Attachment A

XD-AAC-889-A1

THE OCEANIC INSTITUTE

ANNUAL REPORT

1977

THE OCEANIC INSTITUTE

BOARD OF TRUSTEES

Mr. Robert H. Rath, Sr., Chairman
Mr. Charles C. Spalding, Vice Chairman

Mr. Martin Anderson
McCutchen, Doyle, Brown & Enersen
San Francisco, California

Mr. Alexander S. Atherton
President, Gannett Pacific
Honolulu, Hawaii

Mr. William E. Aull
Executive Vice President
Hawaiian Trust Company, Ltd.
Honolulu, Hawaii

Mr. John Bellinger
President and Chief Executive Officer
First Hawaiian Bank
Honolulu, Hawaii

Mr. Lawrence S. Berger
President, KHVH
Honolulu, Hawaii

Mr. Richard A. Cooke, Jr., President
Richard Cooke Developments, Ltd.
Honolulu, Hawaii

Mr. Samuel A. Cooke, Vice President
Dean Witter & Co., Inc.
Honolulu, Hawaii

Dr. John P. Craven
Dean of Marine Programs
University of Hawaii
Honolulu, Hawaii

Mr. James F. Deane, President
J.F. Deane, Inc.
Honolulu, Hawaii

Mr. Bayard H. Dillingham, President
B.F. Dillingham Co., Ltd.
Honolulu, Hawaii

Dr. William R. Furtick
Dean, College of Tropical Agriculture
University of Hawaii
Honolulu, Hawaii

Dr. Wytze Gorter
Professor of Economics
University of Hawaii
Honolulu, Hawaii

Gen. Hunter Harris, Jr.
USAF (Retired)
Honolulu, Hawaii

Mr. John E.F. Hassell, Vice President
Johnson & Higgins of Hawaii, Inc.
Honolulu, Hawaii

Mr. Stuart T.K. Ho, President
Capital Investment of Hawaii, Inc.
Honolulu, Hawaii

Mr. Andrew T.F. Ing
Financial Vice President
Hawaiian Electric Co., Inc.
Honolulu, Hawaii

Mr. Malcolm MacNaughton
Chairman of the Board
Castle & Cooke, Inc.
Honolulu, Hawaii

Mr. Robert C. Oshiro
Wahiawa, Hawaii

Mr. Charles J. Pietsch, Jr., President
Bishop Corporation
Honolulu, Hawaii

Mr. Robert H. Rath, Sr.
Commissioner, State of Hawaii
Public Utilities Commission
Honolulu, Hawaii

Mr. Frederick A. Schaefer III
Vice President, Ainamalu Corporation
Honolulu, Hawaii

Mr. William W. Sellew
ICLARM
Westport, Connecticut

Mr. Charles C. Spalding
Honolulu, Hawaii

Mr. Philip E. Spalding, Jr., President
Molokai Ranch Ltd.
Honolulu, Hawaii

Dr. Athelstan Spilhaus, Soecial Consultant
National Sea Grant Program, NOAA
Washington, D.C.

Dr. H. Burr Steinbach,
President Emeritus, The Oceanic Institute
Woods Hole, Massachusetts

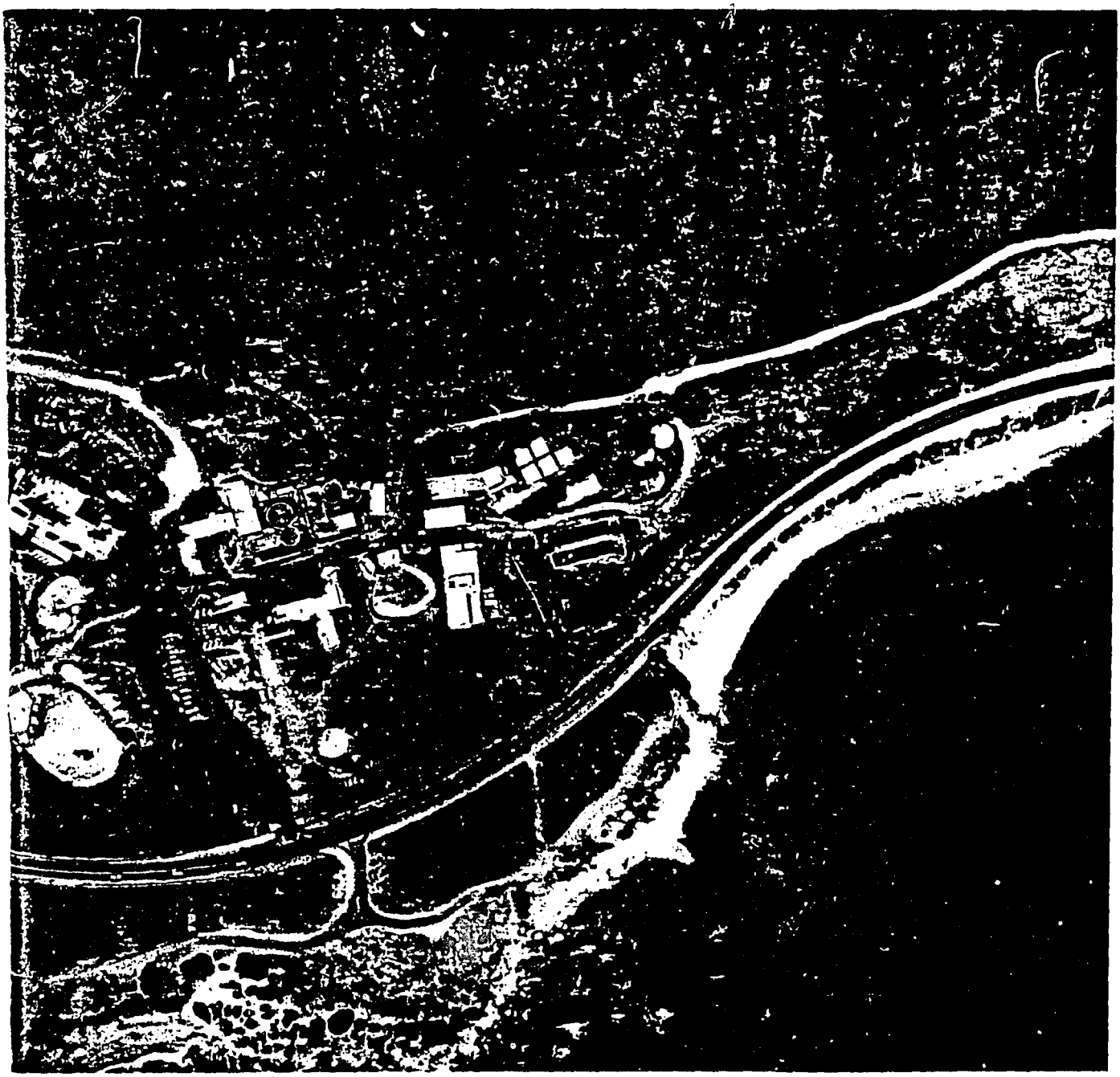
Mr. Myron B. Thompson, Trustee;
Kamehameha Schools/B.P. Bishop Estate
Honolulu, Hawaii

Dr. James H. Wakelin, Jr.
Washington, D.C.

Mr. Henry A. Walker, Jr.
Chairman and Chief Executive Officer
Amfac, Inc.
Honolulu, Hawaii

MEMBERS OF THE CORPORATION

MARTIN ANDERSON
ALEXANDER S. ATHERTON
WILLIAM E. AULL
JOHN BARDACH
JOHN BELLINGER
LAWRENCE S. BERGER
CHARLES A. BLACK
WILSON P. CANNON, JR.
GEORGE CARTER III
RICHARD A. COOKE, JR.
SAMUEL A. COOKE
HERBERT C. CORNUELLE
ROGER H. CORYELL
JOHN P. CRAVEN
JAMES F. DEANE
BAYARD H. DILLINGHAM
TILGHMAN B. EVANS
WILLIAM R. FURTICK
ALAN M. GLOMB
HAROLD L. GOODWIN
WYTZE GORTER
HUNTER HARRIS, JR.
HERBERT D. HART
JOHN E.F. HASSELL
PHILIP HELFRICH
GEORGE HERRMANN, JR.
STUART T.K. HO
CARL N. HODGES
THOMAS P. HUBER
ANDREW T.F. ING
JON M. LINDBERGH
MALCOLM MacNAUGHTON
FUJIO MATSUDA
COLIN E. NASH
ROBERT C. OSHIRO
CHARLES J. PIETSCH, JR.
CHARLES J. PIETSCH III
GIFFORD B. PINCHOT
JOHN PIROVANO
RICHARD W. POWER
TAYLOR A. PRYOR
ROBERT H. RATH, SR.
FREDERICK A. SCHAEFER III
JOHN SCOTT
WILLIAM W. SELLEW
CHARLES C. SPALDING
PHILIP E. SPALDING, JR.
ATHELSTAN SPILHAUS
H. BURR STEINBACH
MYRON B. THOMPSON
JAMES H. WAKELIN, JR.
HENRY A. WALKER, JR.
ALEXANDER WYLLY



Makapuu Oceanic Center, site of the Oceanic Institute and Sea Life Park
(photo by Tryck, Nyman & Hayes, Inc.)

ADMINISTRATION

Richard W. Power ..... President
Colin E. Nash, Ph.D. ..... Vice President and Director of Research
Thomas P. Huber ..... Secretary
Cades Schutte Fleming & Wright
Andrew T.F. Ing ..... Treasurer
Hawaiian Electric Company
Nadine V. Taylor ..... Assistant Treasurer
Nancy A. Roberts ..... Assistant Secretary

THE CHAIRMAN'S REPORT

Robert H. Rath, Sr.

We succeeded, through the combined efforts of our staff, trustees, financial contributors, and state and federal agencies in concluding a rewarding year. Financially, we operated in the black and scientifically we have embarked on several exciting new projects which will be explained in some detail in this annual report. The Institute continues to gain stature and recognition both nationally and internationally and is gaining increased support locally as one of the keystones to future success by the State in aquacultural areas.

During the past year, one of the Institute's prime emphases was to improve communications and exchange information with the local business and community leaders, as well as to continue working with key members of both national and state legislatures and agencies. We hosted more than 280 individuals at the Institute during the year at our monthly luncheons and other social occasions which have greatly broadened interest in the Oceanic Institute.

From the funding point of view, this has been a year of policy change. Many local foundations altered their donation policies from the support of operating overhead to specific project grants. The local foundations contributed to the building of four large holding ponds which will support our finfish hatchery program. In addition to the gifts themselves, these donations enable the Institute to use such awards as matching funds for federal and private grants. We are looking toward the overhead allowances on grants, the resumption of rentals from Sea Life Park, and contributions from friends to carry our operating costs from here on out.

During the past year, Dr. H. Burr Steinbach resigned as President to become President Emeritus from his residence at Woods Hole, Massachusetts. Dr. Steinbach contributed considerably toward the Institute's reestablishment of its national and international reputation. Richard W. Power moved from Administrative Vice President to President and Chief Executive Officer upon Dr. Steinbach's departure and injected new activity and considerable energy to all phases of operation and financing. Dr. Colin Nash, on the other hand, returned to Oceanic on a full-time basis after having been assigned on a half-time basis to ICLARM.

We welcome and need the total community support that we received during 1977 to assure the Institute's continued successes in its varied fields.

THE PRESIDENT'S MESSAGE

Richard W. Power

We are looking ahead optimistically to 1978. We are continuing to stress the practical side of our research and development projects, particularly in the field of aquaculture. We are, for example, exploring the underwater environment for fish farming with cages and other facilities, and developing a new program on the feasibility of marine shrimp farming in Hawaii. These projects are in addition to the many research aspects of our long-term aquaculture program which is involved in responding to the demands of world hunger.

We were disappointed during the year when the funds appropriated by the State legislature for completion of the hatchery were not released. The Institute has held a challenge grant of $150,000 from the Henry L. and Grace Doherty Foundation for over twelve months to complete the hatchery and laboratory facility. It was hoped that the conditions would be met with the State funds and final construction could begin. However, we are hopeful that support by the State will be renewed this year and we can be in production next year.

The Chairman of the Board of Trustees, in his report, referred to the changes in operational procedures enforced by internal policy changes of the private foundations. These have directly influenced the management of the Institute and it is necessary, more than ever before, to maintain a continuous projection for the Institute's interests and income for at least two years ahead. In the world of federal grants and contracts, with its notorious uncertainty and bureaucratic slowness, these are difficult projections to make, and are often beyond our control. The Institute has a need for its independence, and is a more useful organization in that capacity than if it is enveloped in any safe state or federal organization. However, in order to remove it in part from an annual dependence on government agencies, we are looking at some close associations with certain universities and international organizations which, we hope, will lead to some basic long-term funding. We are, in particular, seeking to move into the capacity of a technical education center, offering facilities for technical training and research. This education role will, we feel, provide the Institute with a strong base for its future. We hope that some of these long-term plans bear fruit in the coming months as we now move ahead into the challenging and exciting days of 1978.

THE DIRECTOR'S REVIEW

Colin E. Nash, Ph.D.

National Resources, Environment, Energy — such everyday words of life and language that it is almost impossible to imagine a time without them. Within the last ten years each has risen from obscurity in the dictionary to the heights of international and national authority, complete with bureaucracy and budget. Concern for them is now so important a part of modern society that one wonders why each was not a priority decades ago.

In spite of a seemingly overnight emergence of these major social issues, in reality not a great deal in general attitude has changed. New watchwords may have appeared, but beneath the facade of reorganization and awareness, man is maintaining a concern which he developed through the eons of his existence on earth. Historically, man has always been conscious of the possibility of earthly imbalances. Socially he has had a rationale for specific progress, but with the advantage of evolving the process through leisurely and benign paths.

The problem at present is that man and his society are advancing rapidly up an exponential curve, and there is little room for error. To put this in perspective, compare the slow historical evolution of the stone and bronze ages with the headlong rush of the petrochemical and nuclear ages of modern times. Such comparisions cannot be lightly dismissed. At their respective periods in man's evolution, each was or still is a critical factor influencing man's entire future.

In many ways, man has become a victim of his own ingenuity and technical achievement. For example, the rapidity of modern communication and television can promote a minor national issue into an international problem overnight. In earlier times, man was much more in control of his destiny and at one with his surroundings — and not because of compulsion. In spite of the low odds against individual survival, man's social instincts for doing the right thing in order to increase his chances were probably far higher than those of today.

Time, of course, is truth's great foe. With time the real truth often becomes lost or unalterably embroidered. Villains become folk heroes, and benign cultures are dismissed as unimportant, unprogressive eras in the civilization of man. Probably most of the faculties of man to exist as a benign part of the earth's ecosystem have been lost within the last hundred years. The Indians of North and South America were probably the last societies which utilized an inherent philosophy, evolved through centuries, for living with nature. Their instinct for self-preservation was management — not the management of the plants and animals on which they depended for their existence, but management of themselves within the boundaries of their own environment. Their societies, in fact, may have been the height of man's integration within the earth's ecosystem.

Modern society seems to be unable to manage itself and almost always impulsively overreacts to management issues. The last two decades, for example, illustrated spontaneous attempts to deal with a wide variety of social problems, but with poor and even retrogressive results. Although government by nongovernment is widely accepted as an effective form of managing society, the last two decades have been landmarks for shotgun legislation in vain attempts by man to manage his existence within his world.

And it is going to go on. Throughout 1977, and unquestionably tabled for 1978, the social issues were subjected to much international and national discussion for the purpose of enacting protective laws. The country and the states struggled with energy plans, conservation and environment laws, coastal zone regulations, and all with only half an eye turned toward their impact on the real economies of life.

Such decisions by government on social issues have an immediate effect on the existence and future of the Oceanic Institute. New departments of science and technology are created, others get

folded into bigger bureaucracies, and occasionally some are wiped out. As a consequence, research and development contract funds are to be found in a maze of shifting government corridors, but more and more specific to political priorities. The Institute staff, therefore, has to keep itself continuously informed of the trends and funding programs being developed in the capitol buildings in order to guarantee an existence for the Institute.

However, the Institute still values its independence and its ability to direct its own priorities for project development. More and more the help for such activities is provided by the many private foundations which have supported the Institute for many years. Although private foundations have been redirecting their own efforts to the support of the new watchwords, such as energy and resource management, they are probably more responsible than any other group of organizations for the backing of real innovation. This is greatly to their credit.

Although topical social issues are undeniably important, the Institute is continuing to maintain its objectives to secure scientific and technical knowledge for a wiser use of the oceans and to share that knowledge with the peoples of the world.

The year 1977 has had both its peaks of high hope and its troughs of discouragement. Obviously many projects take years to promote and mature and consequently a great deal of the Institute's work depends on long-range planning and project development — often with nothing to show for it at the end. For example, nowhere was the Institute more hopeful than in the area of finfish hatchery construction. In 1975 the Institute was awarded a challenge grant by the Henry L. and Grace Doherty Foundation for the completion of its unfinished laboratory. In 1976 several State senators worked hard to appropriate funds to comply with the challenge grant and to produce a hatchery and aquaculture educational facility that would be an asset to marine research and development in Hawaii. After 18 months the progress has been thwarted at every turn, and at the end of 1977 the construction had yet to start. Nothing could be more frustrating, particularly at a time when the State authorities are developing an aquaculture master plan which is going to be dependent on pilot-scale facilities, and large resources of federal funds are becoming available that are earmarked for research and development consortia that have both technical talent and large-scale facilities to work on the real problems of aquaculture as a food-production system.

A peak in the year was the signing of a two-year contract with the U.S. Agency for International Development to continue work on the spawning and production of the milkfish. This fish, which is so vital to the protein requirements of many countries in Southeast Asia, must be reared in captivity to guarantee future supplies of fingerlings for the fish farms of those countries. The contract was probably the largest the Institute has signed in its short history.

The Institute is gearing to move into commercial aquaculture in addition to its humanitarian activities with a major program in marine shrimp production. Because of the climate in Hawaii, marine shrimp could be grown successfully in ponds similar to existing practices in Panama and Costa Rica. The Institute has excavated ponds on site for maintenance of the shrimp broodstock that are being imported into the country.

The Institute produced two books during the year in addition to all its other regular publications. Under the editorship of Joe Hanson and Hal Goodwin, "Shrimp and Prawn Farming in the Western Hemisphere" was published by Dowden, Hutchinson & Ross, Inc., of Pennsylvania; and the Director edited a staff publication on mullet breeding and larval rearing techniques for the International Center for Living Aquatic Resources Management. The publication will be produced as a manual for distribution by ICLARM, particularly in the developing countries.

Work on the salmon project in Chile was delayed for 12 months awaiting the restructuring of the fisheries sectors in the country and the appointment of an Undersecretary for Fisheries. This was completed late in 1977 and the Director made one further visit to Chile to initiate the project once more. Hopefully there will be positive progress in 1978.

For 15 months the staff has been involved in the planning of an environmental assessment program for the proposed new superport in Palau. Again this is just one of many similar programs that may break at any time. Alternatively, it could be wiped out overnight by a political decision beyond the Institute's control. It is therefore a continuous process to develop the innumerable leads in the hopes that a small percentage will succeed and provide the year's activities.

Staff and Affiliates

People, of course, make places, and it was with some disappointment that the staff learned of the intention of the President, Dr. H. Burr Steinbach, to retire yet again from an active scientific life and make an early return to his home at Woods Hole. During his tenure of office at the Institute, Burr was responsible for its scientific and technical strength, and he has already been greatly missed on his daily rounds to talk with the staff in the laboratories and offices. Fortunately, he accepted an honorary title of President Emeritus, and he is still therefore with us in spirit if not in daily presence. Certainly we wish both he and Susie a happy return to Woods Hole and a fond hope that they both can visit Hawaii often. Burr, of course, continues to be active on the east coast on behalf of the Institute.

Dick Power took over the role of President following his year with us as Vice President, Administration. In his short tenure, he has been responsible for opening the eyes of the local community to the work of the Institute and its potential role within the State's marine affairs. He has conducted a series of monthly business lunches and other social programs that have had great benefit to the Institute and opened avenues of contractual research with local industry. He has also developed an extensive program for people to become associates of the Institute.

On the scientific and technical staff, there have been several landmark events during the year. At the end of the year, Dr. Robert A. Shleser joined the staff as the Assistant Director. Bob has been involved in a broad range of aquaculture activities from the specialties of crustacean culture to the politics of preparing aquaculture legislation for the U.S. Congress. His career has been distinguished and visible, and his association with the Institute is most welcome.

Dr. Albert C. Smith joined the Institute on a full-time basis from the University of Hawaii Medical School in July. His unusual qualifications of M.D. and Ph.D. in marine pathology provide the Institute with a unique talent, and already his research in pathology using his medical knowledge has produced some spectacular results.

In December, Paul Bienfang was awarded his Ph.D. in oceanography from the University of Hawaii. Paul was one of the few people in the country who had a research grant from the National Science Foundation without having that degree — an unusual achievement in itself. However, it was through his research and with the help of a fellowship by the Institute from the Jessie Smith Noyes Foundation that he was awarded his doctorate just before the end of the year.

Joe A. Hanson left the Institute in midyear on completion of his work with the National Sea Grant Program. During his years with the Institute, Joe was responsible for some of its most futuristic projects. He edited two volumes on mariculture and produced innumerable publications on the Institute's work. He left the Institute and took a position with Jet Propulsion Laboratory in Pasadena, California. Also with the termination of the same contract, Hal Goodwin ended his consulting service arrangement with the Institute. It was a great pleasure to have Hal's association with the staff, and we appreciate his work on a number of projects which have been published under the Institute's name.

Other Institute staff who left during the year were Craig Pelton, Debbie Goodwin, and three of the administrative staff. To them all we send our appreciation and good wishes.

The Institute continued its arrangement with Hawaiian Electric Company's Environmental Department under Dr. John McCain to conduct experimental work. It was a pleasure to have on site Dr. David Ziemann who was working for HECO. The greenhouse project being conducted by the University of Hawaii Department of Botany also continued to function under the direction of Drs. Sanford and Barbara Siegel.

The brine shrimp project under the State Comprehensive Education and Training Program of the Department of Labor and Industrial Relations came to an end during the year. The team, led by Terry Astro, obtained land on Kauai and relocated there to continue its work as a private enterprise.

Dr. Michael C. Mix, Associate Professor of Biology in the Department of General Science, Oregon State University, worked in the summer on marine pathology projects in association with Dr. Smith, as did Dr. Franklin Ramos of the University of Hawaii, Hilo, and David Coleman of the University of Hawaii, Manoa.

Staff Representation

In April, Dr. Ching-Ming Kuo, Craig Paulsen, and Bill Madden spent several weeks in the Philippines working at the Southeast Asian Fisheries Development Center near Iloilo. They went to work with the SEAFDEC personnel on joint research to try to spawn the milkfish. The program at the Institute is supported by the U.S. Agency for International Development, while work at SEAFDEC is supported by the International Development and Research Center of Canada. Following the visit, the staff went on individual visits to Taiwan, Hong Kong, and Japan.

The Director presented a paper on hatchery economics at the annual meeting of the World Mariculture Society in Costa Rica in January, and then another paper on fish larvae survival at the meeting of the International Commission for Exploration of the Seas in Brest, France, in May. A third paper on "Ocean Ranching and Fisheries Management" at a second ICES meeting in Reykjavik, Iceland, was not presented in person because of other commitments.

In September, Dr. Ching-Ming Kuo chaired a session at the international symposium on the reproductive physiology of fish, sponsored by the National Institute of Agronomic Research, in Paimpont, France. He also presented a paper on the use and function of prostaglandins and gonadotropins for the induced breeding of fish.

Fellowships and Awards

In 1975, the Jessie Smith Noyes Foundation of New York awarded the Institute a major grant for it to conduct educational and training activities in marine-related fields at a variety of academic levels. This grant established the first such programs at the Institute and it made possible many national and international awards to postgraduates, graduates, and high school students to conduct joint or independent research at the Institute, or to receive specific training and instruction in aquaculture techniques. In its short history, the education and training program which was regulated by the President and Director of the Institute, made a total of seven international awards, two national scholarship awards, two senior fellowship awards, four Institute staff fellowships, and gave an annual prize for the best marine-related project at the Science and Engineering Fair of the State of Hawaii.

Of the four members of staff receiving fellowships, Paul Bienfang was the first to complete his program and obtain his doctorate in December. Wade Watanabe continues his research for his doctorate at the University of Hawaii, and Craig Paulsen pursues a degree in business administration. Dr. Franklin Ramos and David Coleman were both given scholarships to undertake specific research in association with the Institute's marine pathology program, and Toby Morris from Punahou School was given a summer scholarship to study the potential for using water storage tanks as aquaculture production units. He conducted his work on a farm in Waimanalo.

Receiving can also be as pleasant as giving, and it was pleasing for Al Smith to be awarded a prize for meritorious research work by the American Foundation for Oceanography.

Buildings and Grounds

Thanks mainly to the gift of paint by Mr. Jim Wada and the labor of Steve Ribakoff and his grounds staff, almost all the buildings were painted during the year. Many of the buildings have weathered kindly during the ten years of their existence but were in need of some further protection. The Institute's lease requires that the design and color of the buildings be in keeping with the conservation priority of the area. The buildings were therefore painted in colors which made them aesthetically fitting to the landscape, and the results have been excellent.

As many projects planned for the future had overlapping requirements for building space and outdoor facilities, the master plan for the site was reformed. A picture of the Institute and its facilities, including those now proposed for 1978, is shown in Fig. 1. The drawing was made by Conrad J. Oliver of Makai Ocean Engineering.

Although the building of the hatchery had not been started in 1977 as it was first hoped, four new ponds were excavated between the hatchery and the road. The funding was kindly provided by the Atherton Family Foundation, Inc., the Samuel N. and Mary Castle Foundation, the McInerny Foundation, the G.N. Wilcox Trust, and Charles M. and Anna C. Cooke, Ltd. The new ponds will be an asset for holding broodstock shrimp and finfish, which are so neccesary to the aquaculture projects. The ponds have dirt bottoms, and will provide a good substrate for the feeding behavior of the two groups of animals.

A few other minor projects were undertaken during the year. The larval feeding system operating in the covered tanks beside the Brittingham Laboratory was upgraded. Ten new units were built giving the production unit a capacity of 6,000 gallons. Some indoor changes were made to the round buildings and to the Brittingham Laboratory, improving the laboratory and office space.

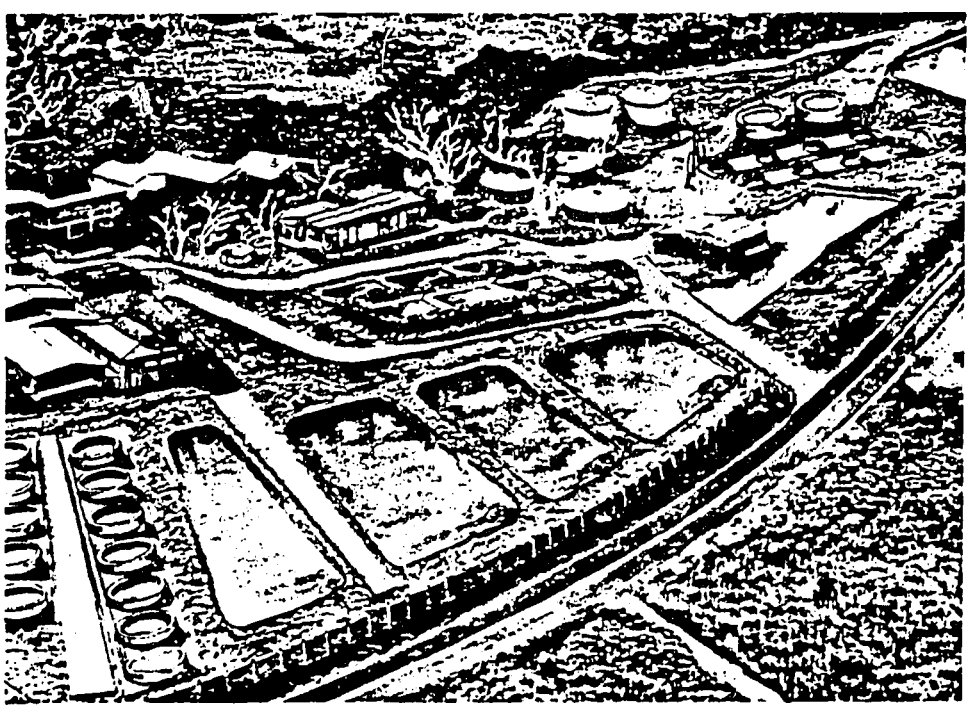


Fig. 1 The Oceanic Institute hatchery and aquaculture facilities.

STATUS OF MAJOR PROJECTS

Larval Food Production

C. Paulsen, D. Goodwin, K. McGovern

In support of expanding larval-rearing experiments, the production of larval food organisms was scaled up and consolidated (Fig. 2). Large-scale phytoplankton cultures are grown in twelve 2,000-liter tanks. More than 4,000 liters of dense (3×10^6 cells/ml) *Chlorella* sp. and *Dunaliella tertiolecta* culture can be harvested daily. This phytoplankton is used to maintain the water quality in larval-rearing tanks as well as to culture the rotifer, *Brachionus plicatilus*. Rotifers are now cultured in two 16,000-liter tanks which can supply some 2×10^7 rotifers/day for larval rearing. As described, this system can sustain 70,000 liters of larval-rearing volume on a continual basis. Techniques learned in developing this system will be applied in the planned pilot-scale hatchery.

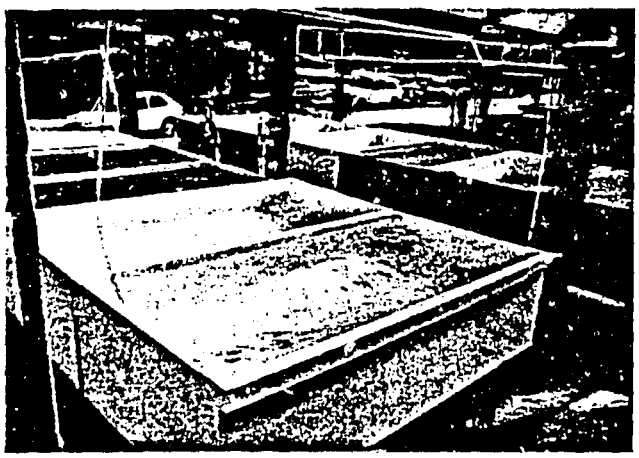


Fig. 2 Large-scale phytoplankton culture facility.

Artemia Culture

C. Paulsen

Brine shrimp nauplii (*Artemia salina* L.) used to feed fish and crustacean larvae are becoming scarce and expensive. This shortage threatens aquaculture development, so a program has been initiated that is intended to conserve available brine shrimp cysts and, ultimately, provide a supply of cysts. Cyst demand can be substantially reduced by feeding smaller numbers of older nauplii to larger fish larvae rather than using only small, newly-hatched nauplii.

To provide larger nauplii on demand, a large-scale, intensive *Artemia* culture system is being developed. Two 1,000-liter prototype systems have been constructed and are being tested (Fig. 3). They are presently capable of culturing 2,000 nauplii/liter using a diet of dried algae (*Spirulina* sp.). The tanks are rectangular, semistatic raceways that use an array of airlift pumps to aerate and circulate the water. Nauplii can be harvested from any of the airlifts as required. Once a culture has been started, the only labor involved is the preparation and filling of a food reservoir twice a week.

It is hoped that this system can also be used to maintain breeding *Artemia* as a source of cysts.

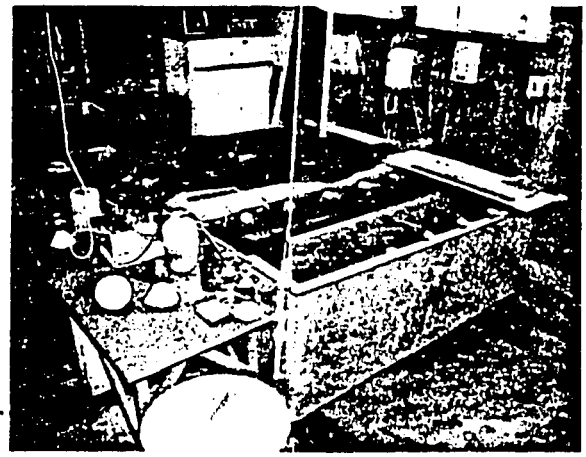


Fig. 3 Artemia culture tanks depicting semi-static raceways.

Invertebrate Separator
C. Paulsen, C. Pelton

Refinements have been made on the separator system used to harvest invertebrate animals from ponds for use as larval food. This system has submersed lights and pumps to attract and collect invertebrates which are then sorted according to size. Experiments using different light wavelengths at the same intensity show that these invertebrates are differentially attracted to colored lights. It was determined that only an isopod (*Paradynamena)* is attracted toward a red light of 635 nm wavelength. Phototropism becomes progressively more positive as the wavelength decreases, peaking at a green color of about 565 nm.

A beam of light focused on the pump intake was also found to attract more organisms than a spot-type light source of the same intensity and wavelength. Combining these findings in the separator system has increased its efficiency as a source of food for larval fish.

Another prototype invertebrate separator has been developed using solar-generated electricity to power the system (Fig. 4). It does not require any additional utilities and consequently can be used to gather food for larval fish in remote pond areas.

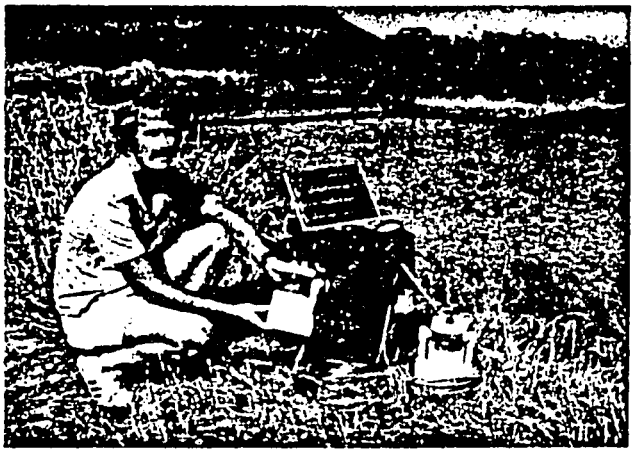


Fig. 4 Solar-powered invertebrate separator prototype.

Larval Fish Production
W. Madden, C. Tamaru

Over 10,000 postlarval mullet were produced during 1976-1977 season. Most of these fish were stocked in four fishponds on Oahu and Hawaii, these being Haena Pond, Keaau, Hawaii island, and three freshwater ponds at Haleiwa, Kualoa, and Waimanalo on Oahu. The remainder are on hand at O.I. to be used for genetic selection of future broodstock.

The most significant success of this past year's rearing was the increased survival rates of the fry. This was accomplished through the identification of some of the factors contributing to the mass mortality of the larvae by gas bladder disease between the second and third weeks after hatching. Specifically, better management of the systems permitted increased survival rates which exceeded 30% (Fig. 5). This was effected by controlling the food densities and by increasing aeration which reduced or eliminated a supersaturated gas condition of the water, resulting from high phytoplankton productivity.

As a result of high larval fish densities in the rearing tanks, feeding of artificial foods after day 30 was possible as a supplement to live *Artemia* nauplii. This was accomplished by the larvae exhibiting intensive and aggressive feeding behavior which was apparently stimulated by the higher numbers of fish. Once accustomed to prepared feeds, the cost and effort required to produce brine shrimp should be substantially reduced.

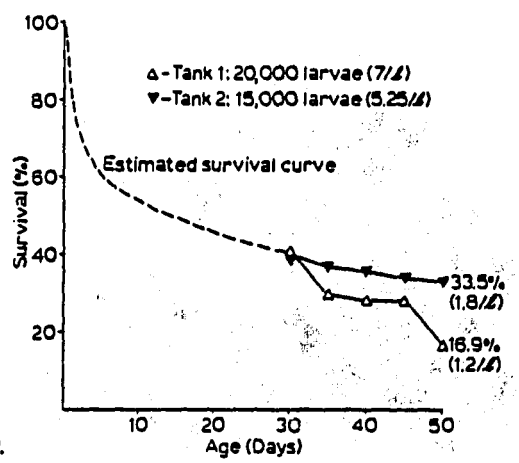


Fig. 5 Survival of grey mullet, 1977 season.

Fish Collection and Fieldwork
W. Madden, C. Tamaru, M. Suiso

Fieldwork on the induced spawning of milkfish at the Lahuipuaa Pond complex on Hawaii was a principal part of this year's work. Three separate trips were made during the summer to capture adult milkfish for injection trials of gonadotropins.

As in previous years, over 60 fish were seined and examined for gonad development. Ripe males and females were placed in pools and injected with crude pituitary extracts from carp and salmon. Induced spawning by hormone injection occurred on June 22 when a female, which had received two injections of crude salmon pituitary mixed with chorionic gonadotropin, began to release eggs in the holding pool. The fish was quickly caught and the eggs expressed into a shallow pan (Fig. 6). Several males were then caught and stripped of their milt in order to fertilize the eggs. Once this was done, the eggs were allowed to stand for 10 minutes and then placed in a clean container and washed with

seawater several times. After washing, the eggs were transferred (Fig. 7) to a large 1,000-liter tank with aeration to incubate. While many of the eggs 1.2 mm in diameter sank and appeared to be infertile, a number remained in the water column undergoing initial cleavage and development. Unfortunately, the eggs did not develop beyond 3 hours after spawning. The probable cause for this was the timing of the stripping relative to the readiness of the eggs. It was determined that the fish had ovulated earlier and had only "dribbled" eggs instead of releasing them enmasse. Thus it is probable that the ovulated eggs were past the critical period when successful development could occur, and that they were "old eggs". Continued efforts to induce these fish to spawn are expected to be successful if sufficient broodstock can be obtained.

Results of the collection this season showed that there were fewer mature fish than in the previous two years. While no reasons for this are known, it is possible that sampling-induced stress contributed to the low levels of gonad production. For this reason and to ensure a continued supply of these fish for future work, nearly 100 subadult and adult fish which had not matured were captured from other ponds and placed in the two best ponds at Lahuipuaa. It is expected that these will mature and be available to continue the injection trials next year.

Fig. 6 Milkfish eggs collected in shallow pan.

Fig. 7 Transfer of eggs by dipnet to incubation tank.

Ornamental Fish Culture
W. Madden, C. Tamaru

A substantial potential exists for ornamental marine fish culture in Hawaii if certain technical constraints can be removed. The most significant technical problem involves obtaining eggs of the species of interest—through induced spawning or otherwise—and rearing the larvae which hatch from these eggs. A research program which would remove these constraints and lead to an industry for culturing ornamental marine fish in Hawaii is desirable and would be an extension of existing culture practices.

An initial project aimed at developing techniques for ornamental marine fish culture was carried out at the Oceanic Institute and the Hawaii Institute of Marine Biology as a coooperative program during 1977. Funding for the work was provided by the office of the Marine Affairs Coordinator for the State of Hawaii.

The project concentrated on five species: *Centropyge potteri* (Potter's angelfish), *Dascyllus albisella* (aio'ilo'i), *Chaetodon miliaris* (lemon butterflyfish), *Abudefduf abdominalis* (maomao), and *Forcipiger flavissimus* (long-nosed butterflyfish). Additional work was done with the triggerfish, *Balistes fuscus.*

The species initially chosen have two distinct spawning modes which we wished to examine. The butterflyfish exhibit pelagic spawning where the eggs are broadcast into the water, fertilized, and allowed to drift while incubating. Laboratory spawning for this group was expected to be unlikely unless induced by injection of pituitary and chorionic gonadotropins. The damselfish, on the other hand, are demersal spawners, laying adhesive eggs in a nest which is guarded by the male parent during incubation. Demersal egg masses of the damselfish, *Abudefduf abdominalis* (the maomao), were collected and the larvae successfully raised. A small number of juveniles were produced as a result and further trials are warranted to develop reliable rearing methods.

Spawning of *Forcipiger flavissimus,* the long-nosed butterflyfish (Fig. 8) was an important success of the program. These desirable aquarium fish were induced to spawn in captivity by a sequence of two injections of Antuitrin S, a gonadotropin, at 2.5 I.U./g. The effect of the gonadotropin is to precipitate the hydration or uptake of water by the eggs and to induce ovulation. When the eggs have hydrated fully, spawning can take place, and this usually occurs within 6-12 hours after the second injection. From earlier work it was determined that injections of hypophysial hormones were effective in inducing ovulation and some egg release when the mean diameter of the eggs was greater than 0.36 mm.

Eggs from each spawning were successfully fertilized and embryonic development, never before observed for this species, was recorded photographically (Fig. 9). As soon as cleavage in the egg was seen, the eggs were transferred to an incubator tank and vigorously aerated. Development was followed hourly and photomicrographs were taken. Development was rapid, with the blastula and gastrulation occurring by the tenth hour. Hatching was completed by 36 hours after fertilization, and the newly hatched larvae were free swimming. Upon hatching, the larva is approximately 1.7 mm long (Fig. 10) and retains a yolk sac with an oil droplet. This food reserve is used up gradually until the third or fourth day, when the eyes become pigmented and the larva is ready to feed.

No larvae survived more than six days (Fig. 11) after hatching; the most likely cause of larval mortality was the unavailability of enough food particles small enough to be consumed by the larvae.

Based on the results of this preliminary project and on assessments of the state of marine fish culture technology, continued efforts are expected to ensure satisfactory control over the culture of these fish.

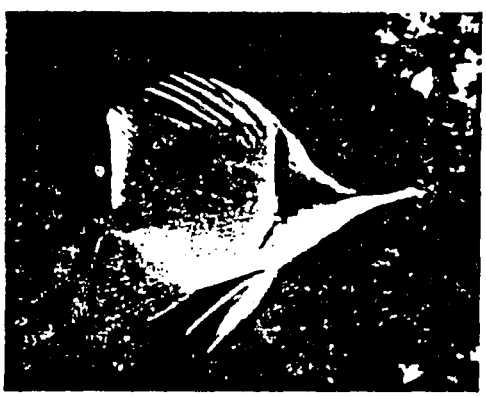


Fig. 8 Adult long-nosed butterflyfish, Forcipiger flavissimus.

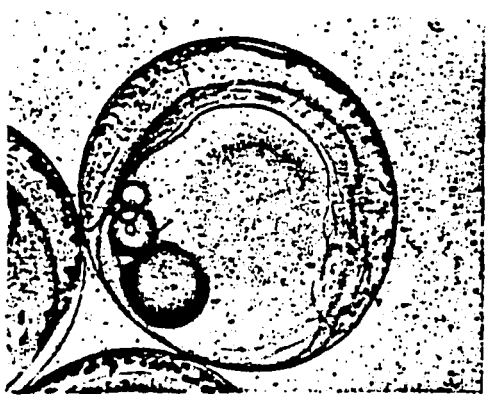


Fig. 9 Butterflyfish embryo in developing egg.

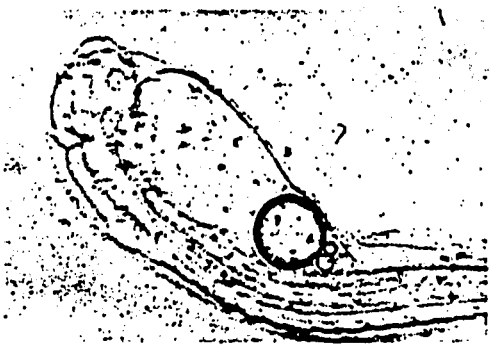


Fig. 10 Newly hatched butterflyfish larva.

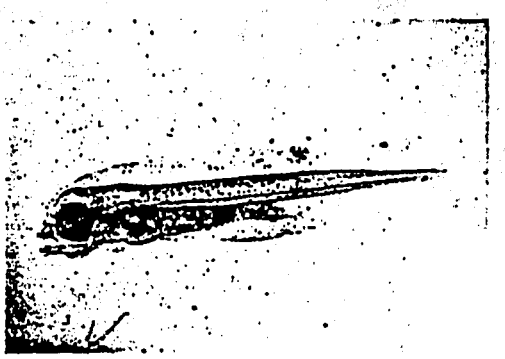


Fig. 11 Six-day-old butterflyfish larva.

Reproductive Physiology
C-M. Kuo and W. Watanabe

Mass propagation of marine fishes has been the ultimate goal of the aquaculture program at the Oceanic Institute. The program has emphasized the control of teleostean reproduction and production of quality seedstock of cultivable marine fish. These objectives have been approached by intensive research in the reproductive physiology, behavior, and ecology of the grey mullet.

The reproductive physiology program has directed its work toward better understanding of fish physiology and the related problems by investigating (1) the processes and mechanisms involved in the gonadal maturation and ovulation, (2) influences of exogenous hormones on eggs, (3) substitution of gonadotropic hormones for induced spawning under controlled conditions, (4) possible use of prostaglandins as an ovulatory agent, (5) circadian rhythm of oocyte responses to exogenous gonadotropins and prostaglandins, (6) osmotic regulation of oocytes during the preovulatory hydration period, (7) physiological causes of larval mortality, (8) preferential physical conditions for embryonic development, and (9) preparation of piscine pituitary gonadotropin. These research activities have aimed to improve continuously the induced-breeding and larval-rearing methods (Figs. 12 and 13).

Fig. 12 Examination of the sex and maturity of adult milkfish.

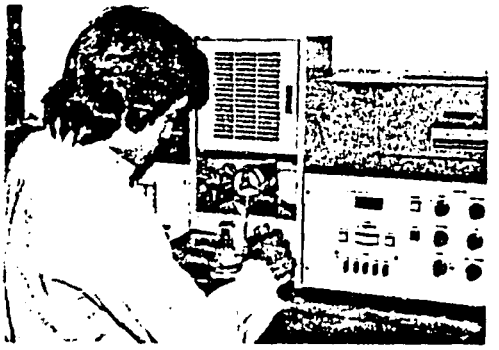


Fig. 13 Analysis of egg quality.

Establishment of a reliable method for inducing spawning and better understanding of physical preferences and nutritional requirements of the grey mullet larvae have led to the readiness for the pilot hatchery. Improvements in the controlled-breeding and larval-rearing techniques have been emphasized in the past years and will continue to be the main goal toward the success of aquaculture programs. The search for the effective triggering agents for gonadal maturation and ovulation, and the most efficient methodology for the artificial propagation of marine fishes, is of continuing interest.

The gonad maturation of the grey mullet has been induced by manipulation of temperature and photoperiod regimes. To date, clomiphene citrate was found to be effective in inducing maturation. The spawnings of these mature females can be induced not only by piscine and mammalian gonadotropins, but prostaglandins are also effective. The presence of prostaglandins in the mature eggs of the grey mullet was further confirmed. The physiological roles of these compounds in fish reproduction are now under investigation.

Circadian rhythm of oocyte responses to gonadotropins and prostaglandins was examined. Effectiveness of the hormone treatment is definitely determined by the endogenous rhythm of oocyte sensitivity to the hormones present. The results were presented to the Symposium of Reproductive Physiology of Fish, held in France, in September 1977. Understanding of this physiological phenomenon will certainly provide basic information needed to develop the most effective and economical induced-spawning method.

The program of artificial propagation of milkfish, supported by the U.S. Agency for International Development, has been continued for the third year. Efforts were continued to investigate the annual cycle of gonadal development, to control the gonadal maturation in captivity, and to induce spawning. The study of the reproductive cycle is completed. The response of the milkfish breeders to hormone treatments was widely variant. Prevention of the mature eggs from atresia, caused by the osmotic and handling stresses, is vital to the success of artificial induction of spawning. This problem has been solved, and the spawnings have been induced by the injections of piscine pituitary homogenate combined with human chorionic gonadotropin.

The limitation on the milkfish breeders available in Hawaii has hampered the progress of the program in the past. The field operation of the program is now in the process of transferring to Christmas Island, where accessible mature milkfish breeders are abundant. The size at sexual maturity of milkfish adults is much smaller and they are mature in the saline lagoons. The problem of the stress causing egg atresia will be solved and the success of the artificial propagation of milkfish is then foreseen.

Marine Pathology
A. Smith and L. Broadgate

Continuing routine autopsies of milkfish from Hawaiian waters has confirmed the impression of a high incidence of a pathological stomach condition, gastritis. In addition, autopsies of milkfish as well as other species continue to strengthen the hypothesis of clotting within the live animals occurring frequently in many disease conditions, and perhaps being a major unsuspected cause of death. Clotting is not a well-studied process in fishes but from the standpoint of fish health, it may be a major factor in whether or not they are able to survive any number and variety of crises (stress, infection, trauma, etc.). Preliminary efforts to develop simple methods to identify the formation and possible propagation of clots in living fishes have been tested and show considerable promise. Diet, to some extent, may be able to control or at least reduce the tendency for clot formation in certain fishes.

The studies in stress have led to the development of a trio of practical tests for detection of early stress. These are (1) the occult hemoglobin test, which can identify nonspecific stress by the presence of trace amounts of hemoglobin in fish skin mucus (and continuing studies may lead to methods of

mass-screening swimming fish for this indicator of stress); (2) the ketone body test, which can identify specific stress due to starvation; and (3) the C-reactive protein (CRP) test, which can detect the specific stress associated with disease. Positive results from any of these tests can alert the fish farmer to a need for corrective action well before irreversible health problems set in.

Identification of sex by external signs is a difficult problem in the milkfish. Unlike some other species, e.g., goldfish and tilapia, there are no apparent external anatomical differences between male and female milkfish. In humans, simple scrapings of surface membranes such as from the mouth cavity reveal sex differences by characteristic patterns of nuclear genetic material in the cells as seen microscopically. This approach, known as exfoliative cytology, was tested in a double blind study of milkfish, goldfish, and tilapia. In none of these species did the results show definite differences between the sexes. However, the cell preparations were excellent and exfoliative cytology has not been used extensively in fishes. Therefore, other possible research using this method is under consideration. For external identification of sex in milkfish, a hormone test using skin mucus will be evaluated next.

The field of immunology has become a major one in recent years, and allergy may play a bigger role in the marine environment than has been previously realized. Basic research and applications have gone hand in hand as rarely seen before. Work on the common Hawaiian sea cucumber, *Holothuria cinerascens*, has revealed the first allergy-type reactions reported for an invertebrate. These animals also, like humans, appear to be able to be desensitized, but much more rapidly. It is hypothesized that this capability for rapid desensitization is an adaptation to minimize tissue reactions from the many symbiotic animals that they frequently harbor. Other studies in the immunology-allergy area have led to: (1) A hypothesis linking in evolution certain pharyngeal structures (Polian vesicles) in the sea cucumber to organs of defense against disease (e.g., lymph nodes) in the higher vertebrates, including man. (2) The identification of naturally occurring substances from invertebrates that behave like antibodies in producing precipitation reactions with foreign proteins, but appear to differ in the type of proteins with which they react. These invertebrate reacting substances are being "packaged" to place them in a convenient form for large-scale pathology and biological studies. It is hoped that these substances will be able to discriminate between normal and cancerous cells, and generally resolve differences not otherwise possible or done as well by antibodies. Their use has already been applied to discriminate fine biochemical genetic differences between fish of the same species. (3) The identification of allergy-like reactions in fishes, with mucus substances from some likely to disrupt the red cells of others in the same tank (Fig. 14). In the figure are shown mixtures of red cells and skin mucus that were prepared on microscope slides: "A" reveals a powerful clumping and destruction of the red cells (central dark mass with radiating, branched strands) from a milkfish, *Chanos chanos*, after mixing with mucus from a snapper, *Lutianus fulvus*. The reaction was rapid, occurring within a few seconds. "B" shows two negative reactions of red cells with mucus from other individuals of these same species. Here, the red cells simply remain dispersed, the crystallin patterns being an effect of drying. Reactions between red cells and mucus occurring in the live fish could conceivably result in anemia and weakness. Such debilitated fish might also be the first to develop disease which, once

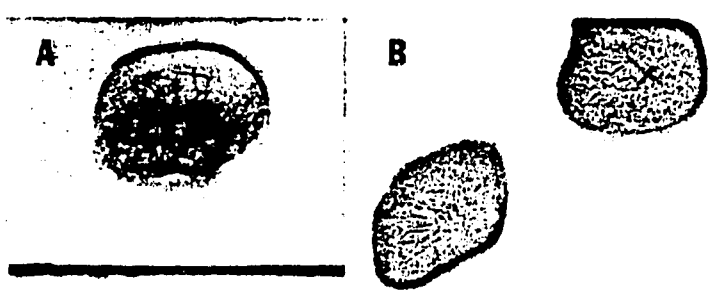


Fig. 14 Reactions of fish red blood cells with skin mucus.

established, may then spread to others in the tank. This phenomenon probably has an immunologic (allergic) basis; its significance to aquaculture and a possible simple preventive are described in a recently published paper.

Proteins of the eye lens core, because of their extreme inertness and other advantages, have found much practical use as genetic markers. Since those in the middle of the lens core are deposited earliest in development and the proteins in the outer layers deposited later, it seemed possible that the former proteins might also be phylogenetically older. Studies to test this hypothesis were carried out on yellowfin tuna and skipjack tuna, the latter being a more primitive species. In both tunas, electrophoretic patterns of the proteins from deeper lens core layers were simpler and more alike (= protein pattern of a common ancestor?); the patterns from progressively more superficial layers showed increasing species specificity.

A number of studies were conducted during the summer with two visiting scientists, Dr. Michael C. Mix of Oregon State University, Corvallis, and Dr. Franklin Ramos of Hilo College, Hawaii. Dr. Mix is a specialist in mollusks, so these animals were used extensively in the research. The possibility that bivalves have different blood types was explored, and no evidence for this was found. An attempt was made to develop a method for collecting and concentrating the low numbers of hemocytes (blood cells) of mollusks by adapting a filtration technique from the medical field. Some progress was made with this technology, but it will require further research to become operational. The last project with Dr. Mix involved developing an optimal extracting fluid for bivalve adductor muscle proteins. This effort was successful, and the extracting fluid was used to produce high-quality electrophoretic patterns of adductor muscle proteins from Hawaiian and northwestern mainland bivalve species. With the development of this extracting fluid and its use in conjuction with electrophoresis, a great range of biological studies (genetic, taxonomic, physiological, environmental) on bivalve mollusks can now more effectively be carried out.

Dr. Ramos is a psychologist/psychobiologist, so the research emphasis was on projects within these areas. A classical experiment in psychology was the demonstration that hyperphagia (overeating) could be experimentally produced in laboratory mammals by administration of gold thioglucose. This substance is selectively concentrated in the appetite-suppression center of the hypothalamus of the brain and destroys this site. Animals so treated have been known to increase their body weight as much as 300%. With a view toward producing increased weight at an accelerated rate in fishes, gold thioglucose was administered to tilapia. The result was hypophagia, or a decrease in eating and, consequently, weight loss, contrasting with the findings in mammals. Toward the end of this experiment, a publication by Canadian workers appeared which reported similar results in goldfish as were found in tilapia. Why and how gold thioglucose produces hypophagia in fishes is currently under investigation. A second experiment was to produce a biochemical or immunological image of the brain. Various studies have indicated that chemical boundaries do not always follow obvious anatomical boundaries; special techniques are, therefore, required to visualize the biochemical architecture of the brain. In this experiment, brain slices were applied to a plastic membrane impregnated with whole brain antiserum. In this way, a biochemical map, or "immunogram", of the brain structures developed on the basis of sites of concentration of reacting antigens. Such information could lead to methods of modifying various behavioral traits, e.g., aggression, eating, reproduction, etc., and nonsurgically destroying areas of brain that are diseased, as with a tumor. The final project with Dr. Ramos was to develop the CRP test mentioned earlier as an indicator of stress specifically associated with the onset of a disease process. The test was adapted from a commercial kit used in human medicine. It was evaluated in tilapia with induced areas of inflammation and necrosis, which are the hallmarks of disease and primarily responsible for the elevated levels of CRP.

Dr. Ramos was supported in his research by a Jessie Smith Noyes Fellowship.

David Coleman, a Sea Grant intern and candidate for a Master's degree from the University of Hawaii, carried out directed research in pathology during the winter months. He was also supported by a Jessie Smith Noyes Fellowship.

Marine Engineering
G. Rothwell, R. Koningsberger, S. Ribakoff, M. Hites

During 1977 planning work was completed for a finfish hatchery to be built on the Institute campus. Documents prepared included a lengthy Project Definition Statement. Environmental Impact Assessment, Construction Plans and Specifications. All required permits have been obtained. This work was done under a contract with the State of Hawaii Division of Fish and Game, the responsible agency for coordinating the State's contribution to the project. The hatchery complex, utilizing and expanding a partly completed building on the Institute campus, will house research facilities, a classroom, and a general-purpose hatchery capable of producing at least a million 50-day fry of any of several species of brackishwater and marine fish of interest to aquaculture. The construction of the hatchery is expected to begin in 1978, with funding from the State and private sources.

In conjunction with the hatchery development, the Institute has completed four new one-eighth-acre (0.05 hectare) experimental ponds, equipped with fresh and saltwater supply, plus discharge gates designed to control water level and circulation, recover and hold finfish, or harvest marine shrimp. With all accessories, these ponds cost $40,000, provided through the generosity of several private Hawaiian foundations. These ponds will be a very important addition to the Institute's facilities in support of both finfish and marine shrimp breeding and growout programs (Fig. 15).

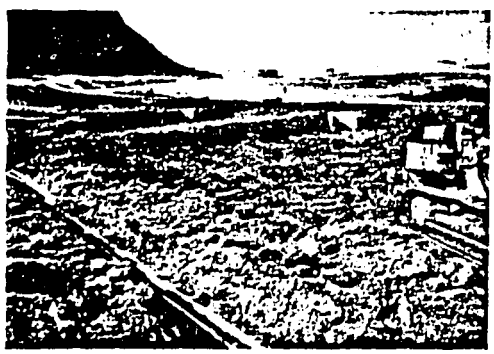


Fig. 15 Saltwater/brackishwater unlined ponds (each is 0.05 Ha.) can be filled and drained independently, and can hold shrimp or finfish juveniles or adults.

The second year of the Sea Cage Project has been successfully completed under the sponsorship of the National Sea Grant Program and the Charles E. Culpeper Foundation of New York. The goal of this project is to develop a technology for cage culture of marine fish in areas of rough water, and to derive criteria for the design of commercial marine aquaculture systems. During this year, the investigation was moved into the sea with an intermediate-sized array of floating, flexible net pen enclosures, each with a volume of 30 m^3 (Fig. 16), and a rigid metal and plastic bottom-located cage

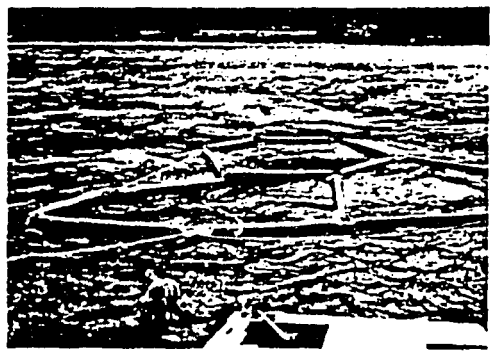


Fig. 16 Flexible float arrangement allows this net pen array to experience large seas without damage.

of 60 m^3 volume (Figs. 17 and 18). These enclosures were stocked with carangid fish (three species of *papio*) and feeding and harvesting methods were investigated. At the same time biofouling and durability observations were made on the arrays. Results were very encouraging. The enclosures withstood periods of rough water very well, with only minor damage to the floating array during a storm, in which no fish were lost. Feeding and harvesting methods for the bottom-located cage were worked

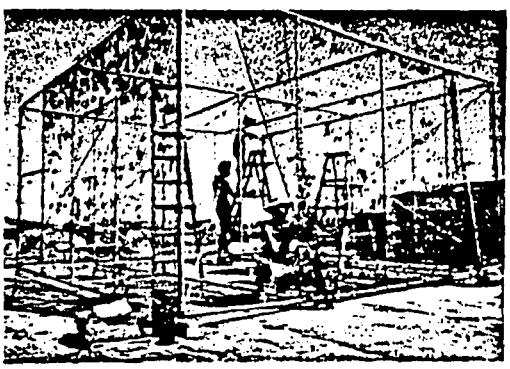


Fig. 17 Rigid bottom-located cage being assembled. White tubes are floodable buoyancy tanks for delivering cage to its ocean site.

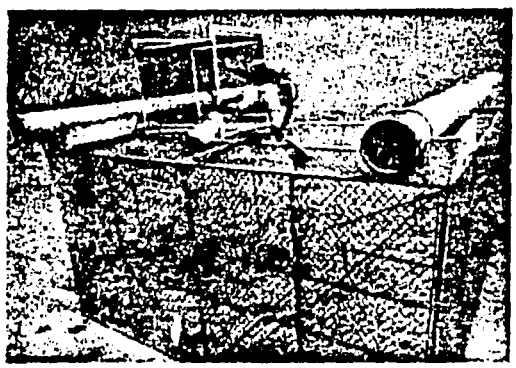


Fig. 18 Rigid cage on site in 30 ft. of water. Small cage on top is harvesting chamber.

out. Feeding by a buoyed hose from the surface proved fully feasible and efficient (Fig. 19), while use of feeding response of the fish to attract them into a harvesting trap proved workable. Trials are now underway with 100 *papio* in a 12,000-liter tank on shore to determine the optimum shape and dimensions of the feeding chamber for attraction, capture and sorting of fish at the stage where they are ready for market. Funding for the coming year has been approved. During 1978 several lines of investigation will be pursued, including deployment and stocking of larger sea cages and experiments with improved feeding and harvesting gear.

Fig. 19 Caged carangids take readily to a diet of chopped herring delivered from the ocean surface through a base.

The Institute has for several years conducted an ongoing mullet-breeding and larval-rearing program, which has led to the accumulation of much practical experience in animal husbandry and hatchery techniques at the laboratory level. Last spring, the engineering group took on the task of codifying and organizing this experience, under a contract with the International Center for Living Aquatic Resource Management. All available data were compiled through interviews with staff members, by observation and measurement of current methods, and by consulting past records. The resulting materials were carefully analyzed, engineering quantities were extracted, and hatchery design criteria were formulated. The result was a draft of a four-part book comprising (1) History of Mullet Culture, (2) Mullet Biology and Physiology, (3) Manual on Hatchery Techniques, and (4) Hatchery Design, Sizing, and Siting.

Environmental Consulting
G. Rothwell, R. Koningsberger

During this year, final plans and specifications were approved by the State Division of Harbors for the small boat launching facility at Mala, Maui. This project involved site studies, a concept plan, an Environmental Impact Statement, and construction plans and specifications for a $350,000 facility, conceived as an environmentally sound way to relieve the use pressures on the existing Lahaina boat harbor nearby.

Early in 1977, the engineering group prepared and submitted to the Department of the Interior an unsolicited proposal to perform environmental consulting services in Palau, Western Carolines District, Trust Territory of the Pacific, in connection with the possible development of a major seaport there (Fig. 20). Palau has an almost undisturbed natural aquatic biota of great richness, which makes the notion of a major port development there highly controversial. During the year, substantial changes have occurred in the political situation respecting Palau, both in Washington and in the negotiations now underway to end the U.N. Trust. Guy Rothwell went to Palau in September, and while there had an opportunity to visit the more promising sites for such a development. As a result of that trip, a revised proposal was submitted to the Palau Legislature, which is under consideration at this time. If awarded, the contract will call for intensive surveys of at least two harbor sites by a team of experts, many of whom will be recruited from other institutions to augment the Institute staff, and preparation of preliminary environmental evaluations. The work will extend over 12 to 15 months.

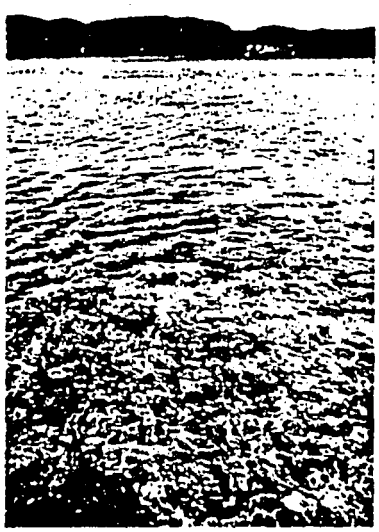


Fig. 20 View across Malakal Harbor, Palau. Even in the harbor, the water is clear and marine life abounds.

MARS Development and Evaluation
P. Bienfang, G. Rothwell, W. Johnson

As a complement to laboratory research on the sinking rates of phytoplankton, Oceanic Institute personnel have developed an instrument called MARS (Multichannel Assembly for Radioplankton Sinking) which enables researchers to measure the sinking rates of natural assemblages of phytoplankton in the open ocean. This instrument detects "labeled" phytoplankton cells which have metabolically absorbed radioactive carbon and is able to register biomass changes with the high sensitivity necessary for studies in the open ocean environment where phytoplankton concentrations are naturally very low.

A grant from the National Science Foundation supports the research program concentrating on development and evaluation of various methodological aspects of the MARS technique. These investigations include laboratory studies with a variety of labeled phytoplankton cultures as well as experiments at sea with MARS capabilities being tested for shipboard use (Fig. 21). It was necessary to develop highly efficient gimbal components in order to dampen ship motion and vibrations since the MARS technique involves the layered introduction of a phytoplankton sample to the surface of a stable seawater column. Cells sink at their own rate to the bottom of the chamber where beta particles emitted by the cells are detected by a Geiger-Müller type assembly and counted by a microcomputer. An important aspect of the development of this technique is a theoretical framework which allows us to deal with the data accurately and in a way that will be meaningful to other investigators in this field. Further research objectives include continued instrument refinements and an evaluation of the MARS experimental environment and its influence on the sinking behavior of test populations.

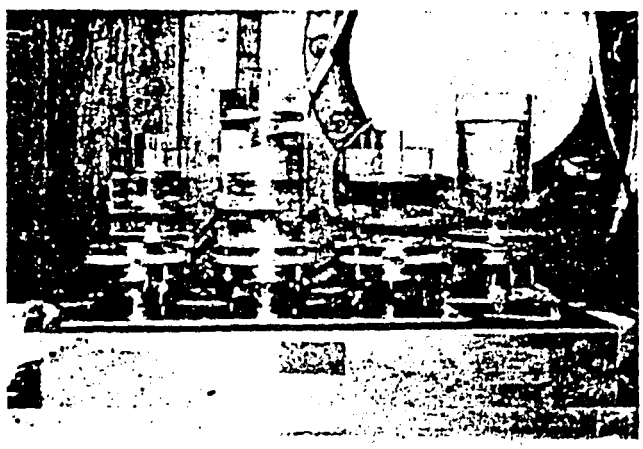


Fig. 21 MARS assembly and gimbal aboard ship.

Thermal Pollution Research
P. Bienfang, W. Johnson

Institute personnel have completed a two-year study, funded by the Hawaiian Electric Company, to determine the effects of thermal pollution on the suspended plants (phytoplankton) in the coastal waters. The photosynthetic activity of phytoplankton provides the primary source of food for higher organisms and any circumstances which influence the phytoplankton may in turn affect the entire marine ecosystem.

The fieldwork was conducted near Waianae at the Kahe Power Plant where seawater is drawn in to cool the condensers and then discharged off the coast. After a residence time of four minutes in the generating facility, an average temperature increase of about 5° C occurs. Changes in biomass and production rates of the phytoplankton were measured during various climatic conditions in the

incoming waters and again after traveling through the power plant. Laboratory experiments were conducted under controlled conditions where the effects of abrupt temperature increases could be investigated without the added variables of pressure or mechanical stress which occur when the microscopic plants are drawn through the generating facility. Field and laboratory data show that exposure to this type of thermal pollution has a rather small effect on phytoplankton biomass. The rate at which phytoplankton may grow and thus produce food does decrease, however, by about 30% immediately after thermal elevation, indicating that the phytoplankton are stressed or shocked but not killed by passage through the power plant. Time sequence experiments suggest that the phytoplankton are able to recover from this stress and original (preentrainment) productivity levels may be attained by seven to eight hours after thermal shock.

Research on the Nutritional Control of Phytoplankton Buoyancy
P. Bienfang, W. Johnson

Work has been completed on a project, funded by the National Science Foundation, to study the biological factors involved with the sinking rates of phytoplankton. These microscopic cells are slightly more dense than the seawater in which they exist so they tend to sink slowly through the ocean. The resulting vertical distribution of phytoplankton is an important factor in the function of marine food webs which are supported by the photosynthetic activity of phytoplankton.

Extensive laboratory investigations were conducted with several different species of phytoplankton which were grown using continuous culture techniques (Fig. 22) with a wide range of controlled nutrient inputs and growth rates. Using a modification of techniques found in the literature, phytoplankton samples were taken from the large growth chambers and poured into specially designed cuvettes which are used in a fluorometer (Fig. 23). This instrument is able to detect the presence of fluorescent material (chlorophyll) and as the cells sink to the bottom, darkened region of

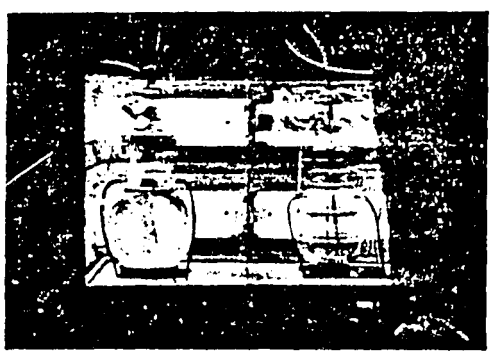


Fig. 22 Continuous culture apparatus.

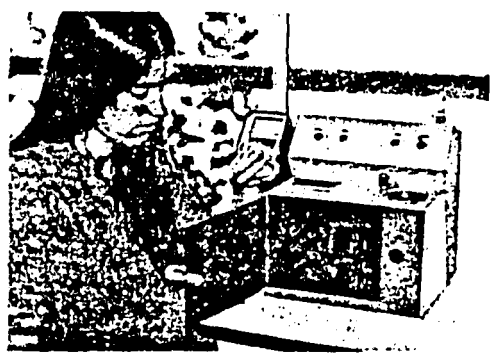


Fig. 23 Fluorometer and cuvette used in sinking rate determinations.

the cuvette, the fluorometer registers a gradual loss of fluorescence which is then used to calculate the mean sinking rate of the phytoplankton population. These experiments yielded results indicating that sinking rates are approximately 10 times slower (.03 - .5 m/day) than had been estimated by other researchers who made measurements only on cells grown in batch culture. We found that the uniform characteristics of phytoplankton populations with a constant growth rate and our revised method of interpreting fluorometric data give a more accurate representation of phytoplankton buoyancy response.

Generally sinking rates do not vary greatly at different growth rates or as a result of varied nutrient inputs. The most pronounced changes in sinking rates occur on a daily cycle with the highest sinking rates at the end of the dark period and the lowest ones at the end of the light period. Further experiments with cells which had been removed from the continuous culture regime and had no fresh nutrient inputs for as long as two weeks also showed a diel buoyancy response, indicating that the physiological control of sinking rates is related to a basal metabolic function.

Gas Chromatography
W. Johnson, P. Bienfang

The analytical capabilities of the Oceanic Institute are being used to assist the Naval Ocean Systems Center in the study of short- and long-term effects of petroleum products on marine communities. Their research involves the introduction of diesel fuel #2 and/or crude oil to a flow-through tank simulating natural conditions and containing semitropical assemblages of marine organisms. The effects of this hydrocarbon stress will be monitored for various time periods by various techniques. One of these is the quantitative analysis for oil in tissue, sediment, and water samples by gas chromatography. The Oceanic Institute possesses a Hewlett Packard 5710A gas chromatograph and integrator suitable for the required analysis and the staff will conduct hydrocarbon concentration determinations on extracted samples provided by the Naval Ocean Systems Center according to their specifications.

Kaunakakai Water Quality
P. Bienfang, W. Johnson

Oceanic Institute staff participated in the Kaunakakai Baseline Environmental Study conducted by Hawaii Planning Design Research for the U.S. Army Corps of Engineers. We provided baseline water quality information which was needed to describe the site of the projected Kaunakakai Deep Draft Harbor and to assess the possible effects of this project on the marine environment. Physical oceanography and fish and coral inventories of the area were investigated by other consultants.

The water quality study included pH, nitrate, total phosphorous, dissolved solids, and chlorophyll determinations as well as bacteriology sampling at several stations in the area of the proposed project. Within the existing Kaunakakai wharf area proper, water quality conforms to the criteria set for class B waters on the basis of requirements set by chapter 37-A of the Department of Health water quality standards. By the same standards, waters adjacent to the wharf area conform to criteria established for class A or AA coastal waters.

Anaehoomalu Ponds Study
P. Bienfang, W. Johnson, W. Madden

A comprehensive survey of anchialine ponds at Anaehoomalu on the island of Hawaii was conducted last summer for Boise Cascade. These ponds occur in shallow depressions and fissures along the flat lava coastline and their slightly saline waters communicate and mix underground. Twelve ponds in the area are to be filled for construction of a resort complex and 50 other ponds were studied in order to establish predevelopment conditions and provide a framework for assessing any direct or indirect impacts on this unique environment. During the field survey a photograph was taken of each pond at high and low tide (Fig. 24) and size and depth data were recorded while surrounding vegetation and aquatic organisms were identified and enumerated. Water quality parameters including temperature, salinity, nitrate, phosphate, ammonium, and dissolved oxygen concentrations were determined for each pond at high and low tide. The water chemistry measurements show relatively high concentrations of nutrients which are typical of groundwater nutrient levels and the pond biota is found to be characterized by low species diversity. Daily flushing of the ponds' water volume is caused by tidal forces affecting the groundwater sources and may serve to control diurnal temperature and salinity ranges within the ponds while maintaining extreme water clarity. The data collected in this study will be used as a baseline for further investigations of the ponds at Anaehoomalu.

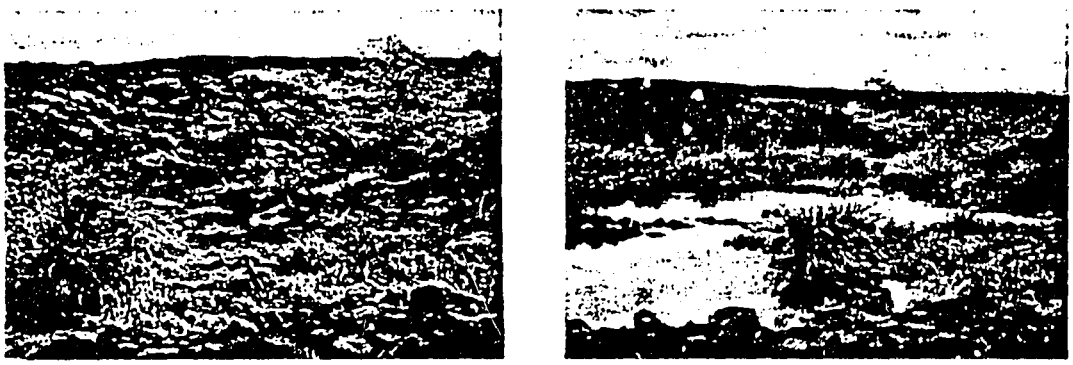


Fig. 24 Low- and high-tide views of one of Anaehoomalu ponds.

PUBLICATIONS — 1977

Bienfang, P.K. Water quality characteristics of Honokohau Harbor: A subtropical embayment affected by groundwater intrusion. Pac. Sci. In press

Bienfang, P.K. and K. Gundersen (1977) Light effects on nutrient-limited, oceanic primary production. Mar. Biol. 43:187-199.

Bienfang, P.K. and W. Johnson. Planktonic properties of Honokohau Harbor, a nutrient-enriched subtropical embayment. Pac. Sci. In press.

Bienfang, P.K., E. Laws, and W. Johnson. Phytoplankton sinking rate determination: technical and theoretical aspects, an improved methodology. Exp. Mar. Biol. Ecol. In press.

Combs, E.R., R.D. Mayo, and C.E. Nash (1977) A preliminary physical and economic description of a Pacific salmon hatchery in southern Chile. Proc. World Maric. Soc., San Jose, Costa Rica, January. In press.

Hanson, J.A. (1977) Towards an ecologically-based economic philosophy. Environmental Conservation 4(1):3-10.

Hanson, J.A. and H.L. Goodwin (eds.) (1977) Shrimp and Prawn Farming in the Western Hemisphere. Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pennsylvania. 439 pp.

Kuo, C-M. and W. Watanabe. Circadian responses of teleostean oocytes to gonadotropins and prostaglandins, determined by cyclic AMP concentration. Ann. biol. anim. Bioch. Biophys. In press.

Madden, W.D. and C.L. Paulsen (1977) The potential for mullet and milkfish culture in Hawaiian fishponds. State of Hawaii Department of Planning and Economic Development, February. 54 pp.

Nash, C.E. (1977) Ocean ranching: the achievements, the problems and the possibilities. Fish Farming International 4(3):42-48, September.

Nash, C.E., C-M. Kuo, W.D. Madden, and C.L. Paulsen (1977) Swim bladder inflation and survival of *Mugil cephalus* to 50 days. Aquaculture 12:89-94.

Paulsen, C.L. (1977) Apparatus for collection and separation of invertebrate organisms from a pond, for use as fish food. Progr. Fish-Culturist 39(2):101-102.

Ramos, F. and A.C. Smith. Ketone bodies in fish skin mucus as an indicator of starvation. J. Fish Biol. In press.

Ribakoff, S.B. and C.M. Pelton (1977) Development of a solid-state environmental controller for aquaculture systems (SECAS). Progr. Fish-Culturist 39(3):109-111

Smith, A.C. (1977) Reactions of fish red blood cells with mucus and sera from other fish(es). Calif. Fish Game, 63(1):52-57.

Smith, A.C. (1977) Immunologic reactions of the sea cucumber, *Holothuria cinerascens*, to serum from the milkfish, *Chanos chanos*. J. Invertebr. Pathol. 29(3):326-331.

Smith, A.C. Hypersensitivity and desensitization in the sea cucumber, *Holothuria cinerascens*. Developmental and Comparative Immunology. In press.

Smith, A.C. Pathology and biochemical genetic variation in the milkfish, *Chanos chanos*. J. Fish Biol. In press.

Smith, A.C. A proposed phylogenetic relationship between sea cucumber Polian vesicles and the vertebrate lymphoreticular system. J. Invertebr. Pathol. In press.

Smith, A.C. and M.C. Mix. The effects of sodium chloride concentration on electrophoretic patterns of adductor muscle proteins from bivalve mollusks. Comp. Biochem. & Physiol. In press.

PROJECT REPORTS AND PAPERS — 1977

Bienfang, P.K. Nutritional control of phytoplankton sinking rates. Ph.D. dissertation, University of Hawaii, Honolulu, December. 137 pp.

Bienfang, P.K. A summary of phytoplankton response to entrainment through the Kahe power generating facility, Kahe Point, Oahu, Hawaii. Report for: The Hawaiian Electric Company. 65 pp.

Bienfang, P.K. Survey of the aquatic biota and water quality characteristics of the anchialine ponds at Anaehoomalu, Hawaii. Report for: Boise Cascade. 151 pp.

Bienfang, P.K. Water quality of Kaunakakai, Molokai. In: Marine Environment and Water Quality Surveys at Kaunakakai, Molokai, Hawaii. Hawaii Planning Design Research. 90 pp.

Bienfang, P.K. Survey of the biological properties in the water column off Ke-ahole Point, Hawaii. Report for: Department of Ocean Engineering, University of Hawaii. 15 pp.

Bienfang, P.K. and W. Johnson. Nutritional control of phytoplankton sinking rates. I. The effects of specific growth rates, limiting substrate, and diel periodicity. Submitted to Limnol. Oceanogr.

Bienfang, P.K. and W. Johnson. Nutritional control of phytoplankton sinking rates. II. Effects of progressive nutrient impoverishment. Submitted to Limnol. Oceanogr.

Carrillo, M., S. Zanuy, C-M. Kuo, and W. O. Watanabe. Daily endocrine and biochemical rhythms observed in *Tilapia mossambica* adapted to long and short photoperiod regimes. Paper presented to the Ninth Conference of European Comparative Endocrinologists, Giessen, Germany, August.

ICLARM Report on Mullet Breeding and Larval Rearing Techniques, May.

Kuo, C-M. and W.O. Watanabe. Circadian responses of teleostean oocytes to gonadotropins and prostaglandins, determined by cyclic AMP concentration. Paper presented to the Symposium of Reproductive Physiology of Fish, Paimpont, France, September.

Nash, C.E. The breeding and cultivation of marine fish species for mariculture. Paper presented to International Council for the Exploration of the Sea, Brest, France, May.

Nash, C.E. Ocean ranching and fisheries management. Paper presented to International Council for the Exploration of the Sea, Reykjavik, Iceland, September.

Ramos, F. and A.C. Smith. The C-reactive protein (CRP) test for the detection of early disease in fishes. Submitted to Aquaculture.

Rothwell, G.N. Project definitions report for a finfish hatchery. Prepared for the Chairman, Board of Land and Natural Resources, State of Hawaii, June.

Rothwell, G.N. Preliminary plans and specifications for a finfish hatchery. Prepared for the Chairman, Board of Land and Natural Resources, State of Hawaii, September.

Rothwell, G.N. Environmental aspects of site selection. Prepared for the Special Committee on Palau Port Authority, Palau Legislature, September.

Rothwell, G.N. and C.E. Nash. Aquaculture in tropical oceans — Year 01. National Sea Grant Program, January.

Smith, A.C. Formation of specific binding activity in fish lens protein. Submitted to Ophthalmic Research.

The Oceanic Institute Marine Science Award — 1977

Joel Yuen of McKinley High School was the winner of the Institute's 1977 trophy in the Zoology Division at the 20th Hawaiian Science and Engineering Fair. The title of his project was "The Utilization of *Zooxanthellae* Photosynthate in the Development of the Coral *P. damicornis*."

FINANCIAL SUMMARY — 1977

The following statement of revenues and expenditures is made on an accrual basis and shows an excess of revenues over expenditures of $41,941. Included in the statement is the final sum of $80,000 of the operating fees from Sea Life, Inc., which were prepaid in 1972 for six years as part of the reorganization agreement. As these advance payments were used to settle the accounts at that time, there has been no cash available from this source for the last six years. On an accrual basis, however, it was necessary to include them in revenues in the years for which they were prepaid. 1977 was the last year of this financial adjustment.

Revenues and Expenditures (Accrual Basis)

(Unaudited)

	1977	1976
REVENUES EARNED		
Research grants and contracts	$640,576	$589,573
Unrestricted gifts and contributions	46,595	176,746
Operating fees (sublease to Sea Life, Inc.)	128,283	121,347
Interest and miscellaneous	19,770	24,393
Total	$835,224	$912,059
EXPENDITURES		
Administration	$119,565	$143,367
Scientific/technical direct expenses	474,773	486,879
General (including indirect expenses and support of scientific work, landscaping and improvements)	198,945	174,004
Total	$793,283	$804,250
Excess Revenues over Expenditures	$ 41,941	$107,809

Contributions Received — 1977

INDIVIDUALS

Mr. & Mrs. Page Anderson
William E. Aull
Lawrence S. Berger
Paul Bienfang (in kind)
Mr. & Mrs. Edward Brennan
Howard Butcher III
Mr. & Mrs. Samuel A. Cooke
Mr. & Mrs. Herbert C. Cornuelle
Mr. & Mrs. Jim Deane
Tilghman Boyd Evans
Dean A. Eyre, Jr.
Marshall Field
George E. Freitas
Mr. & Mrs. Howard H. Hamamoto
General Hunter Harris, Jr.
Mr. & Mrs. Herbert D. Hart
Mr. & Mrs. Thomas P. Huber
Mr. & Mrs. Andrew T.F. Ing
Mr. & Mrs. Davis G. Juell
Malcolm MacNaughton
W.C. Morris (in kind)
Robert C. Oshiro
Mr. & Mrs. A.J. Ostheimer
John Peacock
Charles J. Pietsch, Jr.
David T. Pietsch
Mr. & Mrs. R.W. Power
Mr. & Mrs. R.H. Rath
Nancy Roberts (in kind)
Willis H. Sanburn
F.A. Schaefer III
Mr. & Mrs. C. Frederick Schutte
Mr. & Mrs. William W. Sellew
Charles C. Spalding
Dr. & Mrs. H. Burr Steinbach
George W. Sumner, Jr.
Nadine V. Taylor
Henry A. Walker, Jr.
Mun Charn Wong

Total Individual Contributions $11,682

TRUSTS AND FOUNDATIONS

Amfac Foundation	$ 100
Alexander S. Atherton Trust (in kind)	763
Cyjo Foundation, Inc.	350
Hawaii Newspaper Agency Charities	2,000
Chinn Ho Foundation	2,000
F.M. Kirby Foundation, Inc.	1,000
Boyd and Roberta MacNaughton Foundation	95
Arthur Murray Foundation, Inc.	250
Union Oil Company of California Foundation	1,000
C.S. Wo Foundation	225
	$ 7,783

RESTRICTED

Atherton Family Foundation	$ 17,000
Bank of Hawaii	1,725
Samuel N. and Mary Castle Foundation	10,500
Castle & Cooke, Inc.	15,000
Charles M. and Anna C. Cooke, Limited	3,000
Mr. & Mrs. C.M. Cooke	100
Charles E. Culpeper Foundation, Inc.	30,120
Gordon H. Damon	1,000
The Henry L. and Grace Doherty Charitable Foundation, Inc.	50,000
The Charles Engelhard Foundation	5,000
Frear Eleemosynary Trust	1,000
Mr. & Mrs. Bruce P. Harden	500
Hawaii Newspaper Agency Charities	2,225
McInerny Foundation	10,276
Bernice and Conrad von Hamm Foundation	400
Elsie H. Wilcox Foundation	430
G.N. Wilcox Trust	5,000
	$153,276

BUSINESSES

American Savings	$ 500
Anonymous (in kind)	300
E.E. Black, Ltd.	500
C. Brewer and Company, Ltd.	500
Castle & Cooke, Inc.	9,000
Diamond Head Sprinkler Supply	100
Dillingham Corporation	1,000
First Federal Savings & Loan Association of Hawaii	100
First Hawaiian Bank	3,000
Foodland Super Market, Ltd.	1,000
HC&D, Ltd.	200
Hawaiian Electric Company, Inc.	1,000
Hawaiian Trust Company, Limited	500
Hilton Hawaiian Village	50
Holsum (Hawaii) Baking, Inc.	250
Honolulu Advertiser, Inc.	1,000
International Savings & Loan Association, Ltd.	500
J B G Corporation	500
Johnson & Higgins of Hawaii, Inc.	100
Molokai Ranch Ltd.	1,000
Niwa Painting, Inc. (in kind)	1,845
Olsen Tool & Supply Co., Inc. (in kind)	5
Pacific Resources, Inc.	300
QM Productions	100
Sea Life Incorporated	100
Sears, Roebuck and Company	250
Edward D. Sultan Co., Ltd.	500
Tongg Publishing Co., Ltd.	100
	$ 24,300
Total Contributions	$197,041

SCIENTIFIC AND SUPPORT STAFF

Director	Colin E. Nash, Ph.D.
Assistant Director	Robert A. Shleser, Ph.D.
Senior Staff	Paul K. Bienfang, Ph.D. *Biological Oceanography* Ching-Ming Kuo, Ph.D. *Fish Physiology* Guy N. Rothwell, B.A. *Engineering* Albert C. Smith, Ph.D., M.D. *Pathology*
Technical Staff	Linda Broadgate, B.A., Technician David Coleman, B.A., Technician Wendy Johnson, B.S., Technician Rosine M. Koningsberger, M.S., Data Analyst/Programmer (part time) William D. Madden, B.S., Research Assistant Kathleen McGovern, B.A., Technician Craig L. Paulsen, M.S., Research Assistant Stephen B. Ribakoff, M.S., Engineer Shirley Robinson, M.L.S., Librarian (part time) Dorothea Rosinsky, Publications Clyde Tamaru, B.S., Technician Wade O. Watanabe, M.S., Research Assistant

ADMINISTRATIVE STAFF

R.W. Power, B.A., President
Colin E. Nash, Ph.D., Vice President
Nadine V. Taylor, CPA, Controller and Assistant Treasurer
Nancy A. Roberts, B.A., Paymaster and Assistant Secretary
Helen Carroll, B.S., Accounting Clerk (part time)
Shirley Gregory, A.A., Accounting Clerk
Stephen B. Ribakoff, M.S., Maintenance Supervisor
Edward Porter, B.A., Maintenance
Philip D. Parker, Maintenance

mailing address:
THE OCEANIC INSTITUTE
Waimanalo, Hawaii 96795

January 1978

Telephone: (808) 259-7951
Cable address:
OCEANINST