During the quadrennium, extension staff — through consumer educational and professional organizations such as the Hawaii Nutrition Council, the Cooperative Extension Service, and the International Food Service Executives Association — multiplied their efforts to transfer handling and cooking techniques to potential consumers and to stimulate their use of shark and other underused species. In the latter half of the quadrennium, a local expert and a Sea Grant expert from California were brought together with prospective shark fishermen and marketers in a fishing and handling techniques workshop. At the same time, news releases, newsletter articles, and a public television program on shark cooking introduced consumers to or reacquainted them with the culinary potentials of shark.

Such efforts have demonstrated consumers' acceptance of and demand for shark meat. Seafood retailers and wholesalers note that shark continues to sell well, often "selling fast," when available. One wholesaler now ships 300 to 400 pounds of Hawaiian bronze whaler, thresher, and mako shark meat to California weekly. A fisherman started a shark fin export business, which has now expanded throughout the Pacific. Most important, these innovators have taken a Sea Grant initiative and carried it forth. The adoption of successful approaches and initiatives by clients — organizations and individuals — is a major goal of extension efforts.

Extension publications and audiovisual materials continued to be effective tools for reaching and educating individuals and groups, including the general public. "Roughwater Rescues," produced as both a 28-minute, 16-mm film and videotape, was seen by thousands of visitors and residents. In addition, it was extensively used by military organizations as part of their orientation programs for newly arrived personnel and dependents. An average of about 10,000 copies of extension publications were distributed annually in response to requests. Audiovisual materials loaned to various community groups — together with their presentation at workshops, exhibits, fairs, and seminars — affected an estimated 5,000 to 6,000 people annually.



Short-term research aimed at improving harvest yields of freshwater prawns requires aquaculture specialist Mark Brooks (left) to literally get his feet wet.

## SEA GRANT PROVIDES ADVISORY AND OTHER SERVICES TO PACIFIC ISLAND COMMUNITIES

As the University of Hawaii Sea Grant College Program and its Extension Service developed increased capabilities, the possibility arose of serving a wider Pacific clientele. In 1979, an extension agent was placed on Guam. At the beginning of this quadrennium, the Extension Service expanded Sea Grant's role in the western Pacific.

The UH Sea Grant is in a unique position to assist the developing territories and countries of the Pacific. The university has capitalized on its island heritage and subtropical location to become a center of excellence in marine studies, including oceanography and marine biology, and in interdisciplinary studies of tropical environments and resource management. Although Hawaii is much more highly developed as a modern, technologically oriented society, its marine resource base and insular ecosystems parallel those of other Pacific territories. Moreover, similar social and cultural backgrounds and attitudes link the peoples of Hawaii with the rest of the Pacific, thus providing favorable conditions for cooperation and facilitation of an effective UH Sea Grant extension program.

In the late 1970s, Extension services were established and agents placed in American Samoa and the Commonwealth of the Northern Mariana Islands to parallel the ongoing work in Guam. Programs related to commercial fisheries, aquaculture, water safety, and marine conservation were carried out through direct assistance, workshops, and other activities. Thousands of Pacific islanders have benefited.

Fish handling workshops carried out by the Extension agent in American Samoa illustrate how Pacific islanders – in this case, local fishermen, vendors, and consumers – have benefited. As a result of the workshops, fishermen began to use a brine solution for fish preservation. For the resulting higher quality fish, they received an additional $.40 per pound. Vendors improved their facilities with screening, stainless steel counters, etc. Poundage sold soared from 300 to 1,600 pounds per week and the price of the high-quality products rose by as much as $.80 per pound.

However, program expansion into the western Pacific was shortlived. The early 1980s was a period of federal budgetary cutbacks, and agent positions were not refilled as they became vacant. As the quadrennium ended, only a full-time agent on Guam remained. This agent assumed greater responsibility for extension activities in the western Pacific, especially in the Commonwealth of the Northern Mariana Islands. Other extension activities in the western Pacific were carried out by agents and specialists based in Hawaii.

Internationally, the Sea Grant Extension Service developed a training program in Honolulu for the University of Hawaii. This was accomplished in cooperation with the University of the South Pacific in Fiji. Among the results, several persons from Tonga, Fiji, Western Samoa, and the Solomon Islands received training for extension work.

During the quadrennium, the Guam advisory program matured rapidly as a result of the agent's efforts and the support of the marine and extension components of the University of Guam. A sign of the advisory program's growth and development was its inclusion as part of the University of Hawaii/University of Guam Sea Grant Program. The Guam advisory program has been autonomous since Sea Grant Year 14, but the agent continues to be affiliated with the UH Sea Grant Extension Service.

## UNIVERSITY OF HAWAII/UNIVERSITY OF GUAM SEA GRANT PROGRAM

A joint University of Hawaii/ University of Guam Sea Grant Program was formed during this quadrennium to more effectively develop programs to serve the needs of the western Pacific.

The joint program carried out two research projects aimed at determining the potential for mariculture in Guam of particular species of seaweed and assessing the marine biological resources around the Marianas Islands.

Natural beds of the seaweed *Gracilaria edulis* are harvested and marketed for human consumption in Guam. But, their limited distribution and abundance prevent large-scale harvesting and marketing of these wild crops. Mariculture of species of *Gracilaria,* if satisfactory production rates could be achieved, would provide additional food supplies and additional economic benefits to the people of Guam. There is the possibility, too, of culturing the seaweed for its agar, an increasingly demanded substance for use in a variety of commercial and industrial applications worldwide.

Sea Grant researchers selected two species, *G. edulis* and *G. arcuata,* to study because of their fast growth rates in reef flats and tank-culture systems. A major aim of the study was to determine production rates in such settings. The low-technology reef flat culture, growing *Gracilaria* on ropes, was thought to be suitable for outer islands where the harvested seaweed could be brought to market by infrequent boat service such as in the copra industry. On Guam, close to markets, high-intensity tank culture would be used. Mullet were added to the tanks; the ammonia in their excretions was expected to increase seaweed growth. The mullet themselves represent a highly valued food fish in Guam and represent an additional economic benefit from such mariculture.

Research results showed that *Gracilaria* in tank cultures had growth rates of 2 to 8 percent a day on a dry weight basis. This is comparable with growth rates observed in natural beds of the seaweed. Growth rates were greater in shallow water than in deep water and in light than in shade. Growth rates, however, were not improved by brief exposures of the seaweed to elevated concentrations of ammonia, but rates of photosynthesis increased immediately after exposure.

Of the several species of mullet considered for culture with the seaweed, *Liza vaigiensis* showed the most promise. In cage culture, these mullets grew nearly 1 percent daily and had a 95 percent survival rate.

Another aspect of the research was to determine which species, if any, of *Gracilaria* could produce agar of commercial quality and in sufficient quantity for sale on world markets. Agar extracts were taken from several species of *Gracilaria* obtained from Guam, Saipan, and Taiwan. Commercial cultivation of *Gracilaria* is well developed only in Taiwan.

Among the results, the researchers found that the *Gracilaria edulis* samples from Guam had the highest yields of agar, as high as 71 percent. However, the agar from this seaweed had low gel strength, i.e., the ability of the gel surface to resist breaking under weight. The researchers concluded that if the gel strength of the agar obtained from *G. edulis* could be improved through some means, then its potential for commercial mariculture would be enhanced.

The second project aimed at assessing biological resource stocks of reef, bottom, and open ocean ecosystems surrounding the Marianas archipelago. The research was designed so that data gathered by this project could be integrated with data gathered by the National Marine Fisheries Service through its Resource Assessment Investigations of the Marianas Archipelago (RAIOMA) program.

The resource groups assessed, and of particular interest for their actual or potential commercail value and for conservation, are reef-associated marine plants, reef corals, precious corals, and zooplankton and ichthyoplankton. Additional information was also gathered about water chemistry and nutrient concentrations.

The baseline information gathered on several resource stocks can be used for developing resource development and management plans for the Marianas archipelago. The information obtained from the study has already stimulated further research into the effects of plant-eating fish on reef communities in the archipelago.

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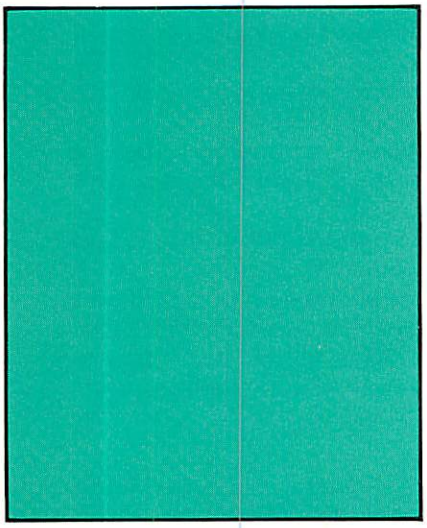


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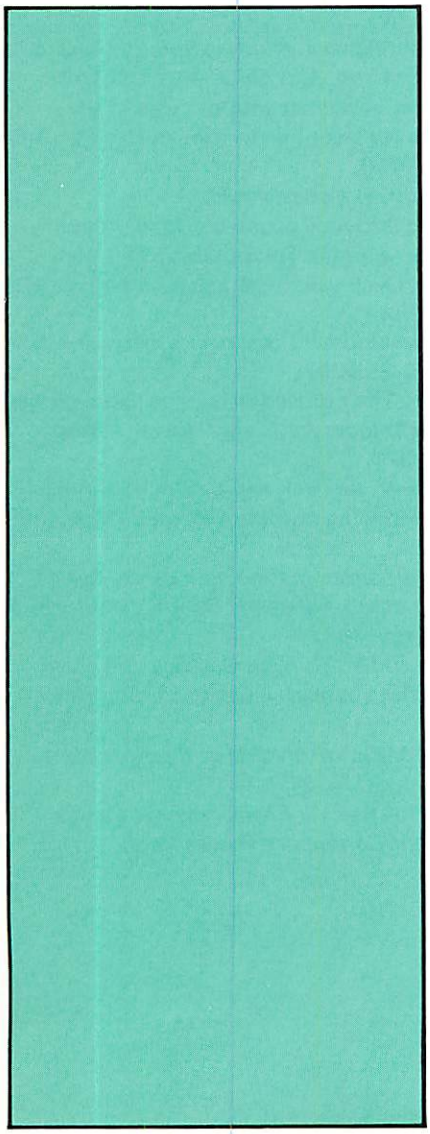


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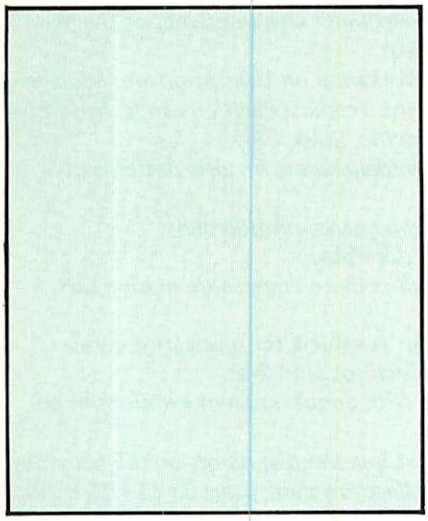

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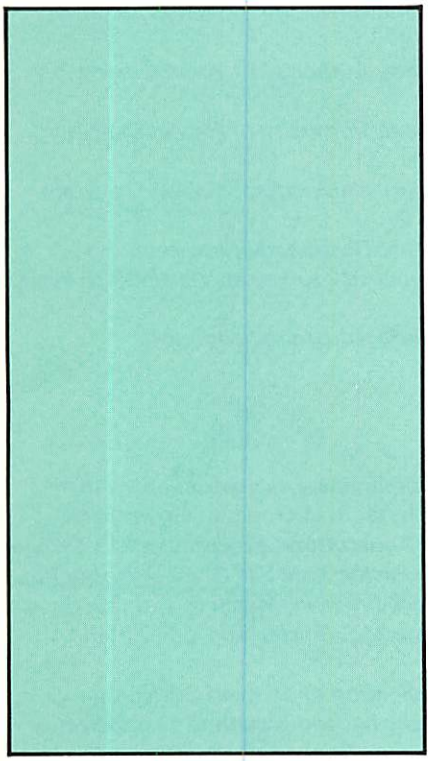

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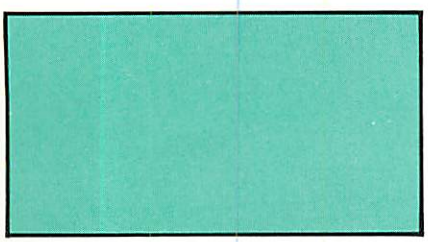

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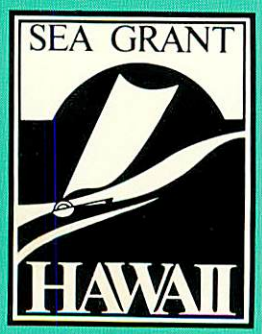


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