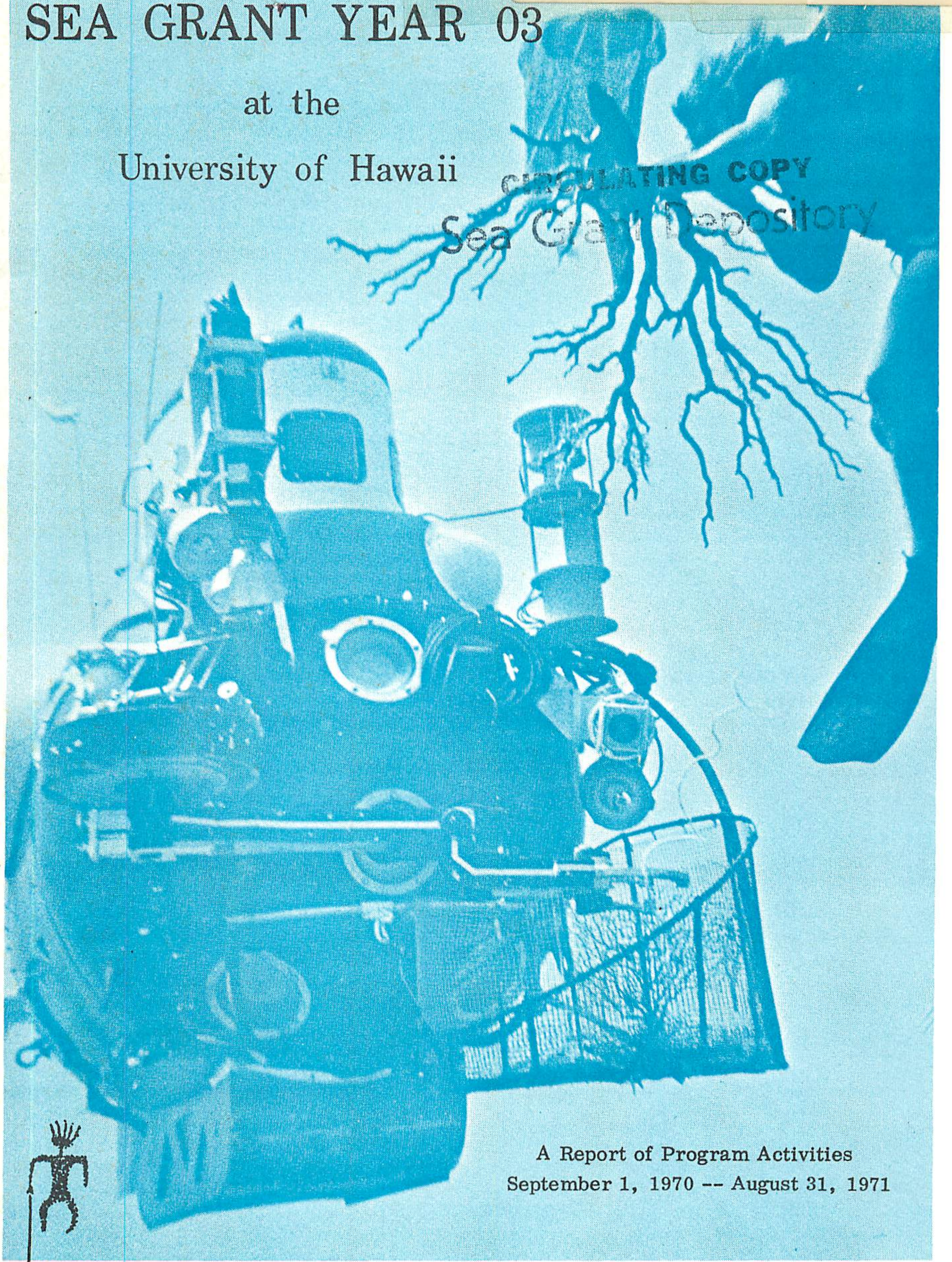
SEA GRANT YEAR 03

at the

University of Hawaii



A Report of Program Activities
September 1, 1970 -- August 31, 1971

The University of Hawaii Sea Grant Program *UNIHI-SEAGRANT-MS-72-02*

SEA GRANT YEAR 03

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UNIVERSITY OF HAWAII

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This report describes Sea Grant Program activities during the period September 1, 1970, through August 31, 1971, with pertinent historic background. The projects reported were supported under Grant No. GH-93 from the National Science Foundation.

Jack R. Davidson
Director

The University of Hawaii Sea Grant Program

ACKNOWLEDGMENTS

The Sea Grant Program Director's Office at the University of Hawaii acknowledges the extensive work of Howard Pennington in compiling the information for this report.

COVER PHOTOGRAPH

Shown on the cover is the STAR II, a submersible, being field-tested in a coral bed. The submersible is equipped with a mechanical arm which can selectively harvest a particular coral head without disturbing adjacent growth. The State of Hawaii and Makai Range Inc. cooperated with the University of Hawaii in developing new, ecologically sound procedures for precious-coral harvesting.

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PART I

The aim and purpose of the National Sea Grant Program, the significance of the program in Hawaii, and the early history of the program at the University of Hawaii are described in Part I of this report.

AIM AND PURPOSE OF THE SEA GRANT PROGRAM

As an aid in evaluating any program that has been in progress for several years, it is often helpful first to review the basic purpose underlying that program.

In the case of Sea Grant, the guiding principle was defined by the Congress of the United States in the "Declaration of Purpose" of the National Sea Grant College and Program Act of 1966* with the following words:

The Congress hereby finds and declares –

(a) that marine resources, including animal and vegetable life and mineral wealth, constitute a far-reaching and largely untapped asset of immense potential significance to the United States; and

(b) that it is in the national interest of the United States to develop the skilled manpower, including scientists, engineers, and technicians, and the facilities and equipment necessary for the exploitation of these resources; and

(c) that aquaculture, as with agriculture on land, and the gainful use of marine resources can substantially benefit the United States, and ultimately the people of the world, by providing greater economic opportunities, including expanded employment and commerce; the enjoyment and use of our marine resources; new sources of food; and new means for the development of marine resources.

The Sea Grant Act calls for programs of research "relating to the development of marine resources, with preference given to research aimed at practices, techniques, and design of equipment applicable to the development of marine resources. . ."

Therefore, while most research programs concentrate on obtaining basic knowledge, Sea Grant research programs employ basic knowledge to solve specific problems, for the benefit of the United States and eventually the world.

The Sea Grant Act also calls for programs of "instruction, practical demonstrations, publications, and otherwise" for the purpose of "imparting useful information to persons currently employed or interested in the various fields related to the development of marine resources, the scientific community, and the general public."

Sea Grant educational and advisory programs may operate in any marine-related area where such services would be helpful in furthering the objectives of the Sea Grant Act; the information and knowledge they may make available is not limited to that developed by Sea Grant research programs.

How has the Sea Grant concept of advisory, educational, and research programs been applied to Hawaii? Before looking at this, it will be helpful to examine first Hawaii's relationship to the sea and to the total marine environment.

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*Public Law 89-688, 89th Congress, H.R. 16559, October 15, 1966.

HAWAII AGAIN LOOKS TO THE SEA

When Captain Cook chanced upon the Hawaiian Islands in 1778, he "discovered" an archipelago that had been found and inhabited hundreds of years earlier by Polynesians who must have been among the greatest seafarers and long-distance ocean navigators of all time. (When the Polynesians arrived at Hawaii, they had paddled, sailed, and steered themselves to the most isolated group of islands in the entire world.) By the time Cook arrived, some of the Hawaiians' nautical skills had apparently been lost, as round trips between Hawaii and Tahiti – more than 4,000 miles of star-guided voyaging in outrigger canoes – were no longer made.

Canoe travel across the rough channels between the various islands of the Hawaiian group was still a common occurrence, however, and the people made much use of the sea. They harvested seaweeds, and ate all manner of marine animals, from tiny snail-like creatures found on wave-swept rocks to tuna and other large fish found in the deep waters far out beyond the reefs. They conserved the resources of the sea with a rigid system of tabus aimed at conserving and maintaining fisheries. And they supplemented those resources by rearing fish in ponds built along the shore with large lava rocks. The sea around Hawaii then played a much more important, direct role in Hawaii's economy than it does today.

The main pillars supporting the modern Hawaiian economy are the military, tourism, and agriculture, primarily sugar and pineapple. It is true that Hawaii's particular location in the midst of the vast Pacific ocean has much to do with its military importance, and its trade-wind cooled beaches are one of its major tourist attractions, but the direct input to Hawaii's economy by marine activities is relatively small. In 1969, for example, the estimated total economy of Hawaii amounted to about $2.5 billion. Commercial fish landings that year totaled $3.4 million – or only slightly more than one-one hundredth of one percent of the total state economy. The citizens of Hawaii still eat a lot of seafood, but most of it is imported from other states and other nations.

Hawaii's interest in the ocean never died. Sea, surf and sand continued to play a major role in Hawaii's recreation. As the University of Hawaii grew, it developed substantial marine programs. But Hawaii's economic dependence on the surrounding sea steadily diminished, once it ceased to be a great haven for whaling ships.

By the mid-1960's the ebbing interest in the ocean as a present and potential economic asset to Hawaii had reached its lowest point. The tide of interest began to flood once more. In 1965, Governor John A. Burns began a series of conferences on Hawaii's oceanographic potential. When the national government issued the detailed report, *Our Nation and the Sea,* Hawaii was the first state to follow its example. In 1969, the State Department of Planning and Economic Development published *Hawaii and the Sea,* a comprehensive set of recommendations that involved the work, thought, and experience of some one hundred of Hawaii's leaders in various marine-related fields. Early in 1970, following recommendations contained in *Hawaii and the Sea,* the state legislature passed a bill creating the post of Marine Affairs Coordinator in the governor's office. The legislature also appropriated, over a two-year period, $870,000 for various projects to support Hawaii's existing marine facilities and to develop the potential of its ocean resources, under the guidance of the Marine Affairs Coordinator.

Following another recommendation of the state report, the position of Dean of Marine Programs was created at the University of Hawaii. (The Dean's responsibilities included the University's Sea Grant Program.) In September of 1970, Governor Burns named Dr. John P. Craven to fill both the position of Marine Affairs Coordinator and that of Dean of Marine Programs, thus assuring the closest possible cooperation between the two functions. It was at this point that the University of Hawaii's Sea Grant Year 03, the year covered by this report, began.

SEA GRANT IN HAWAII: IMPORTANT CHANGES FOR YEAR 03

From the beginning, the University of Hawaii recognized Sea Grant as an important new source of funding with which to carry out important research projects.

The program was first placed under the direction of some of the University's top people in the oceanic field – but on a part-time basis. (They still carried their other responsibilities.)

Following long-established and accepted procedures, research projects were chosen for funding on the basis of their individual worth. All dealt with one problem or another that merited attention – but there was no overall priority plan to assure that all major problem areas received their proper proportion of available funds.

In the months leading up to Year 03, important changes were made both in the direction of the Sea Grant Program and in the method of selecting projects for funding and activation. Those changes are summarized on the following pages.

REORGANIZATION OF MANAGEMENT AREA

During Year 02, the National Sea Grant Program Office issued a "policy statement" defining the criteria for designating an institution as a "Sea Grant College". One of these was that a university seeking such designation must have a person of "high competence and stature who has a full-time staff devoted to Sea Grant affairs."

The full-time position of Director of Sea Grant Programs was established by the University during the latter part of Year 02. Selected for the position, and formally taking up his new duties on September 1, 1970, at the beginning of Year 03, was Dr. Jack R. Davidson.

Prior to his appointment as Sea Grant Director, Dr. Davidson was professor and chairman of the Department of Agricultural and Resource Economics at the University. Although his field was not the sea, his specialty was developing, conducting, and channeling research into the mainstream of the economy in a manner designed to enrich that economy. And that is the ultimate purpose of Sea Grant.

In a move designed to assure close cooperation between the Sea Grant Program and other marine-related activities at the University and in the State, Dr. Davidson has been subsequently named Associate Dean of Marine Programs at the University. Thus, Sea Grant and other University of Hawaii marine programs were linked in the person of Dr. Davidson, while University and state marine activities were linked through Dr. John Craven, the state's Marine Affairs Coordinator and the University's Dean of Marine Programs. This arrangement has worked well, with several interrelated projects resulting.

During the first few months of Year 03, a small Sea Grant staff was selected, and a Sea Grant Office established. Procedures for budget control, and for gauging progress toward objectives, among others, were established.

ORGANIZATION OF AN OVERALL PLAN

The concept of identifying a number of important "problem areas" and concentrating efforts on those areas took shape during Year 02. It grew from two sources. Major impetus came from a number of helpful recommendations and creative criticisms, made by the national Sea Grant Program Office and the National Advisory Committee. The second source was a concern at the University that its program had not yet achieved that important balance – among projects of research and development, education, and advisory services – called for by both the letter and the spirit of the Sea Grant Act.

With the aid of a ten-member Advisory Committee, including five members from the community, and the active participation of more than 80 interested faculty members, an integrated plan was developed. The original plan for Year 03 specified education and advisory service projects, plus research and development projects in eight problem areas. (See Table 1.)

Table 1. Plans for Grouping Sea Grant Projects into Areas of Concern for Year 03, as Specified Originally and as Modified.

Areas Specified Originally	Modified Plan
Education	Education
Advisory Services	Advisory Services
Pollution Shoreline Management "Crown-of-Thorns" Starfish *Acanthaster planci*	Coastal Environment Management
Mineral Resources	Ocean Bottom Resources and Ocean Engineering
Improvement of Fisheries New Fisheries	Fisheries
Tropical Aquaculture - Animal Tropical Aquaculture - Plant	Aquaculture
Continued Year 02 Projects	Continued Year 02 Projects (These two projects evolved into a program later titled "Life in the Sea".)

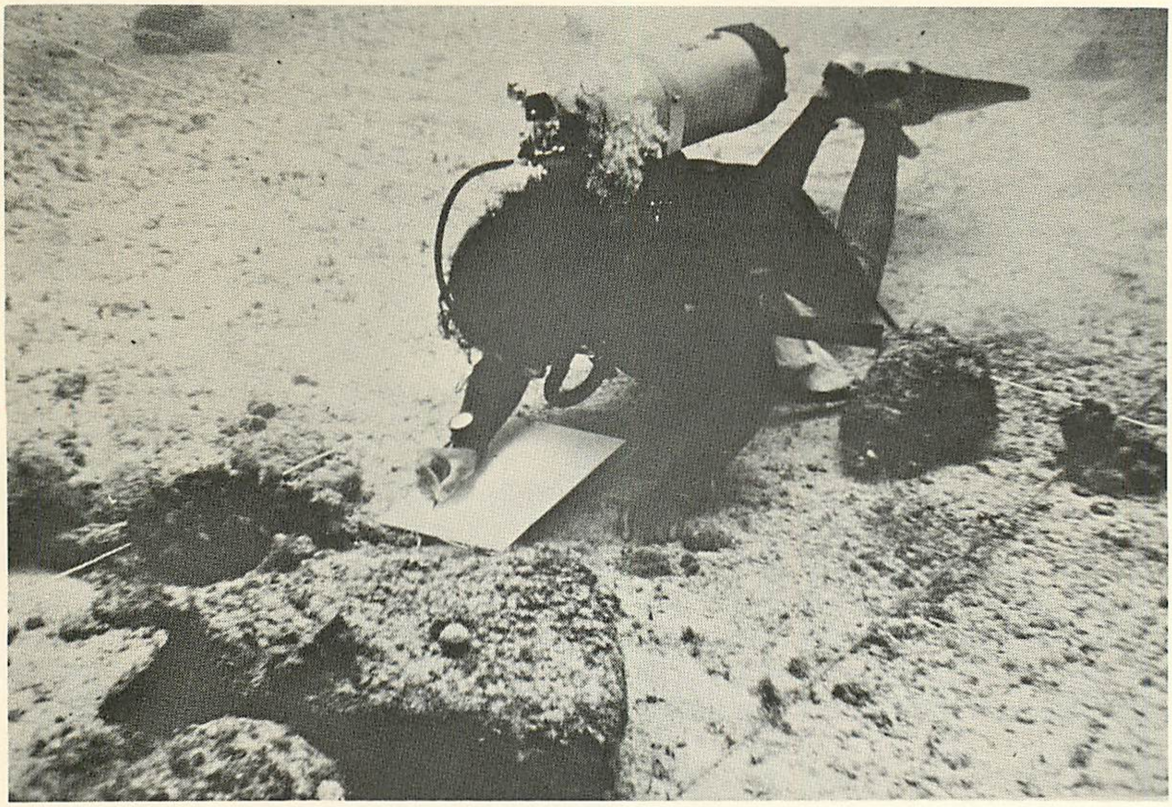
In further refinements during Year 03, "Shoreline Management" became "Coastal Environment Management" and two other areas, "Pollution" and "Crown-of-Thorns Starfish", were incorporated within its scope. The two fisheries areas were combined into one, as were the two aquaculture areas; the mineral resource section was expanded into "Ocean Bottom Resources and Ocean Engineering".

For the Year 03 proposal, 75 projects were carefully considered and 48 were selected. Of these, 28 received funding, including several projects continued from Year 02.

All projects funded during Year 02 were individually reviewed by the Advisory Committee. Where results were promising, and the project fitted into a selected problem area, it was funded as a "continuing" project in that area. Two projects that did not fit into the problem areas, but that clearly warranted continuation, were funded under the heading, "Continued Year 02 Projects". Together they constituted an area of concern later called "Life in the Sea".

PART II

Sea Grant Year 03 at the University of Hawaii began September 1, 1970, and ended August 31, 1971. The following sections of this report describe the projects carried out during that year. Each section begins with an overview of the problems and opportunities to be found in a particular area. Because of the new emphasis placed on projects in education and advisory services for the Year 03, they are discussed first.



Under the Marine Option Program undergraduate students can acquire both theoretical and working knowledge about the ocean, no matter what their academic major may be. Each student in the "MOP" program takes some marine-related courses and acquires a useful marine skill: for example, scuba diving or underwater photography. Shown here are students performing underwater tasks on a Sea-Grant sponsored research project. Undergraduate students at the University of Hawaii planned, organized, and carried out this study. (Photo by Bill Thomas.)

PROBLEM AREA: MARINE-ORIENTED EDUCATION

From the traditional viewpoint of the academic community, marine-oriented education certainly has not been considered a "problem area" at the University of Hawaii. During Sea Grant Year 02, for example, more than 2,000 students were enrolled in 64 credit courses and seminars in marine sciences and related subjects. The master of science degree was offered in ocean engineering, oceanography, and marine biology. The doctor of philosophy degree could be obtained in oceanography and marine biology. (Doctorates in ocean engineering have since been added to the list.) Graduate-level marine-related studies were also pursued in the fields of zoology, botany, microbiology, geosciences, psychology, architecture, economics, and physiology. Each year the State of Hawaii provides over $1 million to support these programs. Backstopping these academic programs with strong research support at the University are the Hawaii Institute of Geophysics, the Hawaii Institute of Marine Biology, the Pacific Biomedical Research Center, the Water Resources Research Center, and the Food Science and Technology Laboratory.

But viewed from the Sea Grant concept of using basic marine-related knowledge (and marine resources) for the purpose of national needs, and of spreading such knowledge wherever it might prove of use or interest, it could be said that "problems" did indeed exist.

For example, all marine-related degrees, and almost all marine-related courses, were available only after the student obtained the bachelor's degree. With only a few recent exceptions, it has been the policy of U.S. universities to consider the ocean a field for graduate students only. This means that a supply of highly qualified scientists was being produced at the University of Hawaii and other institutions, but there was almost no effort to train technicians and other skilled operators needed to operate and repair oceanographic instruments, and to perform the many other functions that are absolutely vital if knowledge obtained by basic research is going to be put to work.

The almost total concentration of ocean-oriented education at the graduate level in the United States poses another problem. It means that the vast majority of U.S. citizens, even those with a college degree, have little or no real understanding and knowledge of the oceans – even though the nation has over 12,000 miles of ocean lapping at its borders. (If the total U.S. shoreline, following every bay and inlet, were stretched out, it would reach around the world at the equator more than three times.)

Still another area of concern is the "knowledge explosion". As research projects continue to increase the total amount of marine-related knowledge, it becomes more and more difficult for people who need that knowledge to find it. To read all the pertinent scientific journals and publications as they appear can be more than a full-time job in itself, leaving no time to apply the knowledge thus discovered. A further complication is the fact that material in scientific journals often includes too much technical vocabulary to be fully understood by someone not a specialist in that field, even though he might be able to make important use of the information if only he had a full grasp of it.

To help alleviate these problems at the local level, seven programs were recommended for funding in the area of education for Year 03; three were actually funded at the start of that year. A fourth project was initiated and funded in midyear.

Project Title: MARINE TECHNICIAN TRAINING PROGRAM
Short Title: Technician Training
Inception: A new project for Year 03
Principal
Investigator: Gary D. Stice
Instructor of Geosciences and Oceanography
Leeward Community College

Despite the fact that Hawaii is an island state in the middle of the largest ocean, a port of call for commercial and research vessels from many nations, and the site of one of the nation's ten largest oceanographic institutions (the University of Hawaii), it had in 1969 no program for training marine technicians. The marine community in Hawaii clearly had need of such a program: a survey during Sea Grant Year 02 showed between 22 and 31 new marine technicians would be needed in Hawaii each year. It was already well known that Hawaii had a sizeable number of people interested in receiving such training. Working together, Sea Grant and the University's community college system could provide the program of education and training that was lacking.

A two-year program leading to an "associate of science" degree was established. Most of the courses taught in the first year of the two-year program are those already part of the standard curriculum, such as English, math, biology, chemistry, science, and basic oceanography. Most of the second year is devoted to technical courses.

The core of marine technology courses includes basic seamanship and marine orientation, applied mathematics, scuba diving, and an introduction to oceanography. Following this, the student may elect to pursue additional courses leading to certification in the broad areas of ship-board or small-craft operation, commercial fishing, and commercial diving.

The program was designed to make it potentially useful to the greatest number of people. Thus, in the first year of actual instruction (Year 03), both the first and second year of the two-year associate of science degree program was offered, so that students who already had completed the academic courses could start on the technical courses at once.

Another feature is that a student completing the two-year course will have accumulated approximately 34 credit hours that can be transferred directly to the University itself, if he should decide to go on with his formal education and obtain a full, four-year degree. It is also possible for people to enroll for specific training without entering the two-year degree program.

During Year 03, 18 courses were offered. A total of 211 students were enrolled in one or more courses. Of these, 13 completed the requirements for the associate of science degree and 21 put their new skills to work at full-time jobs in the marine community.

Because of the success of the first year, and the continuing need for such a program, Sea Grant support was continued for Year 04.

Project Title:	TOPICS IN OCEAN ENGINEERING
Short Title:	Ocean Engineering
Inception:	Project continued from Year 02
Principal Investigator:	Charles L. Bretschneider Professor and Chairman Department of Ocean Engineering

The field of ocean engineering has grown rapidly in recent years; one of the major problems of its practitioners has been to keep up with new developments and technologies. This problem was realized in the first year of Sea Grant at the University of Hawaii, and a seminar series of ocean engineering lectures was established. Year 03 marked the third year of that series.

During Year 03, 30 technical lectures and 14 public lectures were delivered by eleven scholars. Lecturers came from France, Mexico, and both coasts of mainland United States, including Alaska. Local engineers, scientists, and students had many opportunities to consult and exchange ideas. Because of these opportunities, curricula were improved, research aided, and problems in ocean engineering solved. The technical lectures had 21 registered students, plus others who attended but did not register for credit. The public lectures had audiences generally ranging from 50 to 100 persons.

To make the content of these lectures generally and permamently available, they are being published in book form, under the title, *Topics in Ocean Engineering.* Volume I of this series, presenting lectures delivered the first year, was not supported by Sea Grant funding. Volumes II and III are Sea Grant supported.

The complete schedule of the Year 03 lecture series will be found in an appendix to this report.

The success and popularity of this lecture series has attracted enough support to enable it to continue beyond Year 03 without Sea Grant funding.

Project Title: INSTRUCTION IN PLANT AQUACULTURE
Short Title: Plant Aquaculture
Inception: A new project for Year 03
Principal
Investigator: Noel P. Kefford
Professor and Chairman
Departments of Botany and Plant Physiology

For industries based on plant aquaculture to become efficient, trained personnel must be available. Such training was not available at the start of Year 03.

The original purpose of the project was to develop a course of instruction for training prospective plant aquaculturists. Subject matter was to include special courses in marine botany, production of algae, the economic and legal aspects of marine plant production, and similar topics. This course was to be designed to integrate with related core courses at the University, such as chemistry, physics, and biology.

During Year 03 a great deal of material suitable for such a course of instruction was sought out and gathered. A formalized course of instruction was not created during the year, however, because prospective instructors were not able to take enough time from their other duties to perform this task. The materials gathered are presently being used by graduate students. Formalization of the originally proposed course of instruction has been postponed until later; the date has not yet been set.

Project Title: MARINE OPTION PROGRAM
Short Title: "MOP"
Inception: Project started during Year 03
Principal
Investigators: John P. Craven
Dean of Marine Programs

Barry H. Hill
Assistant for Curriculum Development
Marine Programs Office

It was not until well into Sea Grant Year 03 that the idea for this project began to take concrete shape, and it was not proposed to Sea Grant at its inception. Financed by a University of Hawaii Innovations Grant, the Marine Option Program began on March 1, 1971.

The idea of the Marine Option Program is to make it possible for students who have an interest in the ocean – including those who do not plan to take up the traditional graduate school oceanography studies – to acquire both theoretical and working knowledge about the oceans during their undergraduate years.

The program is not designed to offer an entirely new course of studies that would replace those already existing at the University. Instead, it serves as a supplement to various existing departmental programs. An important part of the program, however, has been the creation of a few new ocean-oriented courses that would be of value to students from many different fields of study; students majoring in such diverse disciplines as engineering, liberal arts, chemistry, biology, history, and sociology are enrolled together, sharing knowledge and exchanging viewpoints.

In the Marine Option Program, the student must take a minimum of 12 credit hours, maintaining a B average, with 3 hours being from one of the new interdisciplinary courses described above, 6 hours from two 3-hour courses related to the marine area within the student's major field of study, and one 3-hour course that presents a general introduction to the marine field. (Science of the Sea, an introduction to oceanography, is the usual choice here.)

In addition to the 12 credit hours of marine-related studies, the Marine Option Program requires each student to obtain a marine skill. There is no set list of "approved" skills. Each prospect for the program is interviewed, and a marine skill that ties in with his particular interests is agreed upon. One popular skill is scuba diving; another is underwater photography. Working with marine animals is another popular choice, but there are many more, ranging from celestial navigation to ocean floor mapping. Upon completion of the requirements, the student receives a certificate of accomplishment from the Dean of Marine Programs.

This program was just getting well under way, with 75 students enrolled by the beginning of summer school, 1971, when the first innovation funds supporting the program ran out. Because of problems concerning State of Hawaii finances at that time, the Governor would not release the funds that had been designated to keep the program going. It was faced with termination just as it was getting well started.

Realizing the value of the program, and the fact that it so well matched Sea Grant's objective of making people better informed about the ocean and the total marine environment, the Director of Sea Grant Programs made available funds that kept the program going from July 1; Sea Grant funding has played an important part since that time.

Much of the time during the summer months was spent in developing the program for the fall semester and the beginning of Sea Grant Year 04. A group of interdisciplinary courses were developed. Considerable time was also spent developing an undergraduate seminar series. In addition, some 250 prospects for the fall program were personally interviewed by the Assistant for Curriculum Development, who directs the program.

Tied closely to the Marine Option Program is the Marine Internship Program. This program provides opportunity for on-the-job training to acquire a marine skill, which is required for the Marine Option Program Certificate. Close working relationships were established with the Oceanic Institute and the Hawaii Institute of Geophysics, which provided many opportunities for training. In one instance, two students served as apprentices aboard the Hawaii Institute of Geophysics research vessel KANA KEOKI. In some cases the marine interns work on a volunteer basis; in some they are paid a small salary (perhaps $150 a month).

Also supervised by the Coordinator of the Marine Option Program is the Marine Experience Program. This provides opportunities for any undergraduate student – not just those in the Marine Option Program – to have a "marine experience". In one case students visited a naval shipyard; in another instance they observed navy divers training in the submarine escape training tower at Pearl Harbor.

By the end of Year 03 the program was well organized. When it started into Year 04, with Sea Grant support, there were approximately 250 students enrolled in the Marine Option Program.

PROBLEM AREA: ADVISORY SERVICES

The problems in this area can be stated far more easily than they can be solved: How can the Sea Grant Program get existing knowledge out to those who need it, in such a manner that they can fully understand that knowledge and can make maximum use of it? And how can information regarding practical problems be fed back to researchers, so that on-going research will be relevant and have ultimate practical application?

These problems are closely related to those discussed in the "Marine-Oriented Education" area: they involve making pertinent knowledge (including recent findings) available to those who have need of it.

For the purposes of this report, the areas of education and advisory services might be differentiated as follows: In an educational program, the knowledge to be presented is organized in some predetermined manner by those presenting it. The person seeking useful information studies the stream of knowledge presented as it flows past, selecting out those bits that he can use currently, probably retaining at least the outline of the rest for possible future use.

In an advisory service program, a person (or group) with a specific problem presents it and is offered, whenever possible, the specific information needed to solve that problem. He does not spend time reviewing the full flow of knowledge that is presented in an educational program. In addition, an advisory service often includes the feedback of information regarding problem details that may require additional research, as mentioned above.

One of the first steps taken during Year 03 was to engage the services of a full-time coordinator, John L. Ball, Jr., to supervise the advisory service area. Much organizational work had to be done.

As Year 03 got under way, the need for centralized handling of Sea Grant reports and advisory publications became clear. In April, 1971, an experienced technical publications specialist, Suzanne Morris, was engaged and began setting up a publications office.

Responsibility for publication of Sea Grant research reports had previously been scattered through several offices; these responsibilities were centralized in the new publications office. Editors of already-published Sea Grant reports were consulted, and publication procedures were evaluated. Several manuscripts were reviewed and started through editing.

Plans for a University of Hawaii Sea Grant Newsletter were developed. This newsletter would not be restricted to reporting Sea Grant activities. In keeping with Sea Grant's advisory and educational aims, any marine news events of genuine interest and importance might be included. The first edition of this monthly newsletter was issued July 1, 1971.

During the last quarter of Year 03 preparations for full-scale operation in Year 04 were made. By the end of Year 03, three editions of the newsletter had been published, and tentative distribution dates for several reports had been established.

Two advisory service projects were funded in Year 03; they are described on the following pages. At the end of Year 03, on advice of the National Sea Grant Program Office, all advisory service activities were brought into the office of the director, under the supervision of the coordinator. No separate projects in this area were funded for Year 04.

Project Title: BAITFISH HANDLING
Short Title: (None)
Inception: Based on a project from Year 02
Principal
Investigator: Wayne J. Baldwin
Assistant Marine Biologist
Hawaii Institute of Marine Biology

Most of the major problems facing the Hawaiian skipjack tuna fishery are described in the section of this report devoted to fisheries. One of these problems involves the pole-and-line method of fishing for skipjack tuna: it requires that live bait be thrown into the water to attract the tuna. The baitfish must not only be alive, but extremely active, or they won't do the job. The tuna fishermen use as bait an anchovy locally known as "nehu". At least 30 percent of the fleets' working time is devoted to netting the nehu – which immediately start to die off following capture. Many die from injuries received while being caught. In the bait wells on the tuna boats, the mortality rate has been calculated at one percent per hour. Nehu can seldom be kept alive in bait wells for as long as four days; generally 25 percent dies off before they can be used for fishing. This severely limits the time that the fleet can spend actively fishing for tuna.

During Sea Grant Year 02 the principal investigator of this project headed a Sea Grant project titled "Reduction of Baitfish Mortalities"; its objective was to find ways to keep more nehu alive – and alive for a longer time. Not all of the experiments in this Year 02 project had been completed by the beginning of Year 03 (the year covered by this report), but enough had been completed successfully so that the remaining parts of that project were combined into this one, which has the objective of informing the tuna fishermen as to what has been learned about reducing the death rate of nehu.

Experiments had shown that the number of nehu dying from injuries sustained while being caught would be substantially reduced if the nehu (a saltwater species) were immediately placed in a mixture of ocean water and fresh water, rather than in the sea water that is their natural home. Improvements in design of the bait wells also kept nehu alive for longer periods.

Although no formal demonstrations were scheduled during the final experiments, a great many of the commercial fishermen observed them, because most of the tests were conducted at Kewalo Basin, where the commercial fishing fleet docks.

No matter what handling procedures are used, some of the baitfish still die before they can be used, but the techniques developed definitely reduce the death rate, thus making possible more fishing with the same stock of bait.

At the end of Year 03 an advisory booklet, describing the recommended handling techniques, was being prepared. The booklet will be heavily illustrated to make the new techniques easier to understand. It will be printed in both English and Japanese, since Japanese is the language of many of the commercial fishermen working out of Honolulu.

Because its work had been accomplished, the project did not seek funding for another year.

Project Title:	ADVISORY SERVICE ON SHORELINE UTILIZATION
Short Title:	Shoreline Utilization
Inception:	A new project for Year 03
Principal Investigator:	Wade W. McCall Soil Management Specialist Department of Agronomy and Soil Science

Living near the sea presents problems as well as benefits. One of those problems is the ocean salt that is carried ashore by waves or windblown droplets of sea water. Food crops and other plants may be affected by salinity from sea spray, as may objects made of metal (including cars, furniture, and structural support members).

The purpose of this project was to provide information and advice in dealing with this problem. Put to use, such information could reduce damage to plants, soil, and metal objects, and help lead to better use of shoreline areas.

On request, the project performed a number of chemical and physical analyses of waters and soils in various shoreline areas, and provided information to developers concerning the best plant types for use in shoreline areas.

The main accomplishment of the project was the writing and publishing of an informational pamphlet, "Soil Salinity Problems in Shoreline Areas of Hawaii"

Some funding was continued into Year 04, so that requests for information could be met, but the main work was completed at the end of Year 03.

Hawaii's skipjack tuna fleet spends more than one fourth of its total working time seeking and netting nehu for use as baitfish. These small, fragile anchovies, once abundant in the shallow coastal waters, are becoming scarcer and their habits make them unsuitable for rearing in captivity. One fisheries project during Sea Grant Year 03 involved development of techniques for captive rearing of other, hardier species which might be suitable for tuna baitfish. (Photo by National Marine Fisheries Service.)

PROBLEM AREA: FISHERIES

The people of Hawaii are hearty eaters of seafood. Yet despite the state's mid-Pacific location, which would seem to make it an ideal base for thriving commercial fisheries, a great deal of the seafood consumed in Hawaii must be purchased from fisheries of other states and other nations. The same is true of seafood shipped out of Hawaii.

The boats that fish for skipjack tuna make up the largest segment of the Hawaiian commercial fishing fleet; these vessels land some 5,000 metric tons of fish a year. Almost all of this is sold to Hawaiian Tuna Packers (Bumble Bee Seafoods, Inc.) for canning and shipment out of the state. Here, too, the Hawaii-caught supply does not meet the Hawaii-based demand. At least half of the cannery's total pack of tuna each year must be purchased from foreign sources.

Although there is an apparent need to take more food from the sea to feed growing populations (and a definite need for the United States to improve its balance of payments position), commercial fisheries in Hawaii appear to be declining – if not indeed a dying – industry. The reasons for this condition are clear.

With only one notable exception, the commercial fishing vessels in Hawaii are old, generally outdated, short-range vessels using relatively inefficient methods and lacking modern equipment.

While there is nothing that Sea Grant can do about equipping the fleet with modern, long-range vessels fitted with the latest in electronic fish-detection gear, there is considerable that Sea Grant might be able to do in showing how to make more productive and more profitable use of existing facilities. Five projects were recommended for this area; four of them were funded and put into operation for Year 03.

Project Title: FURTHER EXPLORATION AND DEVELOPMENT OF A TUNA BAIT RESOURCE
Short Title: (None)
Inception: A new project for Year 03
Principal
Investigator: Wayne J. Baldwin
Assistant Marine Biologist
Hawaii Institute of Marine Biology

The Hawaiian commercial skipjack tuna fleet might increase its productivity by spending more time at sea fishing. The National Marine Fisheries Service has calculated that the skipjack tuna fleet spends at least 30 percent of its total working time catching the anchovy *(Stolephorus purpureus)* that it uses for live bait. Locally known as "nehu", this saltwater fish must be taken from shallow waters with nets, and kept alive in bait tanks aboard the vessels until used. One of the problems is that the nehu only lives for a few days in the bait wells. (At least 25 percent of the bait dies before it can be used.)

Because of the method of fishing, it is vital that the bait be alive when used. The Hawaiian live bait vessels employ the traditional pole-and-line method for capturing skipjack tuna. The hooks, neither barbed nor baited, are designed to look as much like the baitfish as possible; they are further camouflaged with either feathers, a plastic skirt, or a piece of dried fish skin. When a school of tuna is located, usually by spotting seabirds flying low over the school, the boat maneuvers close to the school and begins chumming with live nehu. The shiny, silvery baitfish dart about actively, and the tuna go into a feeding frenzy as they chase the baitfish. The nehu usually remain near the vessel, rather than diving deep to escape, and the tuna must come near the vessel to feed on the live bait. The tuna bite on the disguised hooks as vigorously as they feed on the nehu; often the fishermen land them as fast as they can swing them aboard.

The National Marine Fisheries Service and the Hawaii State Fish and Game Division have for some time been interested in the possibility of finding other species of baitfish that could be obtained by the fishing fleet without so much time being lost from actual fishing.

One possibility seems to be threadfin shad, *Dorosoma petenense.* The results of a series of sea trials with this baitfish are promising. Threadfin shad can live its entire life in fresh waters, but it can also survive in brackish waters and sometimes swims well out into the ocean. However, before it can be made available to the tuna fleet, the various problems of rearing and handling must be worked out.

The purpose of this Sea Grant project was to develop alternate sources of live bait for the Hawaiian tuna fishery. The investigators worked in close cooperation with the NMFS and the state. It was decided that during Year 03 the project would concentrate on rearing threadfin shad in captivity.

Twice during the year the shad were induced to spawn in captivity, and twice shad were reared in captivity from eggs to mature fish, both in fresh water. Feeding requirements and general biology of the shad were studied. Experience showed that the shad could not be kept alive indefinitely in sea water, but that they would survive in a mixture of fresh water and ocean water.

Results during Year 03 were promising and the project was continued for a second year. (Tests conducted during Year 03 by the National Marine Fisheries Service, with support from the State of Hawaii, showed that using mixtures of shad and nehu as baitfish resulted in good catches.) During Year 04 further studies will be made on threadfin shad. Other potential baitfish will also be studied. Final success of this project would greatly strengthen the economy of the Hawaiian tuna fishery, and lessen the cannery's dependence on foreign-caught fish.

Project Title:	ALTERNATIVES TO LIVE BAIT FOR THE TUNA FISHERY
Short Title:	(None)
Inception:	A new project for the Year 03
Principal Investigator:	E. Donald Stevens Assistant Professor Department of Zoology

An alternative to the use of live bait is another possibility that might let the Hawaiian commercial tuna fleet spend more productive time at sea. (The methods used by the Hawaiian fleet, and the live bait, nehu, are described in the report immediately preceding this one.)

The purpose of this project was to determine whether skipjack tuna could be attracted by some type of artificial lure that resembles live nehu in appearance and action, or be attracted by the use of sounds duplicating those noises made by nehu when pursued by tuna. A third possibility to be investigated was the use of chemical attractants similar to chemicals that might be produced by nehu.

The study of chemical lures had to be abandoned because of logistic problems.

In order to study the action of nehu when chased by tuna, slow-motion pictures of nehu-bait fishing were taken from an underwater observation gallery aboard the National Marine Fisheries Service vessel CHARLES H. GILBERT. Means of studying the sounds made by nehu were also devised.

Although progress was being made on this project, it was terminated at the end of Year 03, on the advice of the National Sea Grant Office, as being too basic.

Project Title: EXPLORATION FOR NEW MESOBENTHIC FISH AND CRUSTACEAN RESOURCES

Short Title: (None)

Inception: Project continued from Year 02

Principal Investigator: Thomas A. Clarke
Assistant Professor
Department of Oceanography and
Hawaiian Institute of Marine Biology

Do additional resources of commercial fish and shellfish exist around Hawaii, down deeper than the relatively shallow depths from which they are usually taken? Can species of commercial fish and shellfish not found in abundance at normal fishing depths be discovered in marketable quantities by probing deeper? Can the use of fishing methods and gear not now used in Hawaii increase the present catches of commercial species?

The aim of this project was to answer these questions; if any of the answers were found to be "yes", the catch and income of the Hawaii fishery could be increased.

Exploratory fishing for various species was carried out at depths of 180 feet down to 3,000 feet.

During Year 02, some success had been achieved; a shrimp species of potential commercial value, *Heterocarpus ensifer,* was trapped in quantity at depths of 900 feet. After samples were taken, some 134 pounds of these shrimp were marketed, at prices ranging from $1.50 to $1.89 per pound; the total sale amounted to $216.87. However, it became clear that local demand will not sustain these initial prices.

During Year 03 several different species, depths, and methods were studied further, and fishing on a commercial scale with a chartered vessel was attempted. The results are summarized here.

(a) The shrimp *Heterocarpus ensifer*

The object was to determine more precisely the depth ranges and seasons in which this species could be trapped in commercial quantities. (This was the shrimp that had been caught in the Year 02 project.)

The shrimp occurred between 480 and 2,400 feet, with highest catch rates between 900- and 1,500-foot depths; creatures from this zone were significantly larger. Using strings of eight traps each, eleven different settings were made in this depth range; median catch ran about 4-1/2 pounds per trap. The shrimp were present at these densities from about October to March. Economic and marketing studies are needed, to determine whether such catch rates can support a fishery. The limited attempts to market this species indicate that retail prices will have to be no more than about $1.25 per pound for whole shrimps, if demand is to be great enough to sustain a regular fishery.

It is likely that if fishermen were assured a price of $0.50 to $0.75 per pound for all the shrimp they could catch, a vessel could make a profit by fishing 100 or more traps per night during the season.

(b) The crab *Portunus sanguinolentus*

Like the shrimp *H. ensifer* (above), this is another creature of potential economic value. These crabs were most abundant between 180 and 300 feet; catches ran about 3-1/3 pounds per trap. At about the time of the study, a few local fishing vessels started to catch this crab around Oahu; their efforts appear to be profitable.

Other creatures, both fish and crustacea, were taken in the traps used in these two experiments, but none appear to have commercial potential.

(c) The shrimps *Penaeus marginatus* and *Pandalus martius*

These two species of commercial shrimp are known to exist in Hawaiian waters. Could they be caught economically with traps?

Both species were trapped on occasion between 360 and 600 feet, but neither in sufficient numbers to sustain a trap fishery.

(d) The spiny lobster *Panulirus japonicus;* the kona crab *Ranina serrata*

Both of these commercial species are presently taken in Hawaiian waters at relatively shallow depths. Efforts were made to see if they could successfully be trapped in deeper waters.

Several times the spiny lobster was trapped as deep at 360 feet, but not in large-enough numbers to suggest that a commercial trapping operation at such depths would be profitable. The kona crabs were not found in any of the traps.

(e) Lutjanids - the snapper family

Several species of this large, tasty deep-water fish are found in Hawaiian waters. Generally they are fished with handlines. Could they be taken in larger numbers with gill nets?

The nets were set over known handline fishing grounds, at depths of from 300 to 1,500 feet. Several substantial catches were made. Damage to nets, however, both from sharks and from the rough bottom, was so substantial as to make it seem that the extra fish taken this way might not pay for the cost of repairing the nets between catches.

With all the questions answered by the end of Year 03, the project was concluded.

Project Title:	NEW PRODUCT AND PROCESS DEVELOPMENT FOR MARINE LIFE AVAILABLE TO HAWAII
Short Title:	Fish Products
Inception:	Project continued from Year 02
Principal Investigator:	Francisco S. Hing Associate Professor Department of Food Science and Technology

Even though Hawaii has to import a large percentage of the fish it consumes, the best possible use is not made of fish presently taken from local waters – or readily available in them. Many of the species caught locally are in demand only as table fish. If more are caught than can be immediately consumed by this market, there is loss of income to the fishermen and waste of a potentially valuable food resource. These unsold fish may be frozen for possible sale later, but if fresh-caught ones are available in the market at the same time, the frozen fish are slow sellers.

Possibilities for processing these fish locally are limited at present. The cannery packs only tuna. Five fish-paste processing operations exist, making a product known locally as "kamaboko", but not all species are suitable for that use. There are also a few quite small fish-curing operations; this is the extent of the present fish-processing industry in Hawaii.

This project seeks to make better use of those fish that are not sold fresh, and not suitable for the cannery or kamaboko processors. It hopes to provide safe, nutritious, convenient, and tasty products from today's "left-over" fish. By developing the necessary techniques and technology, and making them available to interested parties, this project will be able to offer opportunities for expanding the present fish-processing operations and for creating new processing plants. It should also help fishermen improve their income, because a stabilization of market prices for their catches should result when their perishable fish can be converted into stable products with relatively long shelf life in stores. (Such improvement in income would *not* be at the expense of the ultimate consumer.)

During the Year 02 project personnel made an extensive review of fish-processing technology outside of Hawaii, to provide guidelines for the work here. They also began experimentally processing local fish, and started evaluating the possible market potential of the resulting products. For maximum economy and economic benefits, frozen fish, rather than fresh-caught ones, were used as the raw material. Smoked tuna was prepared from three-month old frozen fish. The smoked fish was then stored for three months; at the end of that period, it showed no bacterial growth and no loss of quality.

During Year 02 several samples of fish "hams" and fish sausages were prepared from local species, following procedures used in Japan. Some of these were flavored for American taste, and some for Japanese taste. (The writer of this report tasted samples at that time; the products resembled United States-style "lunch meats" of good quality and had no "fishy" taste.)

A mailing list of commercial fishermen, fish handlers, and fish processors was put together for use in sending fact sheets and newsletters to the industry.

During Year 03 a study was conducted to assess the stability of the fish sausages developed during Year 02. Fish sausages were stored at temperatures of 35° F and 45° F; the product was stable for 15 to 26 weeks at both temperatures. From the standpoint of bacterial safety, it should be stored below 38° F and heated or boiled before serving. The product has a relatively long shelf life, considering the fact that Hawaii-made kamaboko has a shelf life of two weeks, and that frankfurters stored at 45° F have a shelf life of only four weeks. This longer shelf life could be a marketing advantage for fish sausages. The results of this study, plus information on the formulation, manufacturing procedure, heat penetration and chemical composition of fish sausage, are presented in an article scheduled to appear in the 1972 *Journal of Food Science.* (The article is titled "Stability of Fish Sausage at Low Temperature Storage".)

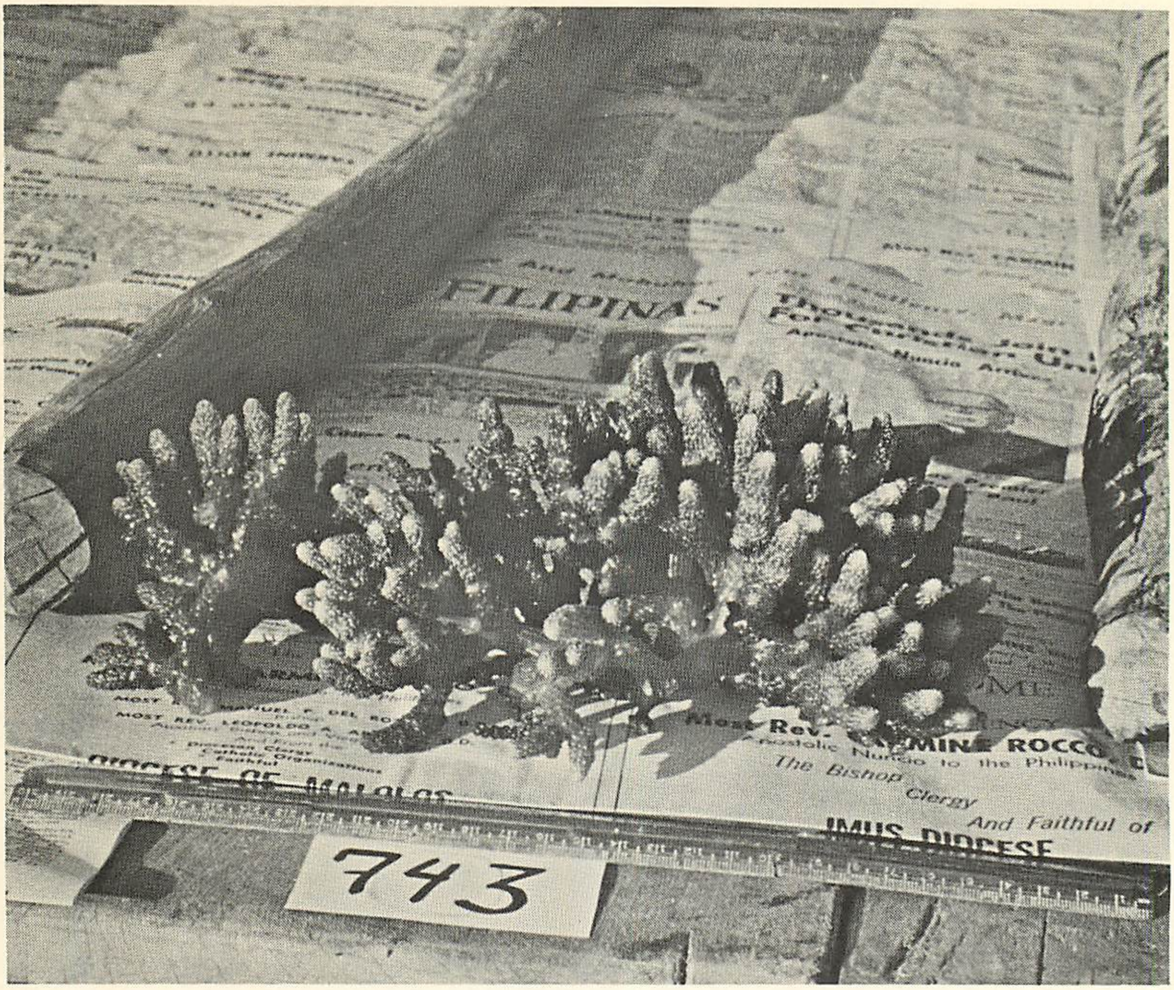
The possible market potential of fish sausages may be indicated by figures from Japan. Annual production of fish hams and sausages there rose from 2,000 tons in 1953 to over 270,000 tons in 1965, and the market continues to grow.

The sausage developed in Year 03 was made from striped marlin (a'u), yellowfin tuna (ahi), and skipjack tuna (aku). During Year 03 preliminary work in making fish sausages was done with several other species of local fish: jack crevally (ulua), amberjack (kahala), bluefin tuna (also called ahi), pink snapper (opakapaka), gray snapper (uku), and big-eyed scad (akule). Obvious differences in color and texture existed in these products. Work on developing them will be continued.

Other work completed during Year 03 included developing a method of digesting fish samples for mercury analysis with a Coleman Mercury Analyzer, and demonstrating a fish-flesh separator from Japan to interested fish processors. The machine separates skin and bones from the flesh of small fish.

During Year 03 studies on water-holding capacity, which is an important functional property of fish protein, were initiated and will be continued.

Because of the potential importance of the work being done on this project, the gratifying results so far, and the need to continue these studies, this project was funded and continued into Year 04.



America's food and pharmaceutical industries use large quantities of carrageenan – a colloid that stabilizes emulsions. One source of carrageenan is the genus of algae called ***Eucheuma.*** *A Sea Grant aquaculture project directed by University of Hawaii researchers has as its goal the farming of Eucheuma in the Philippine Islands and other tropical Pacific regions. (Photo by Gerald T. Kraft.)*

PROBLEM AREA: AQUACULTURE

With the world's population increasing at a rapidly accelerating rate, the ability to produce food becomes more and more vital. (In 1830 world population was an estimated 1 billion people; by 1960 it had tripled. Within this decade the 4 billion mark is expected.)

One potential means of providing additional protein food is aquaculture, the rearing of aquatic plants and animals under at least partly controlled conditions. But the technology of aquaculture has scarcely entered its infancy. In addition to needing vast improvements in technology, we need a comprehensive understanding of any species we propose to cultivate. Without such understanding, successful rearing of a species is impossible.

A tropical area such as Hawaii is an ideal location for an aquaculture project for two reasons: the warm climate produces a twelve-month growing season, and the higher water temperatures produce a more rapid growth rate than in temperate climates.

The immediate objective of the animal aquaculture projects funded by the University of Hawaii Sea Grant Program is to develop the technology for the rearing, selective breeding, and harvesting of a variety of creatures that live in the ocean, plus some that live in waters either more or less salty than normal ocean water. (Freshwater aquaculture is not presently included.)

These projects will include all facets of animal culture, such as inducing a species to spawn, disease control, pollution control, and proper nutrition. Once techniques for rearing are developed, information on those techniques will be made available and efforts will be made to encourage private industry to start commercial culture of the species.

Long-range objectives are to strive for improved technology for existing aquaculture projects (or those that might be developed by these programs), and to search for additional species that may be cultured practically. (Some popular food creatures, such as tuna and crabs, consume far too much protein food to be practical aquaculture animals – at least with present knowledge and methods.)

In addition to the need to furnish more protein food from the sea, our nation's present food-processing industry has expanded its need for certain small marine plants (types of algae) that must be presently harvested from wild crops. One project is devoted to this area. Another plant aquaculture project seeks to grow plants for use as food for aquatic animals being cultured, just as corn and other cereal grains are grown to feed livestock. Still another project attempts to solve some of the problems of sewage disposal by using sewage as fertilizer to produce important aquatic plants.

There are six individual projects funded in this area, but one of them, "Fish and Shellfish", covers a wide variety of creatures and activities.

Project Title:	CULTURE OF FISH, CRUSTACEANS, AND MOLLUSKS IN HAWAII
Short Title:	Fish and Shellfish
Inception:	A project combining three projects started in Year 01
Principal Investigator:	Philip Helfrich Associate Marine Biologist and Acting Director Hawaii Institute of Marine Biology

Because of the great potential importance of aquaculture to Hawaii (and eventually to all mankind), the State of Hawaii has been funding aquaculture research since Fiscal Year 1965-66. In the first year of Sea Grant in Hawaii, three aquaculture programs that complemented the state-sponsored program were initiated. One dealt with fish; one with mollusks such as clams, limpets, and octopus; and the third with crustaceans, primarily shrimp and crabs. For Year 03 these three animal aquaculture programs were combined into one program. The consolidation is based on the many common requirements of the three programs, especially in areas of larval rearing and disease control.

By combining larval-rearing facilities, and thus bringing together the extensive experience in larval culture of several scientists, the project will have the capacity to systematically handle any larval forms, while providing a broad spectrum of environmental conditions and food organisms for them. In addition, the facility will provide valuable training for students and technicians in larval rearing, one of the most difficult and critical phases of aquaculture.

The project lists ten broad objectives, starting with the evaluation of various creatures native to Hawaiian waters as possible subjects for successful aquaculture (some introduced species will also be studied), and ending with the development of marketable products or recreationally important species from aquaculture crops. This project is expected to require nine years, from its inception in Year 01 to completion.

Specialists were organized into teams, with each team taking an active role in researching one set of problems related to the overall effort. Animal scientists, with their special knowledge of nutrition and feed development, worked closely with marine biologists.

There are seven areas of special effort: (1) disease control; (2) nutrition and feed development; (3) physiology and genetics; (4) larval culture problems; (5) engineering aspects, such as rearing ponds and rearing cages; (6) product development, economics, and marketing; and (7) advisory services.

Several fish and shellfish species were studied to see if they offered potential for aquaculture. These were selected on the basis of their present acceptability as either food or bait, and their ability to survive and grow in captivity. The creatures to be studied were collected in the egg, larval, juvenile, or adult stages of growth, depending on what the researchers were able to secure. An attempt was then made to study the environmental requirements of each species. A number of stiuations were provided including small tanks, water tables, small pools, and floating rafts. Many aspects of feeding were studied, including food preferences and substitutes for natural foods. Growth rates to sexual maturity and marketable size were investigated. The areas of reproduction and disease also received attention. Some of the highlights of the Year 03 research are given here.

The fish studied most completely was a Hawaiian species of jack, locally known as "omaka"; its scientific name is *Caranx mate.* The omaka is a popular food and sport fish in Hawaii. Juveniles and adults were collected for study, and eggs were taken from the plankton – that free-floating conglomeration of tiny plants and animals which includes egg and larval forms of many creatures that eventually grow much larger. Larvae were reared in the laboratory, both from eggs obtained from plankton and from eggs stripped from ripe females that were then artificially fertilized. In attempting to rear larvae, aquaculturists and marine biologists have almost always come upon a "critical stage", a certain period of time when many – and sometimes all – of the larvae die off. With omaka, the critical stage was the fifth larval day; survival varied from 20 percent to 80 percent. Those that survived for a week after hatching usually reached maturity. A great many related experiments were conducted on critical environmental factors, including light, water salinity, oxygen, and others. An outline of rearing conditions necessary for larval survival has been established. Factors of major importance are food quantity and quality, and elimination of bacterial contamination. Further experiments will be performed to ensure more predictable results. One interesting finding was that there seemed to be no significant difference in rate of growth between fish laboratory-reared from eggs and fish captured in the wild as juveniles.

Similar but less extensive research was done on the yellow ulua, *(Gnathanadon speciosus)*, another Hawaiian species in the jack family. Eggs were not as abundant in the plankton, but survival through critical larval stages was consistently high (up to 80 percent): Other methods of egg collection are being tested.

Another highly prized food fish studied is the threadfin, (*Polydactylus sexfilis*), known in Hawaii as "moi". Preliminary measurements show that growth to a marketable size may only take seven months to a year, which seems to offer excellent aquaculture potential. Also moi survive well in ponds. Because the eggs are not found in the plankton, research on reproduction and spawning in captivity will be emphasized.

Work was done on baitfish, as well as food fish. Attempts were made to raise the nehu, which Hawaiian tuna fishermen use as live bait. (See the Fisheries reports for details on use and importance of baitfish.) The nehu seem poor prospects for culture, since survival rates were poor, larval life lengthy, and juveniles and adults relatively delicate. Work on this species was discontinued. Attempts to raise another baitfish, the iao *(Pranesus insularum)* were also discontinued; eggs could not be located in the wild and reproduction could not be induced in captivity.

Results were more promising with the threadfin shad *(Dorosoma pentenense)*, described in the Fisheries project, "Tuna Bait". Adults are hardy, unlike nehu, and the first attempt to raise this fish from eggs was successful, with approximately 10 percent survival. Survival rate should increase with improvements in culturing technique. Further experiments with threadfin shad are planned.

A search is being conducted for other ocean fish suitable for culture. Some species are not suitable because they take far too long to reach marketable size. Others eat only fairly large fish that are not easily available in quantities. In either instance, culturing fish of such species would not be economically practical, at least in the foreseeable future.

Among mollusks, three types of shellfish representing four species were studied.

Two limpets, *Cellana exarata* and *Cellana sandwicensis,* collectively known in Hawaii as "opihi", are highly prized for authentic (as opposed to tourist) Hawaiian luaus. They sell for as much as $70 per gallon. Every year one or more persons meet their death when waves wash them off of seaside rocks where they must go to collect opihi. Preliminary work indicates potential for aquaculture but further ecological studies are required for closer evaluation.

Another creature on which research has started is the Japanese littleneck clam, *(Tapes philippinarium).* This clam was introduced into Hawaii some years ago, and a population became established in Kaneohe Bay on Oahu. Digging for clams in the bay became a major annual event, but recently the population has been severely declining. Research will seek the reasons for the decline, and also look for methods of improving growth and survival rates.

Another mollusk that seems a prime aquaculture prospect is the day octopus *(Octopus cyanea)*, a food delicacy much prized by millions of Orientals and by many people of all races in Hawaii. They grow rapidly, reaching a minimum marketable size of one pound in about three months; from 83 to 88 percent of the total body weight is edible. This species eats crabs; attempts are being made to develop an acceptable substitute food that will maintain the high growth rate. Larval rearing has not yet been successful.

With crustaceans, two species of crabs are being studied. These are the Samoan or mangrove crab *(Scylla serrata)*, a fairly large crab, and the small white crab *(Portunus sanguinolentus)*. There are no major findings to report as yet.

Considerable work is being done with the Royal Hawaiian shrimp *(Penaeus marginatus)*. Techniques for intensive cultivation are being developed; large-volume larval-rearing facilities are under construction, as is an intensive-culture enclosure within which the shrimp are arranged vertically in small cages on frames, to allow the use of the entire water column, top to bottom.

Considerable work has also been done on the problem of disease. The research strongly indicates that disease seriously reduces survival rates in captivity, for all species and at all stages of the life cycle. Studies of bacterial populations have been conducted; viruses and fungi will also be studied.

In conjunction with larval-rearing experiments, three species of planktonic plants have been cultured, either for use as food or as "conditioners" of the water used in culturing fish larvae. A local species of *chlorella* seems to improve larval survival rates significantly when it is included in the rearing water. The reasons for this have not yet been clearly established.

To complete all the planned work will require several more years. This promising project was funded for Year 04, and will no doubt continue for several years beyond that.

Project Title:	THE CULTURE OF *ARTEMIA* IN HYPERSALINE PONDS
Short Title:	*Artemia* Culture
Inception:	A new project for the Year 03
Principal Investigator:	Philip Helfrich Associate Marine Biologist and Acting Director Hawaii Institute of Marine Biology

One of nature's more unusual creatures is *Artemia salina*, better known as the common brine shrimp. It lives and thrives only in hypersaline waters – those that are considerably saltier than seawater. No other animal shares this environment, only a few species of algae that *Artemia* uses for food. Until one learns about the brine shrimp, this small creature with such an unusual life-style may seem useless. Yet *Artemia* is one of the pillars on which much aquaculture research depends.

Dried eggs of the brine shrimp can be preserved in cans for long periods. When dumped into water, they quickly hatch into tiny, swimming larvae. These provide the live food that many aquatic creatures require at some stage of their development. Without the discovery that brine shrimp could serve as live food, rearing of aquatic creatures might not have been possible.

Artemia grows rapidly, achieving sexual maturity within two weeks after hatching. It will reproduce continuously during its six-month to one-year life span, at the rate of 200 offspring every five days. Only two pounds of food are needed to produce one pound of *Artemia*; this 50 percent energy-conversion rate is unusually high. The creature could be an excellent source of cheap protein.

It was proposed that *Artemia* might be raised at Christmas Island, the largest land mass (382 square miles) of any coral atoll in the Pacific. Much of Christmas Island is covered by saline ponds that are considered "useless". They provide an ideal environment for *Artemia.*

The principal investigator on this project has conducted research on Christmas Island over a period of several years. The local government has encouraged his efforts to utilize the many highly saline ponds, now unused.

Artemia culture promises to be one of the most efficient means of animal protein production yet devised. It holds great promise for tropical islands in low rainfall areas previously considered "unproductive". This, in turn, holds promise of inexpensive protein and employment for areas such as the southern Gilbert Islands. In addition to possible use as a protein source for humans, *Artemia* are in growing demand by people with home aquariums and by aquaculturists. A former source of supply in the Great Salt Lake area has been contaminated by DDT and is no longer suitable for the pet market. *Artemia* might also be used as food for carnivorous creatures that are presently in high market demand.

Several phases of this project were planned:

1. A study of the Christmas Island ponds, to determine their suitability for *Artemia* culture
2. A monitoring program at the ponds, to determine environmental fluctuations that might affect such culture.
3. Laboratory studies, in Hawaii, to determine optimum culture conditions and to check the suitability of existing plant life in the Christmas Island ponds as food for *Artemia.*
4. A pilot study, in Hawaii, to determine whether optimum laboratory conditions can be duplicated in a pond.
5. Economic studies, from which projections can be made for Hawaii, Christmas Island, and possibly other areas that might be suitable for *Artemia* culture.
6. Product development and nutritional studies on *Artemia.*

The work got well under way in Year 03; because of its great potential for meeting important needs it was continued by Sea Grant in Year 04.

Project Title:	ALGAL FOOD FOR AQUATIC ORGANISMS
Short Title:	Algal Food
Inception:	A new project for the Year 03
Principal Invesgator:	Maxwell S. Doty Professor Department of Botany

Scientific aquaculture on a commercial basis is just beginning to become a serious reality; one of its problems is finding and supplying enough proper food for the creatures it plans to raise and market. Most of the aquatic animals presently being cultured, or considered for culturing, are plant eaters, at least during the greater part of their life cycles. To culture creatures that are primarily or wholly flesh eaters would be far more difficult and expensive, at least at the present stage of the art and technology, because their animal food would have to be either cultivated or captured in large quantities and kept alive until needed.

Some aquatic plants, including many species of tiny algae, are now being cultivated. There is much still to be learned in this area. The aim of this project is to learn as much as possible about the best ways to grow aquatic plants, especially the free-floating phytoplankton species which could be important foods for the rearing of fish and shellfish.

Work during Year 03 started with collecting various algae in the wild and culturing them for use in the laboratory. Several species of algae were cultured in ponds containing the giant Malaysian prawn *(Macrobrachium rosenbergii)*, which is now under scientific cultivation in Hawaii. Practical techniques for mass cultivation in saltwater ponds have been developed. Personnel have been trained to work on the project. Some three dozen different species of aquatic plants are being studied.

The project, which was planned to extend from Year 03 to Year 06, was funded for further research and development work in Year 04.

Project Title:	LOCATION OF PROSPECTIVE INDUSTRIAL AQUACULTURE SITES IN HAWAII
Short Title:	Aquaculture Sites
Inception:	A new project for Year 03
Principal Investigator:	Maxwell S. Doty Professor Department of Botany

The question, "Where is aquaculture to be conducted?" seems so deceptively simple at first as to be hardly worth answering. Obviously, it will conducted "in the water". But in what water? What regions? What areas are best suited for aquaculture? What are the characteristics of a good site for aquaculture? What makes a site a poor one? In Hawaii there are other vital questions: Are any physically and economically suitable sites left for aquaculture? And what is their extent? How much can probably be grown on these sites?

Some day, perhaps, much aquaculture might be conducted out in the open ocean, tended by aquaculturists living and working on floating, stable platforms. But that day lies in the future. Right now, aquaculture must be done in ponds, or in shallow, sheltered, near-shore areas.

This project was proposed to develop criteria for marine farming sites, and search out and record those areas that match such criteria. It was first envisioned as a three-year program. But once criteria had been developed, it was soon apparent that finding the sites available in Hawaii would not take long. A report on the findings was prepared for eventual publication; it might well prove useful in areas outside of Hawaii. The project was not funded for Year 04.

Project Title:	PRODUCTION OF FOOD COLLOIDS FROM TROPICAL MARINE ALGAE
Short Title:	Food Colloids
Inception:	Project continued from Year 02
Principal Investigator:	Maxwell S. Doty Professor Department of Botany

Seeweed, kelp, and other plants that grow in the sea, including many species of tiny algae, play a more important part in the modern world than is generally realized. One important use of them is as a source of colloids. The algal colloids are stablizing agents that make emulsions possible. An important type of industrial colloid is carrageenan. It is now obtained primarily from Irish moss, but can also be extracted from a score of species of red algae. The food and pharmaceutical industries make much use of carrageenan. It is an ingredient in many milk-based products, toothpaste, hand creams, paint, ink, insect sprays, shampoos, and cosmetics. U.S. industry is seeking a twenty-fold increase in the present available supply.

The purpose of this project is to farm carrageenan-supplying algae, especially of the genus *Eucheuma,* on reefs in tropic seas. Such marine agronomy would not only help to meet the heavy present U.S. demand, but would also greatly improve the economy in regions where such farming might be done. (Areas where local authorities are cooperating with the project include Guam, Samoa, the Trust Territory of the Pacific, and the Philippines.)

In Year 02 pilot-plant production was successfully demonstrated. Certain problems also were identified. These are being worked on. In Year 03, small farming operations were conducted in various provinces of the Philippines, and demonstration units were set up in other areas of the Pacific. Three species of *Eucheuma* have been successfully grown. This method of farming has been adapted to a species in the Gulf of California, and has been successfully demonstrated in Palau, Yap, and Ponape. One species is being produced by this method on the protected reef areas of the northern Sulu Sea; another is being farmed on the western edge of the Celebes Sea.

The principal problems are the physiology of the algae, the cost of the facilities, and the general hazards associated with operations of this nature. These problems are being studied by this project, and also by industry. Firms cooperating include Marine Colloids Philippines and Marine Colloids Inc. of Rockland, Maine.

Small pilot farms for studying these problems have been successfully installed in Occidental Mindoro, Palawan, Zamboanga, and Sulu Provinces of the Philippines. Early cost analyses are promising. It appears the farming will provide these important seaweeds at less than $100 per ton FOB; at present world prices, that means at least $50 per ton profit to the farmer.

It should be noted that industry's contribution to these projects has greatly exceeded the required minimum for matching funds. Based on its success to date, and the important studies still to be conducted, the project was funded to continue in Year 04.

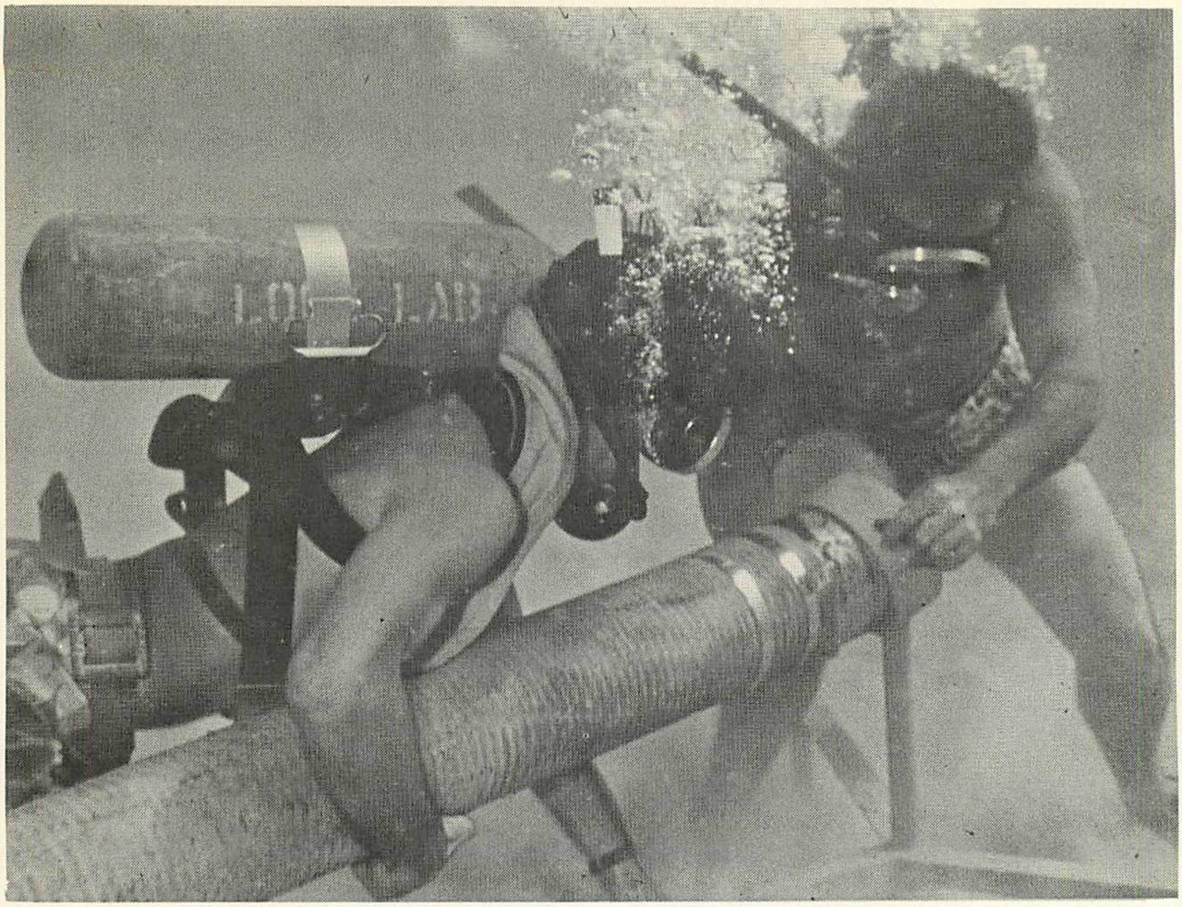
Project Title: EXPLOITATION OF HAWAIIAN ALGAL SPECIES FOR FOOD, FOOD ADDITIVES, AND DRUGS
Short Title: Hawaiian Seaweeds
Inception: Project continued from Year 02
Principal Investigator: Maxwell S. Doty
Professor
Department of Botany

In water, just as on land, many substances that "pollute" also fertilize. Sewage, both animal and human, is both pollutant and fertilizer, for example. Many regions of the deep ocean, including the waters around Hawaii, are often referred to by biologists and other scientists as "barren", or "a watery desert", because there are not enough fertilizing materials present to stimulate the growth of algae and other aquatic plants that form the basis of all life in the sea.

The idea of this project is to use sewage and other waste products as fertilizers to grow various species of algae under controlled conditions. Many of these marine plants could be used for commercial animal feed, or as a source of drugs or industrial chemicals. The large-scale production of such items by the use of pollutants should be of major importance, especially since making such use of the polluting materials will mean that they no longer pollute, and the quality of the water containing them would be measurably increased.

In Year 02, the first year of this five-year project, preliminary selections of certain algae were made for pre-pilot plant studies. The selections were based on the results of studies of the natural products of these algae and their characteristics.

The next step was to culture them for a short time in the laboratory, to study their responses to water movements, fertilizer, and to various intensities of light. During Year 03 the initial light and water-movement studies were completed, and larger-scale growth was started in ponds at a facility of the State of Hawaii Fish and Game Division. During the year, however, the State moved the Fish and Game facility to a new site, so that the pond culture had to begin again. Much work at the new site consisted of adapting the light and water-control methods developed for use in the rectangular ponds of the former site to the circular ponds of the new site. Experiments were completed with four species of algae. The main objectives planned for the year – obtaining information on the costs and conditions necessary for Year 04 work – were attained. The project was funded for continued work in Year 04.



A long-range project at the University of Hawaii seeks to develop an ecologically sound method of recovering underwater sand which can be operated by an independent contractor from a small vessel. During Sea Grant Year 03 field tests with the suction device shown above, a one-half-size scale model, yielded encouraging results. (Photo by Fred Casciano and Scott Sullivan.)

PROBLEM AREA: OCEAN BOTTOM RESOURCES AND OCEAN ENGINEERING

For future generations, the bottoms of the oceans may prove to be earth's richest source of valuable and vital resources. Certainly the ocean bottoms will play a far greater economic role than they do now. For, in addition to the seafood taken from the shallower regions, they hold unmeasured – but certainly vast – quantities of resources, ranging from the sand needed for construction to a wide variety of metals and minerals needed for manufacturing. They also hold gold, diamonds, and rare corals from which prized jewelry can be crafted. For centuries these resources have been ignored, because land-based deposits have easily satisfied the world's needs. But now most experts agree that many of these land-based mineral reserves will be used up in the forseeable future. So the challenge of recovering resources from the seabeds is at last being faced. The research and development tasks are formidable, because so many new techniques must be devised and perfected.

The problem of recovering seabed resources can be divided into three parts, as follows:

- Finding the location of the resource
- Determining if the quantity at that location is such that useful amounts can be recovered without harming the ecology of the area
- Devising a way of recovering the resource that is economically profitable without being environmentally destructive

Together, the projects funded in this area involve all of these three parts.

The ocean bottom resources of particular interest to Hawaii at this time are sand, manganese deposits, and precious corals.

Sand is being taken from the beaches of Hawaii for construction at the rate of half a million cubic yards a year. Since the total sand supply on all Hawaii's beaches combined is estimated at only 40 million cubic yards, continued use at this rate would soon seriously denude Hawaii of one of its greatest attractions for both tourists and residents. If off-shore supplies of sand having no connection with the beaches could be found and utilized, it would be of great long-term benefit.

Manganese nodules and deposits are important to the nation, as well as to Hawaii. Along with manganese itself, they hold tremendous reserves of important metals such as copper, cobalt, iron, nickel, aluminum, magnesium, lead, and titanium. The United States presently has to import large quantities of many of these metals. Both domestic and foreign land-based supplies of many of these metals are dwindling, even as the demand for them increases rapidly. The greatest known quantities of manganese nodules are in the Pacific Ocean; Hawaii's mid-Pacific location makes the state a natural center for nodule prospecting and "mining". If Hawaii could develop a manganese nodule recovery technique and processing industry, both would be of major economic benefit to the state and the nation.

Although the true long-term significance of precious corals is undoubtedly not as great as that of manganese nodules and sand, at present their direct economic importance to the state is greater than either. In 1971 the precious coral jewelry industry in Hawaii accounted for $4 million in retail sales. Most of this jewelry is made from pink coral, which has to be purchased from Japanese sources. Interestingly enough, much of this coral comes from the underwater slopes of the tiny islets and shoals stretching northwest of the main Hawaiian Islands to Midway; both legally and geologically, these are part of the State of Hawaii. (Except Midway, which is only geologically part of Hawaii.) If precious corals exist offshore of the tiny islands in the chain, they might well exist near the major islands. If such a nearby resource could be found, then selectively harvested by local firms (in a manner not damaging to the rest of the ecosystem), this would provide additional employment in Hawaii. It would also keep within Hawaii a considerable sum of money which now leaves the country each year. (Pink coral sells, in raw form, for $40 to $45 a pound.)

Four projects were funded in this area: one dealing with precious corals, one with manganese nodules, and two with sand.

Project Title: MANGANESE NODULES
Short Title: (None)
Inception: Project continued from Year 02
Principal
Investigator: James E. Andrews
Assistant Professor
Department of Oceanography
and
Hawaii Institute of Geophysics

While manganese nodules usually contain percentages of commercially important metals such as copper, cobalt, iron, nickel, and lead, the composition of nodules found in one area usually differs from that of nodules from another area. In fact, the percentages of the various metals may even differ from nodule to nodule in the same area.

This project, started in Year 02, was designed to investigate variations in the content of economically important elements in the nodules. Special attention was to be paid to studying the influence of topographic features and other local source effects. Elements studied included copper, cobalt, nickel, iron, and manganese, the principal component of the nodules. Copper, cobalt, and nickel are the three elements that commercial mining projects will probably concentrate on, at first, once commercial mining of the nodules becomes reality.

During Year 02 nodules were collected from several regions in the Pacific and studied. In the latter part of Year 02, a laboratory finding altered the original plans. Not long after the Year 03 proposal had been submitted and accepted, one of the investigators on the project – while working on another matter – was examining some bottom cores that had been taken in 1967 off the Hawaiian island of Kauai. He found evidence of manganese, enough to suggest the possibility that manganese nodules, with their important trace elements, might exist near Kauai. It was generally assumed at the time that manganese nodules were found only in deep (15,000 or more feet) mid-ocean waters. In May and June, 1970, the investigators were able to take further core samples from the University's R/V TERITU. (This was done without the use of Sea Grant funding.) The samples showed that large-scale deposits of manganese, rich in trace elements, covered a wide area. Most of these deposits were in the form of crusts, rather than nodules or lumps, but some nodules did exist. Depth of the crusts varied from 5,000 to 8,000 feet below the surface.

During Year 03 further investigations were made, disclosing deposits off the east and south coasts of Kauai, off the west coast of Oahu, and off the east and west coasts of the small island of Niihau, near Kauai. These deposits were found as deep as 8,000 feet and in waters as shallow as 1,200 feet. The new findings enlarged the known areas of manganese enrichment beyond those found in the first surveys by sevenfold. Two-thirds of the new deposits are in shallower water than the original findings. One deposit is located near Barber's Point, an industrial center of Oahu.

Chemical analysis showed that the deposits contain high concentrations of cobalt and titanium, average Pacific concentration of manganese and iron, and average Atlantic values of nickel. These analyses are preliminary; future work is planned.

Private industry, including firms from Germany and Japan, began to show interests in the deposits. The project was funded to continue in Year 04; it could prove of major economic significance to the state, the nation, and indeed the world.

Project Title: ECOLOGY OF PRECIOUS CORALS AND THE DEVELOPMENT OF PRECIOUS CORAL FISHERIES IN HAWAII
Short Title: Precious Coral
Inception: Project continued from Year 02
Principal Investigator: Richard W. Grigg
Marine Biologist
Hawaii Institute of Marine Biology

Hawaii has had a precious coral jewelry industry since 1958; at the start of Year 03 (1970) it employed some 100 people and produced products worth $4.0 million at the retail level. As mentioned in the introduction to this section, all of the raw material for this industry must presently be bought from Japanese sources, with the exception of some black coral brought up by divers working just off the major Hawaiian islands. The majority of precious coral sales, at present, are of pink corals.

Prior to the start of this project, it was known that some pink corals existed off Oahu's Makapuu Point; these had been exploited with primitive and destructive dredging techniques. Furthermore, much of the pink coral imported to Hawaii from Japanese sources is collected from banks north of Midway and part of the Hawaiian island chain geologically. Therefore, it was logical to assume that other beds of pink coral might exist within the chain.

The Precious Coral project started late in Year 02 (in March of 1970). First steps were to study the literature on precious corals, make a survey of the existing precious coral industry, and begin preliminary field work. The survey of the precious coral industry in the Orient and Italy showed that precious pink-coral harvests are declining and prices are rising. The future of the industry appears to depend on the discovery of new beds of pink coral.

Full-scale field work began in Year 03. Exploratory surveys were conducted aboard the University's R/V TERITU, using tangle-net dredging and underwater still and television cameras. Beds were discovered at Necker Bank and Brooks Bank, northwest of the main islands, and off Kaena Point, Oahu's northwest extremity. (Makapuu Point, location of the previously known bed, is Oahu's southeast extremity.)

In order to assess the economic and technological feasibility of harvesting coral with a submersible, the state, Makai Range, and the University of Hawaii entered into a contract. The Marine Affairs Coordinator of the State of Hawaii secured funding of $45,000 from the State of Hawaii, and Makai Range Inc. contributed $65,276 worth of equipment time, consisting primarily of ten working days with the submersible STAR II. (This support was in addition to the required one-third matching funds from the University.) The main objective of this program was to establish a local precious-coral fishery. The submersible was equipped with a mechanical arm capable of selectively harvesting the coral bed without damaging it,

Surveys with the submersible established that the Makapuu coral bed was approximately 3.6 million square meters in area, with an average pink-coral density of 0.03 colonies per meter. Each colony weighs approximately one pound. Carbon 14 studies support the hypothesis that growth rings of the coral formation are annual; these showed that the average colony had an estimated life of 25 years. Recruitment rates were estimated at 0.001 colonies per square meter per year. Based on these figures, and an appraisal of pink coral by the local jewelry industry, the total value of the pink coral in this bed was estimated to be $2.5 million. Some $100,000 worth of this could be selectively harvested each year without depleting the bed, since new coral – growing at the estimated rates – would replace the harvested quantity each year.

The submersible work also determined the extent of two other potentially valuable precious corals (gold and bamboo corals). These are not presently used commercially because there has been no adequate, assured supply. There are considerable amounts of both the gold and bamboo corals in the Makapuu beds.

Three public presentations on the findings were made during Year 03, including one at the U.S. National Museum, Washington, D.C. Two Sea Grant advisory publications were issued and a third was in preparation. The project was funded into Year 04 for the continuance of a number of planned surveys and studies on other coral beds and on improved harvesting methods.

Project Title: SAND INVENTORY
Short Title: (None)
Inception: Project continued from Year 02
Principal
Investigator: Ralph Moberly
Associate Professor
Department of Geosciences
and
Hawaii Institute of Geophysics

The purpose of this project, started in Sea Grant Year 02, is to locate undersea deposits of sand that can be mined and used for construction purposes or for artificial nourishment of eroding beaches, so that the taking of sand from Hawaii's beaches may be stopped without stopping necessary construction. The project recognizes the fundamental importance of making sure that any underwater deposits recommended to the construction industry are not composed of sand that spends part of its time on the beaches. (At certain times of the year, much of the sand on some of Hawaii's beaches "disappears" out to sea; later it returns and builds the beach back to its former fullness.)

In Year 02 the project started with detailed studies of sand deposits in Oahu's Kaneohe Bay. The studies started there because of the easy availability of University facilities at the Hawaii Institute of Marine Biology in the bay. One of four large bodies of sand found in the bay was mapped in detail, and the findings were issued in an early Sea Grant report. Reconnaissance surveys were also made with sparkler-type continuous seismic reflection profiling equipment used aboard the University research vessel TERITU. (In seismic reflection profiling, sound waves are sent down into the water. Some of these waves reflect back off the bottom material immediately underlying the water. Others travel down through the first layer of underlying material and reflect back up when they hit a layer of different material. By measuring and analyzing the time it takes for the various sound waves to return, some idea of the thickness and nature of the material underlying the water can be determined. This system was used along the leeward coast of Oahu, resulting in records for some 120 miles of coastlines. Three-fourths of the area lying between depths of 60 feet and 300 feet was shown to have sand deposits.

Four goals were established for Year 03, following the initial survey and reconnaissance work:

1. Locate sand deposits lying in water shallower than 300 feet around the principal islands of Hawaii, mainly by using the reflection profiling technique.
2. Map the bodies of sand found by this reconnaissance, and determine the area and thickness of these deposits by various means.
3. Evaluate the various sand deposits by obtaining samples; determine and record their characteristics, such as color and texture.
4. Make available to potential users the information obtained.

During Year 03 project personnel were able to assemble a seismic reflection system that could pick out layers of sediment, including sand, as thin as three feet. The previous system had not been able to distinguish layers less than 60 feet thick.

The new system was first put to use off Honolulu, in a detailed study of sand deposits seaward of Sand Island. (This island is the natural "breakwater" that shelters Honolulu Harbor.) This area is closest to Hawaii's major consumers of sand; an offshore mining operation here would have minimum transportation costs. There was no real opportunity for careful study of the accumulated data at the end of Year 03, because the records were loaned to a local engineering company. This firm needed the information because it is planning the location of a new outfall for the Honolulu sewage system in that area. These records have been returned and are now being studied; the immediate practical use to which the information was put certainly justifies the delay in this long-term project.

During Year 03 the areas off northern and windward (eastern) Oahu were given preliminary surveys. So far, the surveys around Oahu indicate some 500 million cubic yards of sand, compared with only 40 million cubic yards on all the state's beaches.

A detailed survey of Kahana Bay, on windward Oahu, was also completed during the year. Most of the physical and biological factors controlling deposition of different types of sand in the bay, from the shoreline out to 120-foot depth, were determined. The results appear to be applicable to other Hawaiian coastal areas having a similar exposure to trade winds; results of this study have been published by Sea Grant.

Although the Sand Inventory project was successful in locating deposits of sand important to the state, the Sea Grant site team recommended that it not be supported in Year 04. Failure to generate the active interest and participation of business, and generally constrained funding at the national level, were cited as reasons. Although some work continued past Year 03 without Sea Grant support, the main program was shelved pending future funding. In the meantime the state has ruled that beach mining must be ended by 1975 and the need for alternative sources of sand grows more acute.

Project Title: ENGINEERING ASPECTS OF SAND RECOVERY
Short Title: Sand Recovery
Inception: Project continued from Year 02
Principal Investigator: Robert Q. Palmer
Associate Researcher
Department of Ocean Engineering

Methods already exist for dredging up underwater deposits of sand, but they require vessels, large crews, and expensive equipment. Rough seas halt their operations. They need quite large deposits to operate economically. And these methods cause considerable environmental damage, breaking down coral reefs and stirring up silt that clouds the water. Murky water cuts the light needed for coral growth; when stirred-up sediments settle on living matter, they often cut off its oxygen supply.

A principal aim of this project was to develop a method of sand recovery that would avoid these adverse features of present mining methods. Also, for economic usefulness in Hawaii, the method would have to be one that did not require large investments; a small contractor should be able to acquire and use the system.

In addition, Hawaii faces the common problem of sand disappearing from beaches where it is desired, and moving into channels and harbors where it is not wanted. An aim of the project was to develop a sand-recovery system that could not only bring up sand for use in construction, but that could also move wandering sand back onto beaches where it was wanted.

During Year 02 a program of dyeing sand various colors, in order to trace its movement between beaches and the offshore bottom, was put in operation in a sand channel off Waikiki Beach. Sand movement studies are continuing. Several design ideas for new sand-recovery systems were conceived and studied during the year. Two systems were chosen for model development.

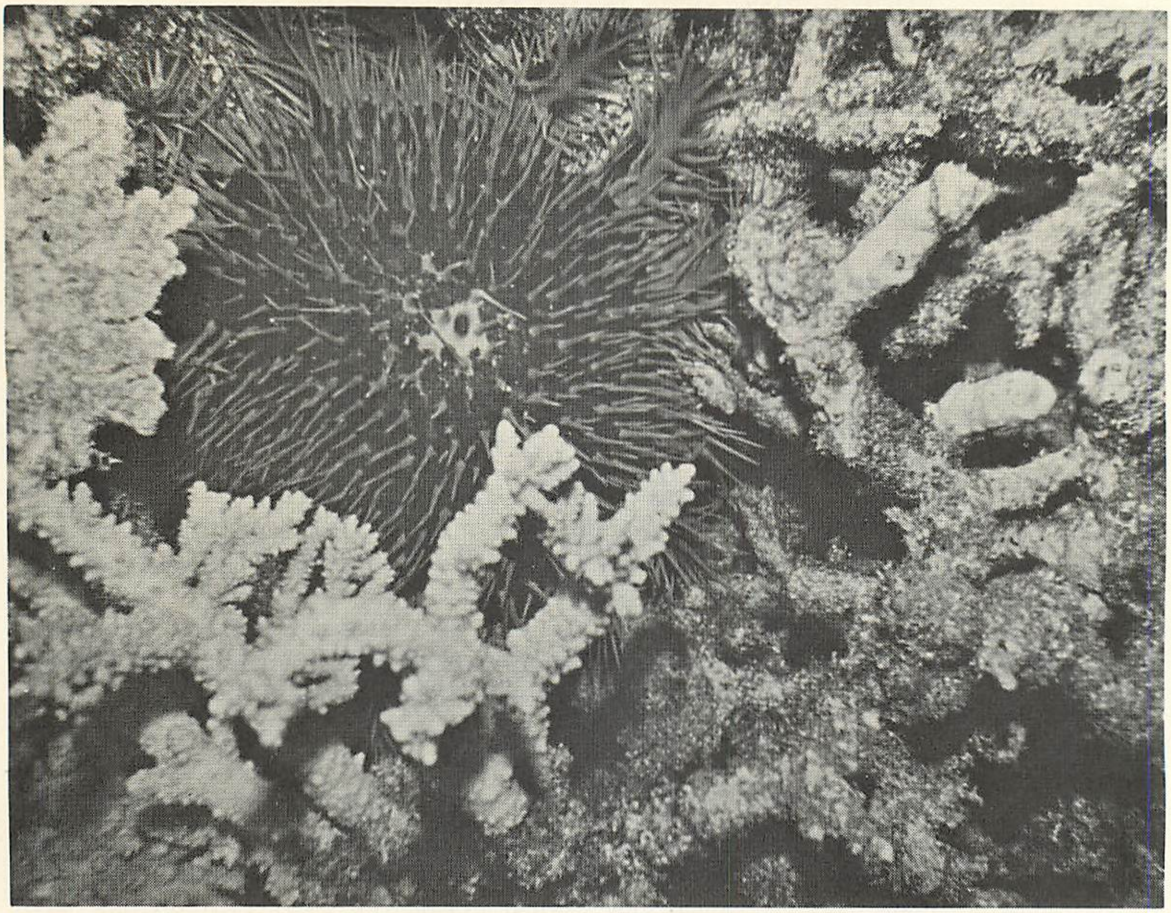
One system, known as "sand cratering", is for use in deposits of sand at least 50 feet thick or thicker. In this method, a self-burrowing suction head is jetted to the bottom of the deposit, and sand is sucked out from there. Material above falls into the cavity that forms. When the suction head has pulled out all the sand it can, leaving only a water-filled crater above, it is moved to another area covered by thick sand. This method could be used to supply sand to existing beaches at a slow rate, or to pump sand ashore to form new beaches at a rapid rate. This method minimizes stirring of bottom sediments, and thus causes little clouding of the water.

The second system, for use with shallower deposits of sand, is known as the "buried intake field". This is primarily for returning eroded sand back to beaches at a low rate of movement. In this system, intakes are fixed in position under shallow deposits of sand; the jets are activated when needed by high-pressure water pumped from shore.

One-tenth-size models of both systems were constructed and tested in laboratory tanks. These tests verified the principle of the concepts and allowed for some design modification.

Next, one-half-size models were constructed, using 3-inch plastic piping, and tested in the ocean. Tests were encouraging, although shell fragments and bits of coral in the sand tended to clog the intake pipes. Necessary modifications to solve this problem were undertaken; a solution seems highly probable.

Because of the importance of securing adequate supplies of sand for both construction and beach replenishment without doing environmental harm, and the success of the project to date, Sea Grant support for the Sand Recovery project was continued for Year 04.



Acanthaster planci, popularly called "Crown-of-Thorns" starfish, feeds on living coral. The specimen shown here is resting between older, dead portions of the coral, ***Acropora*** *(on the right) and live coral (left foreground). Reef killings by starfish were once thought to be a great danger to Pacific island regions. More recently, scientists have uncovered evidence to suggest that periodic invasions by great numbers of the starfish may be a normal part of the long-term cycle of coral reefs, and may even be useful. Since coral reefs protect island shorelines from serious erosion, and shelter the reef fish eaten by island inhabitants, more knowledge is needed concerning the ecological balance in the reefs and the role played by the starfish. (Photo by D.M. Devaney.)*

PROBLEM AREA: COASTAL ENVIRONMENT MANAGEMENT

The coastal environment of any state or nation is much more than the shoreline where land meets water, although the shoreline is an important part of it. It includes the sandy beaches upon which tourist hotels may be located and from which huge amounts of sand may be scooped for construction projects. It includes deep, sheltered harbors where ships load and unload for commerce, and small bays and inlets where people fish, swim, and dive for sport. It includes the underwater reefs that lie offshore, protecting the beaches and offering safe haven for marine creatures, while at the same time threatening vessels that venture too close. It includes the nearshore waters themselves, from which foodfish may be taken – and into which sewage may be dumped.

The coastal environment is always valuable to those near it, and in the island state of Hawaii it is especially valuable. Such an environment – with its often-delicate ecological balance – would seem to need careful management, planning, and protection if it is to be widely used by man without being destroyed by man. But in Hawaii, as in most coastal areas, there is little, if any, coordinated management, planning, or protection. This problem was pointed out in the state report, *Hawaii and the Sea,* referred to earlier, as follows: "...various responsibilities for each of its (coastal zone's) facets were fractionated among federal, state, county, and military entities in Hawaii. As a result of this overly broad dissemination of responsibilities, there is no individual agency that can establish policy and delegate authority in dealing with problems ranging from water pollution to beach sand removal..."

While Sea Grant programs cannot delegate authority or establish policy, Sea Grant projects can attempt to bring various groups together for workshops and seminars, and can work on specific problems and in specific problem areas.

As mentioned earlier in this report, Sea Grant in Hawaii started the Year 03 with research and development projects in eight problem areas; during the year these eight areas were adjusted and consolidated into four research and development areas. One of the eight original research and development areas was titled "Shoreline Management". When the Year 03 Sea Grant proposal was submitted, a number of projects were proposed under that heading. Due to both the short funding at the national level and the apparent overlap in some of the proposals, the National Sea Grant Program Office provided a limited budget and advised that Year 03 be used as a time for planning and coordination of work in the coastal zone area. Under this directive a shoreline management planning project was developed, designed to explore the scope of coastal zone problems in Hawaii, and to assess the role of the various agencies – federal, state, and county – involved in coastal zone management in the State of Hawaii. It also aimed at assisting the state in preparing to meet the requirements expected under the national coastal zone legislation then before Congress. For organization and future planning purposes, this shoreline management planning project was placed into a new category, called "Coastal Environment Management". Details of this project are contained in a specific report in the following pages.

The broad problem area of pollution, with a number of proposed projects, met with the same response from the National Sea Grant Program Office: take a year to carefully assess and plan in this area. This planning project concerning pollution was also placed, during Year 03, under the new heading, Coastal Environment Management; it is reported in the following section. Another of the original eight areas, the one concerning the Crown-of-Thorns starfish, was also placed in the new category. When the category originally called "Mineral Resources" was transformed into "Ocean Bottom Resources and Engineering" during Year 03, the project titled "Sand Economics" was switched from it into Coastal Environment Management. A continued project from Year 02, "Coral Reefs", was placed in the new coastal environment category when the category was created. At the end of Year 03, therefore, this category contained five projects, including two that were planning projects.

Project Title: SHORELINE MANAGEMENT PLANNING
Short Title: (None)
Inception: A new project for Year 03
Principal
Investigator: Jack R. Davidson
Director, Sea Grant Program

One of the first objectives of this planning project was to determine the role that Sea Grant could and should play in meeting the research and advisory needs that would arise from any serious attempt to "manage" the coastal zone environment of Hawaii. The project also aimed at providing an early perspective on the coastal zone problems of the state, and at preparing to meet the challenges expected from early passage of then-pending federal coastal zone legislation.

To accomplish these aims, a series of workshops were conducted. They were jointly sponsored by the University of Hawaii Sea Grant Program and the state's Department of Planning and Economic Development. The effort was spearheaded by Dr. Davidson and Dr. C. Gopalakrishnan. Under the general title "Hawaii's Coastal Zone Management", the topics discussed in the workshops included background and current status of coastal zone management; conflicting uses of the coastal zone and their resolution; county, state, and federal relationships in coastal zone management; and defining the public interest in the coastal zone. Approximately 30 state, county, and federal officials participated on panels in these workshops, together with a varied audience representing all segments of the community.

Working with the information provided by these sessions, a special University of Hawaii faculty committee met throughout the year to define the role of the Sea Grant Program in coastal zone research and advisory services and to suggest priorities for Year 04 and subsequent Sea Grant proposals.

The failure of Congress to pass federal legislation regarding the coastal zone during 1970-71 resulted in a cooling-off of interest at the state level. However, the interval provided an excellent opportunity to develop the information that would be needed at such time as federal legislation might be enacted. It also provided a base for making meaningful improvements in management at the state and county levels. Special consultants were brought in, to advise the Sea Grant Program and state agencies faced with problems in coastal zone management. The consultants included Dr. S. V. Ciriacy-Wantrup of the University of California at Berkeley, and Dr. Clynn Phillips, Director of Business and Economic Research at the University of Wyoming. Dr. Ciriacy-Wantrup is a recognized leader in the development of coastal management legislation and planning in California; he worked closely both with the Sea Grant Program and with state agencies having problems that had been identified in the workshops. Dr. Phillips served in a similar capacity. In addition, Dr. Phillips wrote two useful reports: "Shoreline Management Advisory Services" and "Coastal Zone Management Problems with Special Emphasis on Recreation Uses".

The deliberations of the special faculty committee, plus the consultants' advice and reports, served as a basis for developing priorities for Year 04 and 05 Coastal Zone Environment Management programs, and also for identifying on-going projects to be included in this problem area. Due to the limited funding, only a portion of the projects identified as "high priority" have been proposed for funding, and a lesser number actually funded. Among the projects funded for Year 04, for which some 03 funds were allocated for an early start (during the summer months) were: "Economic and Institutional Aspects of Multiple Uses in Hawaii's Coastal Zone" and "Law of Coastal Zone Management in Hawaii". Other projects planned and identified as high priority, but held in abeyance for future funding, include some on research in the recreational uses of Hawaii's coastal zone.

Project Title: QUALITY OF COASTAL WATERS
Short Title: (None)
Inception: A new project for Year 03
Principal
Investigator: L. Stephen Lau
Director, Water Resources Research Center
and
Professor, Department of Civil Engineering

In the original proposal for Year 03, nine projects were submitted under the heading of "Inshore Pollution". As explained earlier in this report, the National Sea Grant Program Office requested that Year 03 be a year of planning in this area, just as in the area of shoreline management.

A number of events occurred between the preparation of the University of Hawaii Year 03 Sea Grant proposal and its review by NOAA that warranted this change in emphasis. The most important of these events was the awarding of a contract by the City and County of Honolulu for the Oahu Water Quality Program to conduct studies necessary to resolve sewage discharge problems at Kaneohe Bay and at Sand Island, where the sewage of the City of Honolulu is presently dumped into the Pacific Ocean with no treatment whatsoever.

Funding was provided for the purposes of re-appraising the problems of managing the quality of coastal waters in Hawaii, and for planning an appropriate program of research.

A planning group, composed of University of Hawaii faculty members from a wide variety of backgrounds, was organized under the chairmanship of Dr. L. Stephen Lau, Acting Director of the Water Resources Research Center at the University.

Professor P. H. McGauhey, Director Emeritus of the Sanitary Engineering Laboratory of the University of California at Berkeley, led the group on a full-time basis from October through December, 1970. To assure that the final proposal would best meet the needs of Hawaii, members of the Oahu Water Quality Program (a consortium of prominent engineering firms) and representatives of the Hawaiian Sugar Planters' Association were assigned to the group. Frequent meetings were held with the State of Hawaii Department of Health, and much information was obtained from various state and local committees concerned with pollution problems. In addition, a series of workshops were held, with consultants brought into the state on a short-term basis. Numerous discussions were held with scientists and other individuals aware of problems throughout the state, in order to help identify the major problem areas. A special report was prepared for the planning group, concerning the use of agricultural chemicals in Hawaii and the ways by which they might get into the coastal waters.

All of this planning effort resulted in the development of a single, broadly based project concerned with the quality of coastal waters in Hawaii. The project was concerned both with finding solutions to specific instances of existing pollution, and with finding means for preventing future pollution from such sources as land development and population growth in sparsely populated areas of the state. Both scientific and administrative solutions were to be sought.

The overall project, under Dr. Lau as principal investigator, was structured into 14 integrated activities, directed by affiliate investigators. These 14 activities had several specific objectives, including identifying and measuring various pollutants and possible pollutants entering coastal waters; monitoring changes in water quality; evaluating the adequacy of present coastal water quality standards; developing scientific data on which to base water quality protection measures; recommending changes in policy and practice necessary to protect coastal waters (and also assessing the economic and social effect of those recommended changes); and maintaining an informational and advisory program to keep the public informed of the project's findings and the implications of the project's recommendations.

While the overall project was planned to start at the beginning of Sea Grant Year 04, one phase was given an earlier start because of a critical time factor. The Kilauea Sugar Company announced it would cease operations at the end of the 1971 harvest season; in order to identify the effects of its wastes over a period of time, the situation would have to be assessed while it was still operating and dumping wastes, as a number of mills were doing. For that reason, work was started on the island of Kauai in July, 1971, using a small residue of Year 03 funds, assistance from other projects and agencies, and time donated by the project control group. When Year 04 funds became available, this work was extended and the initial phase of the study was completed before the mill shut down.

Project Title: ECONOMIC EVALUATION OF BENTHIC SANDS FOR THE CONSTRUCTION INDUSTRY
Short Title: Sand Economics
Inception: A new project for Year 03
Principal Investigator: C. Gopalakrishnan
Associate Professor
Department of Agricultural Economics

In the original form of the Year 03 proposal, this project was one of three concerned with offshore sands included in the section then titled "Mineral Resources". With the restructuring of the general plan (previously explained in this report), this sand economics project was placed in the area called "Coastal Environment Management". The first of the three sand projects was an inventory of benthic, or underwater, sand deposits around Hawaii; the second project was concerned with better ways of mining these undersea sands. This project investigates the costs and general economics of using offshore sand as against land-based deposits of sand.

Since Hawaii's first cement plant started operation in 1958, the demand for concrete for construction has increased at an approximate rate of 50 percent a year. Because sand is an important ingredient, along with cement, in making concrete for construction, the industrial use of sand in Hawaii has been increasing rapidly over the past few years as construction has boomed on Oahu, and, to a much lesser extent, on the other main islands of Hawaii.

Construction costs in Hawaii are among the nation's highest. Therefore, a study of whether or not the use of offshore sands might increase construction costs – and the possible amount of that increase – was deemed significant, especially in relation to the other sand projects.

The research carried out under this project was comprised of an economic analysis of future sand requirements; production costs of offshore vs land-based sands; cost effects on the construction industry in Hawaii; a review of government decisions in this area; and the conservation aspects of offshore sand mining.

A review was made of both the current and historical demand for sand by its major nsers in Hawaii. Forecasts and equations relating to sand demand in construction were developed, producing demand estimates for every five-year interval through 1995. During Year 03 the state ruled that, beginning in 1975, no more beach sands could be mined; the economic and institutional consequences of that ruling were examined.

A report covering the results of the project's research has been completed and is now being prepared for publication. The project terminates with the issuing of that report.

Project Title:	ANALYSIS OF THE ECOLOGICAL DYNAMICS OF THE CORAL-EATING STARFISH, *Acanthaster planci*
Short Title:	Acanthaster Ecology
Inception:	A new project for Year 03 (growing from a special project in Year 02)
Principal Investigator:	Joseph M. Branham Assistant Professor Department of Zoology

Coral reefs serve at least two important functions for the islands they fringe. First, the reefs provide necessary shelter for the many reef fish used for food by islanders. Without the reefs, there would be few fish available near shore. Second, reefs take the main pounding from ocean waves. Without protecting reefs to absorb much of the force of incoming waves, beaches and shoreline would be badly eroded; smaller islands might vanish altogether.

The sixteen-arm starfish known to scientists as *Acanthaster planci,* and to the non-scientist as the "Crown-of-Thorns" starfish, is a normal part of the animal life on many coral reefs. Although it eats living coral, it had never appeared to pose any threat to coral reefs. In 1966 the starfish was discovered in what appeared to be far greater than normal concentrations on Australia's Great Barrier Reef. Huge herds of starfish were reported to be moving slowly over the reef, grazing as they went, and leaving only expanses of dead skeleton coral behind, picked clean of life. Between 1967 and the middle of 1969, the starfish appeared in great clusters on Guam; it was reported to have eaten away more than 90 percent of the living coral on Guam's northwestern reefs. Newspapers headlined the "starfish invasion" and predicted disaster for the Pacific islands.

Then reports of "starfish invasions" also began to come in from the U.S. Trust Territory islands of Micronesia. In mid-1969 the Department of the Interior, which has the responsibility for the Trust Territory, gave the Westinghouse Ocean Research Laboratories a contract to survey many of the Pacific island coral reefs. The University of Hawaii sponsored several teams of observers to take part in the survey; part of this was with Sea Grant funding. In September 1969, following the survey, Trust Territory officials met with members of the survey groups, and with representatives of the Bureau of Commercial Fisheries (now National Marine Fisheries Service) at the University. Many of those present had years of experience in observing and studying coral reefs. When they finally had a chance to talk the matter over calmly with colleagues, they all agreed that the news reports had greatly overemphasized the "danger to Pacific islands" from the "starfish invasion". They agreed that most reefs normally contain far more dead than living coral, and that dead coral seems harder to break up than living coral, so that the reported danger of islands disappearing when dead reefs were "reduced to rubble" by pounding waves was probably not a real danger.

By this time several campaigns and crusades had resulted in the killing of many starfish by chemical injections. This was deplored by most of the scientists present, who suggested that – since there was no serious danger to the existence of present coral reefs – the phenomenon should be studied. It might be a normal, recurring event which had simply never been noticed before. A Sea Grant project was funded to explore that possibility. Plans were made to study a population of some 20,000 starfish discovered near the Hawaiian island of Molokai. The study was just getting under way when a "scuba divers' crusade" destroyed most of the Molokai starfish population, effectively ending this Sea Grant project. The remaining money was transferred to the next-reported project, a study of how coral reefs might be encouraged to grow.

Subsequent findings on starfish seem to indicate that these "reef killings" may indeed be a normal – and even important – part of the long-term life cycle of coral reefs.

Project Title:	SUCCESSION AND STIMULATION OF SUCCESSION ON DENUDED CORAL REEF SUBSTRATES
Short Title:	Coral Reefs
Inception:	Project continued from Year 02
Principal Investigator:	Keith E. Chave Professor and Chairman Department of Oceanography

The coral reef environment is among the most complex of marine environments in terms of biological, geological, chemical, and physical factors. No long-term, comprehensive studies of reefs similar to this study have ever been attempted. (This project began in Sea Grant Year 01 at the University; it is planned to continue until the end of Year 05.) One reason studies of this type may be made in Hawaii is that it is one of the few places where coral reefs are accessible to the faculty and students of a major university on a day-to-day basis. The laboratory of the Hawaii Institute of Marine Biology is located on a coral reef in Oahu's Kaneohe Bay. This laboratory has served as a base of operations over the last three years for a team of researchers from the departments of oceanography, zoology, botany, and geosciences.

The objectives of the study are to understand: (1) how a reef community functions normally, to build islands and provide shelter for food fish; (2) what happens when a reef community is disrupted or destroyed by natural or man-made processes; and (3) how a reef community can be stimulated to recover faster than normal from a destructive event.

Because of the importance of reefs in protecting shorelines from being eaten away by waves, in providing relatively calm inshore waters behind the reefs, and in providing living spaces for many food fish, the ability to restore damaged reefs and stimulate faster growth of reefs in certain areas could be of immense value in many parts of the world.

One of the participating investigators has been studying coral ecology, with major efforts directed toward coral transplantations, to evaluate causes of coral growth and death. Another phase of the project concentrates on growth of algae. Still another phase involves studying what reef fish eat: this is determined by examining the content of their stomachs and intestines. One result will be to determine the various position of each species in the food web or chain; another will be to see what creatures directly affect the reef structure by competing with the corals for food. Still another phase of this project concerns the physical energy of waves pounding against the reef.

In addition, some 350 locations have been selected, around the bay, where a number of different factors are being measured. Investigations pertaining to Kaneohe Bay in particular include studies of the effect of sewage and of freshwater runoffs into the bay. A study of all the diverse corals found in the bay has also been made. In one phase of the project, coral transplant studies were made in American Samoa. The reason for this is that one of the principal worldwide reef-building coral genera, the *Acropora,* is not found in Hawaiian waters. Data on this family are needed, to compare with growth and survival data on major coral families present in Kaneohe Bay.

Initially the study was directed toward understanding the mechanisms of reef growth, with the goal of eventual reef management. As time progressed, it was discovered that what was being studied was not simply a reef complex, but a reef complex strongly affected by outside factors, especially the two major sewer outfalls at the southern end of the reef.

Since the inception of this study, the pollution of Kaneohe Bay, both by sewage and by clearing and grading of land above the bay for various construction projects – with a consequent increase in the amount of silt and fresh rainwater running into the bay – has become an important and often heated topic in Hawaii. Because of this, the educational and advisory aspects of the project have already been the source of considerable service to the public. Data produced have been presented and discussed at many government agency and civic group meetings. When completed, the reports from the project will include information on the relatively unpolluted reefs in the northern part of the bay, and the badly polluted reefs in the southern part. The work should stimulate community action to help preserve the environment of the bay, and will provide a base line from which to measure improvements to the environment as they are implemented. The data will eventually be compiled into an atlas of Kaneohe Bay.

As noted earlier, the study is planned to continue until the end of Sea Grant Year 05.

CONTINUED YEAR 02 PROJECTS

Of the Year 02 projects that were continued into Year 03, either directly or by being consolidated into related projects, only two did not fit into one of the six major areas finally established for Year 03. One of these, "Human Performance in the Sea", was considered of enough importance to man's future use of the sea to be continued outside of any fixed category. The second project, "Improvement of Hyperbaric Facilities", so strongly supported the "Human Performance" project that it also was judged worthy of continued support.

By the time the proposal for Year 04 was completed, these two projects had been made the basis of a new category, "Life in the Sea", for which six projects were proposed.

The importance of these Continued Year 02 Projects is described in the two reports immediately following.

Project Title: HUMAN PERFORMANCE IN THE SEA
Short Title: Human Performance
Inception: Project started in Year 01
Principal Investigator: Suk Ki Hong
Professor and Chairman
Department of Physiology

As man's interest in exploring the ocean and making use of its resources continues to grow, there will be more and more need for divers working beneath its surface. Their tasks will range from simple observation of underwater structures to maintenance and heavy construction work. Interest in sport diving should also continue to grow. (Already there are known to be some 15,000 sport and professional divers in Hawaii.)

What are the limits of the human capacity for physical exertion under water? What stresses do increasing pressure and colder waters put on heart and lungs? Not much was known about these important areas at the beginning of this project, which started in Sea Grant Year 01 in Hawaii. Most experimental work has, of necessity, focused first on whether man can exist under water without harm, then on how deep he can safely go. Some important studies on reactions to cold have been conducted at Duke University, but they stressed diving to great depths (several hundred feet) and heart functions. This project focuses more on heat regulation functions, and on stresses encountered in shallower depths where much work diving and almost all sport diving is done.

The human performance project was coordinated with the sand recovery project, which required working divers to perform such tasks as taking core samples. The human performance project sought to find the physiologic limitations on such tasks. It will use information about those limitations to develop recommendations on such topics as: safety procedures, including warning devices; team and crew sizes for specific tasks; optimal duty cycles; and instrument or tool improvement.

Other objectives include (1) defining the upper limit of human work capacity as a function of depth, temperature, and other variables that affect that limit; (2) continuing the survey of heart/lung function of local sport and working divers, which has already led to the making of safety recommendations on an individual basis for those divers; identifying the minimum reliable monitoring index which will accurately predict the work performance of a diver; and exploring the biomechanics of underwater movement, with a view toward increasing the mechanical efficiency of divers.

During early parts of the project, volunteers performed various physical exercises, first on land (but breathing from a standard scuba-diving air supply) and them immersed in water at 30°, 22°, and 16° Centigrade (approximately 86°, 72°, and 61° Fahrenheit). The air the volunteers exhaled was collected and analyzed for oxygen and carbon dioxide content, and factors such as heart rate, rectal temperature, respiratory rate, and work rate were monitored constantly. These studies would provide base-line data against which to compare future measurements. Other laboratory studies investigated heart rates (and the slowing of the heart) during breath holding under various conditions. These tests indicated that the heart rate during diving may be determined by the water temperature, depth of the dive, and level of physical activity. (Colder water seems to slow the heart rate, while increased pressure from greater depth seems to speed it up.)

During Year 03 tests were carried out at sea, with professional scuba divers. Each subject dove to depths of 15, 30, 45, or 60 feet, then held his breath while an electrocardiograph recorded his heart activity continuously. Confirming the earlier tests, the results showed that breath holding did not slow the heart rate at depths as much as at the surface.

A number of other tests were also conducted, including studies of divers in water at 30° and 15° C (86° and 59° F) at a depth of 33 feet, where pressure is double that of pressure at the surface. These tests indicated that estimations of diver work-stress based on surface equivalent data are invalid; they underestimate actual stress.

Much educational and advisory work has already been done by personnel on this project. Nine scientific reports of various test results have been published. A graduate course, "Cardiovascular and Respiratory Physiology", has been developed; a weekly series of discussion sessions, "Diving and Hyperbaric Physiology", has been conducted with staff and graduate students. Seven lecture presentations were delivered, to diving clubs and hospital staffs; one was at the annual meeting of the Southwestern Division of the American Association of Health and Physical Education and Recreation. In cooperation with the Nippon Television Company, a documentary series on diving physiology was filmed. In addition, a large number of individual inquiries have been answered.

Groundwork has also been done in developing interdepartmental biomedical research projects on work performance in the sea; discussions were held with the departments of psychology, biochemistry, pharmacology, pathology, nutrition, and mechanical and electrical engineering. Investigators have also worked with local diving instructors; one serves as a member of the Hawaii Diving Council.

One important result already achieved through this project is a re-evaluation of the role of carbon dioxide in diving accidents. This was reported to the American Physiologic Society.

With a great deal of important investigation remaining to be done, the project was funded for Year 04.

Project Title: IMPROVEMENT OF HYPERBARIC FACILITIES
Short Title: Hyperbaric Facilities
Inceptions: Project continued from Year
Principal Investigator: John T. O'Brien
Director, J.K.K. Look Laboratory
Department of Ocean Engineering

This was originally two projects, started in Sea Grant Year 01, and combined in Year 02. Both sections deal with hyperbaric facilities – those in which higher-than-normal atmospheric pressures can be obtained and maintained. Hyperbaric facilities are essential to both deep diving research and actual deep diving.

At sea level, the normal atmospheric pressure is 14.7 pounds per square inch of area. This comes from the weight of the gases (primarily nitrogen and oxygen) in the earth's total atmosphere. This pressure increases as an object goes down into the water; because water weighs so much more than atmospheric gases, pressure increases rapidly, at a rate of approximately 0.45 pounds for each foot of descent. At a depth of 33 feet, pressure is double that at sea level; it increases by 14.7 pounds per square inch for every additional 33 feet of depth. This fact has many ramifications, and creates a wide variety of possible problems when men go down into the sea. Hyperbaric facilities are used to slowly decompress divers after deep or long-lasting dives to prevent "the bends" and other serious physical problems. Other hyperbaric facilities can create the pressure of various depths in a dry atmosphere, for scientific and technical studies relating to diving and underwater operations.

The first section of this project called for designing a hyperbaric facility capable of creating any pressure desired, with a final limit equal to 100 times surface pressure, which is equal to a depth of 3,000 feet. This would cover the extreme depths in most of the channels between the major Hawaiian islands. While no divers have yet gone that deep, they have reached half that depth in other hyperbaric facilities, and Navy divers have gone more than one-third that depth in the open ocean. Plans for this facility were completed by the end of Year 03.

The second phase of the project called for the improvement and maintenance of an existing facility at the University's J.K.K. Look Laboratory of Ocean Engineering. This is a 40-foot high, 30-foot diameter steel tank within which pressures equal to a depth of 100 feet can be produced, either in air or in water. This facility was in operation early in Year 03, and much of the research reported in the preceding project was conducted in it.

During the year the fabrication of an in-out lock for this diving chamber was begun. This is a cylinder 8 feet long and 40 inches in diameter, with quick-opening doors in each end. When completed, it will be installed horizontally in the side of the existing facility, about 15 feet above the bottom, near the existing side hatch. This lock will allow passage in and out of the diving chamber while it is pressurized, without loss of pressure in the chamber. (A pressure lock could be compared to a canal lock, which receives a boat in one end at one level, and lets it out the other end at either a higher or a lower level.) Since this in-out lock will be capable of creating pressures equal to a depth of 400 feet, it can also be used as an individual hyperbaric facility for pressures greater than those possible in the large facility.

Because of its importance, this project was funded for Year 04.

IN SUMMARY

Sea Grant Year 03 in Hawaii was a year of development that would lead to further changes in structure and organization in Year 04. But by Year 03 the Sea Grant Program at the University of Hawaii had firmly set itself on a course heading directly toward achievement of Sea Grant College status, in line with the objectives of the overall national program.

Of the twenty-seven projects in Year 03, 10 were concluded at the end of that year, while the balance were continued into Year 04.

One point worth stressing is that several projects received more outside support than the one-third minimum required by law. Often this support took the form of additional goods and services; had these not been furnished without charge to Sea Grant, their purchase with Sea Grant dollars would have been necessary. Three projects (Precious Corals, Manganese Nodules, and Human Performance in the Sea) received substantial additional dollar funding, with some of the money coming from the State of Hawaii's Marine Affairs Coordinator program.

This additional support, both in cash and in goods and services, is strong evidence that the state and nation are responding to Sea Grant's efforts to make better use of the many resources of the sea in an effort to benefit the nation and the world.

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APPENDIX

TOPICS IN OCEAN ENGINEERING

Lecture Series at the University of Hawaii, Spring, 1971

SPEAKERS	TOPICS
Dr. Russ E. Davis Scripps Institution of Oceanography University of California, San Diego	Laboratory Modelling of Internal Wave Motion Wave Generation by Wind
Ing. Rafael Vazquez De La Cerda Instituto Politecnico Nacional Comision Operacion Y Fomento De Actividades Academicas, Mexico	Different Armored Units in Breakwater
Dr. Gerald Jarlan Consulting Engineer Versailles, France	Deep Water Harbors Concept The Application of the Perforated Breakwater Concept to Harbor Design
Captain V. Rinehart Director National Data Buoy Project U.S. Coast Guard	Oceanographic Instrumentation Design of an Oceanographic Instrumentation System Buoy Hulls and Moorings
Dr. Fredric Raichlen Division of Engineering and Applied Science California Institute of Technology	Tsunamis in the Laboratory Harbors and Moored Vessels
Dr. D. W. Hood Institute of Marine Sciences University of Alaska	Pollution of the World's Oceans
Dr. John P. Craven Dean of Marine Programs University of Hawaii	Ocean Systems Floating Platforms as an Ocean System
Dr. Robert Eisner Scripps Institution of Oceanography University of California, San Diego	Classical Studies in Diving Mammals Current Research in Breath-Hold Diving The Comparative View of Asphyxial Defense Mechanisms - Humans and Fetal Animals

Dr. Donald Rennie Department of Physiology State University of New York at Buffalo	Temperature Regulation in Water: Theory Temperature Regulation in Water: Practice Exercise in Water: Local Circulation Exercise in Water: Overall Circulation
Dr. Albert B. Craig Department of Physiology University of Rochester	Physical Factors in Breath Hold Diving Physiological Factors: Before the Dive Physiological Factors: During the Diving Physiological Factors: Limits of the Dive
Dr. H. W. Gillen Director Department of Neurology Marion County General Hospital Indianapolis, Indiana	Unsolved Problems of Saturation Diving Theoretical Aspects of Decompression Injury Location Oxygen Toxicity Offshore Operational Safety