Center for Tropical and Subtropical Aquaculture

1995 Annual Accomplishment Report

December 1, 1995

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Executive Summary

Mission

The Center for Tropical and Subtropical Aquaculture, or CTSA, is one of five regional aquaculture centers funded by the U.S. Department of Agriculture. The mission of CTSA is to support aquaculture research, development, demonstration and extension education to enhance viable and profitable U.S. aquaculture. Research projects span the American Insular Pacific, using its extensive resource base to meet the needs and concerns of the tropical aquaculture industry.

The Center for Tropical and Subtropical Aquaculture is jointly administered by the University of Hawaii and The Oceanic Institute. The Center's offices and staff are located at The Oceanic Institute's Makapu`u Point site on windward Oahu.

Organization

CTSA funds aquaculture research, development and demonstration projects. Each year's program is the result of several groups working together for many months. A Board of Directors oversees the Center's programmatic functions, and an Executive Committee is responsible for the Center's administrative policy and functions.

In addition, CTSA has two working groups. The Industry Advisory Council (IAC) comprises members from financial institutions, aquacultural and agricultural enterprises, government agencies and other business concerns. The Technical Committee (TC) is made up of researchers, extension agents and fisheries officers.

The Board, the IAC and the TC draw their members from American Samoa, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, Guam, Hawaii, the Republic of Belau and the Republic of the Marshall Islands.

Program Scope

The Center has funded 88 projects in its eight years of operation. These projects fall into six categories:

- National Aquaculture Priorities;
- Information Dissemination;
- Extension Support to Further Industry Development;
- Marketing and Economics;
- Development of New Technologies;

- Demonstration and Adaptation of Known Technologies.

A brief listing of the principal accomplishments of the active projects in these categories during 1995 are presented below. Details on each project's funding, participants, objectives, anticipated benefits, progress and future plans are presented in individual sections on each project.

National Aquaculture Priorities

Effluent Discharge Program

Accomplishments

Under the sixth year of this program, investigators prepared a summary of the results from the first five years of work. The summary pointed out that government regulation is a critical limitation to the success of the domestic aquaculture industry, that aquaculture effluent does not negatively affect the environment, and that a comprehensive revision of aquaculture effluent discharge regulations offers an opportunity to develop new methods of resolving environmental issues.

Potential Drugs and Chemotherapeutants for Marine Shrimp Production: Selection, Evaluation and Approval Process

Accomplishments

As a direct result of this project, the U.S. Food and Drug Administration approved the use of formalin to treat penaeid shrimp diseases.

Information Dissemination

Library Aquaculture Workstation

Accomplishments

This project, known as the Pacific Regional Aquaculture Information Service for Education or PRAISE, established remote workstations equipped with modems. From these workstations, users can connect to the information service at the University of Hawaii to perform CD-ROM database searches 24 hours a day. Six remote sites were established in Hawaii and two were established in Guam. In addition, PRAISE entered a cooperative agreement with PEACESAT, a federally funded communications satellite. Under the agreement, residents at five Pacific Island sites can directly access the Aquatic Sciences and Fisheries Abstracts (ASFA) database through an Internet connection between the local PEACESAT station and the mainland vendor. This access method is being tested for one year.

Publications

Accomplishments

This project produced a quarterly newsletter, biannual technical bulletins on each of the Center's active funded projects and a video update on selected projects. In addition, two project reports were published in 1995:

- A Bibliography of Specific Pathogen-Free Organisms; and
- Raising the Silver Arowana (*Osteoglossum bicirrhosum*).

Extension Support to Further Industry Development

Aquaculture Extension and Training Support in the U.S.-Affiliated Pacific Islands

Accomplishments

This project provides extension and training support to aquaculturists and to government fisheries and aquaculture staff throughout the region. This support includes conducting aquaculture training courses at various locations, providing scientific advice to the FSM National Aquaculture Center and other private and public concerns, and assisting with reef surveys and reseeding programs for giant clams, sponges and other species as requested by local authorities.

Expert System Disease Module for Hawaiian Aquaculture

Accomplishments

This project adapted a DOS-based computer software program that was developed under the project's first two years to run in a Microsoft Windows 3.1 environment and on the Macintosh platform. The software program helps farmers to diagnose diseases and syndromes afflicting cultured tilapia.

Gill Discoloration in Penaeus stylirostris

Accomplishments

This project is examining the primary and secondary causes of gill discoloration in market-sized *P. stylirostris* and developing measures to prevent the condition.

Mangrove Crab as a Model for Development of a Quarantine System to Screen Species for Aquaculture in Guam

Accomplishments

This project established an aquatic animal quarantine area at the University of Guam Marine Laboratory, where captured local mangrove crabs will be

examined for pathogens. A list of pathogens found in the animals will be compiled, and the economic feasibility of commercial scale mangrove crab production in Guam will be evaluated.

Disease Management for Hawaiian Aquaculture

Accomplishments

This project is identifying factors that may contribute to the occurrence of bacterial disease during growout of Chinese catfish (*Clarias fuscus*) and developing strategies to control those diseases.

In addition, methods of decontaminating shrimp ponds infected with the IHHN virus are being tested, and groups of imported freshwater tropical fish are being surveyed to document mortality patterns, portray environmental conditions and determine the presence and prevalence of certain protozoan and metazoan parasites and specific bacterial pathogens.

Development of New Technologies

*Development of Threadfin (*Polydactylus sexfilis*) Fry Production Technology*

Accomplishments

This project is developing methods to produce threadfin fry for commercial production. This year's efforts focused on overcoming the high mortality rate of threadfin larvae during the first 15 days after hatching and developing a rearing technology with less than 1 percent mortality per day during the cannibalistic period (Days 25 to 50).

Demonstration and Adaptation of Known Technologies

Commercial Feasibility of Giant Clam Mariculture in American Samoa

Accomplishments

This project established a giant clam culture demonstration station that is used for training, extension and economic feasibility studies. It has also trained local residents in growout culture techniques and established 11 ocean growout nurseries that are owned and managed by local residents. In addition, a marketing study and taste test were conducted to determine the economic feasibility of commercial giant clam culture.

Differential Growth Rate Studies in Cultured Commercial Sponges

Accomplishments

This project is conducting growth comparison studies to improve the production efficiency of commercial sponge culture.

Sponge Aquaculture Demonstration Project

Accomplishments

This project established a demonstration sponge culture farm, trained five local residents in sponge culture techniques and assisted them in starting their own private farms.

Improvement of Tilapia Stocks in Hawaii

Accomplishments

This project is reviewing the international, national and Hawaii state technical and regulatory status of tilapia strains in relation to improvement of the tilapia culture industry in Hawaii. Morphometrics and genetics are being used to assess the status of both farmed and wild tilapia stocks in Hawaii. Growth characteristics of farmed tilapias will be determined and compared with the data in relevant scientific literature. Finally, measures will be recommended either to improve existing stocks or to import new strains or species based on review of the information collected.

Ornamental Aquaculture Technology Transfer

Accomplishments

This project is evaluating the culture potential and production economics of a number of ornamental fish species in Hawaii. In 1995, the project established ornamental fish in commercial production at a number of cooperating commercial aquaculture facilities in Hawaii, began reproducing Amazon Basin fish using reverse osmosis technology and produced an analysis of the feasibility of an ornamental culture business in Hawaii.

Introduction

During 1995, the Center for Tropical and Subtropical Aquaculture completed work on projects funded under its Fifth Annual Plan of Work and continued work on projects funded under its Sixth and Seventh Annual Plans of Work. In addition, the Center initiated work on projects developed under its Eighth Annual Plan of Work and developed its Ninth Annual Plan of Work.

Eleven projects were funded under the Center's eighth year program, which was approved by the Center's Board of Directors on January 18, 1995. Five projects were new, and six were continuations of projects begun under previous years' programs.

One sign of the effectiveness of the Center's program is the willingness of other agencies to provide supplemental funding for projects. During the Center's second through seventh year programs, other agencies provided $2,109,428 in additional support to projects.

The development of the Year Nine program was initiated in March 1995, when the Industry Advisory Council (IAC) met. The IAC reviewed the progress of funded projects and recommended Year Nine research priorities that would aid industry development. Members identified 11 project areas; eight were in new areas, and three were continuations of projects funded under previous years. These were :

1. Disease Management for Hawaiian Aquaculture -- Year Four;
2. Library Aquaculture Workstation -- Year Nine;
3. Aquaculture Extension and Training Support -- Year Eight;
4. Differential Growth Rate Studies in Cultured Commercial Sponges -- Year Four;
5. Improvement of Growth Rates in Cultured Chinese Catfish -- Year Two;
6. Understanding *Gracilaria* Gall Syndrome in Seaweeds -- Year Two;
7. Improvement of Tilapia Stocks in Hawaii -- Year Two: Acquisition of Superior Stocks;
8. Diversification of Species for Aquaculture in Guam -- Year Two;
9. Expansion and Diversification of Freshwater Tropical Fish Culture -- Year One;
10. Development of Pacific Threadfin and Milkfish Growout Technology and Production of Live Feeds -- Year One;
11. Public Policy Impact on Aquaculture Development in Guam -- Year One.

In April 1995, the Technical Committee (TC), acting on the IAC's recommendations, drafted problem statements for new or expanded projects. Those formed the basis for the Preliminary Plan of Work, which was approved by the Board

of Directors in June. The Center staff then solicited proposals for projects, and 11 proposals were submitted.

In September, the Center began its three-month review process. New proposals were first subjected to external peer review by at least three experts in the project topic area; these experts were identified with the assistance of the directors of the other Regional Aquaculture Centers and the U.S.D.A. program administrators. Proposals for both new and continuing projects then underwent review by panels comprising members of the Industry Advisory Council and the Technical Committee. The final version of the proposals will be incorporated into the Ninth Annual Plan of Work, which will be sent to the Center's Board of Directors for approval. Following Board approval, the plan will be submitted to the U.S. Department of Agriculture for final approval.

Since the inception of the Center for Tropical and Subtropical Aquaculture in 1988, it has funded 88 research, demonstration, development and extension projects. Eighteen projects were active during 1995. These projects fall into six categories:

- National Aquaculture Priorities;
- Information Dissemination;
- Extension Support to Further Industry Development;
- Marketing and Economics;
- Development of New Technologies;
- Demonstration and Adaptation of Known Technologies.

Projects addressing national aquaculture priorities comprise:

Aquaculture Effluent Discharge Program;
Potential Drugs and Chemotherapeutants for Marine Shrimp Production.

Projects addressing information dissemination comprise:

Library Aquaculture Workstation;
Publications.

Projects addressing extension support to further industry development comprise:

Aquaculture Extension and Training Support in the U.S.-Affiliated Pacific Islands;
Expert System Disease Module for Hawaiian Aquaculture;
Gill Discoloration in Penaeus stylirostris*;*
Mangrove Crab as a Model for Development of a Quarantine System to Screen Species for Aquaculture in Guam;
Disease Management for Hawaiian Aquaculture.

Projects addressing marketing and economics comprise:

A Market Study of Pacific Giant Clam Products;
Aquaculture Marketing Assistance Program for Guam.

Projects addressing development of new technologies comprise:

Exploratory Study of Hawaii and Guam as High Health Aquaculture Stock Centers;
Investigation of Mullet Net-Pen Stocking Densities in Coastal Fishponds;
*Development of Threadfin (*Polydactylus sexfilis*) Fry Production Technology.*

Projects addressing demonstration and adaptation of known technologies comprise:

Commercial Feasibility of Giant Clam Mariculture in American Samoa;
Differential Growth Rate Studies in Cultured Commercial Sponges;
Improvement of Tilapia Stocks in Hawaii;
Investigation of Mullet Net-Pen Stocking Densities in Coastal Fishponds;
Ornamental Aquaculture Technology Transfer.

Organizational Structure

Title XIV of the Agriculture and Food Act of 1980 and the Food Security Act of 1985 authorized establishment of aquacultural research, development and demonstration centers in the United States (Subtitle L, Sec. 1475[d]) in association with colleges and universities, state departments of agriculture, federal facilities, and non-profit private research institutions.

The five Regional Aquaculture Centers encourage cooperative and collaborative aquaculture research and extension education programs that have regional or national applications. Center programs complement and strengthen existing research and extension educational programs provided by the U.S. Department of Agriculture and by other public institutions. The Centers' objectives are to:

- promote aquaculture research, development and demonstration for the enhancement of viable and profitable commercial aquaculture production in the United States for the benefit of producers, consumers and the American economy;
- utilize the Regional Centers in a national program of cooperative and collaborative research, extension and development activities among public and private institutions having demonstrated capabilities in support of commercial aquaculture in the United States.

Administrative Center

The Center for Tropical and Subtropical Aquaculture Administrative Center is located at The Oceanic Institute, on the island of Oahu in Hawaii. The Administrative Center staff provides all necessary support services for the Executive Committee, the

Board of Directors, the Industry Advisory Council, the Technical Committee, various project review panels and delegations and project work groups. Dr. Kevan L. Main, Center Director, supervises operation of the Center.

Executive Committee

The Executive Committee is the legal entity responsible for the Center's overall administrative policy formulation, budget and procedures. It also appoints the CTSA Director. The members of the Executive Committee are:

- Dr. Paul K. Bienfang, The Oceanic Institute, {Executive Committee Chairman}:
- Dr. Dean Smith, University of Hawaii.

Board of Directors

The Board of Directors is responsible for the development and implementation of the Center's program policy, including concurrence on total budget issues. The Board is also responsible for development of ancillary agreements with other agencies and institutions.

The members of the Board of Directors represent educational, state and non-profit private research institutions throughout the region. The Board of Directors:

- establishes initial guidelines for regional aquaculture research, development and demonstration activities;
- appoints and removes members of the Industry Advisory Council and the Technical Committee;
- approves the proposed strategy for project selection;
- approves the priority areas and goals for industry development identified by the Industry Advisory Council and Technical Committee;
- approves the Annual Plan of Work, including budget allocations;
- approves the Annual Accomplishment Report for consistency with the goals and objectives of CTSA and the authorizing legislation;
- develops ancillary agreements with other institutions.

The members of the Board of Directors are:

- Dr. Jeff Barcinas, College of Agriculture and Life Sciences, University of Guam;
- Dr. Paul K. Bienfang, The Oceanic Institute;
- Mr. John Corbin, Hawaii State Aquaculture Development Program;
- Dr. Charles Helsley, Sea Grant College Program, University of Hawaii;
- Dr. Dean Smith, University of Hawaii, {Board Chairman};
- Ms. Anita Suta, Land Grant Program, College of Micronesia;
- Dr. Harry Yamamoto, Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii.

Industry Advisory Council

Members of the Industry Advisory Council include commercial aquaculture farmers, aquaculture suppliers and members of government bodies and financial institutions. Members are appointed by the Board of Directors for three-year, renewable terms. In the Industry Advisory Council's capacity as an advisory body, it provides an open forum for information exchange from those involved in the aquaculture business. With the approval of the Board of Directors, contributions of the IAC can be incorporated into annual and ongoing plans for CTSA. The Industry Advisory Council:

- recommends research and development needs and priorities from the perspective of the aquaculture industry;
- participates as needed in the review of proposals, project progress reports, program review delegations and other functions of the Center;
- recommends to the Board actions regarding new and continuing proposals, proposal modifications and terminations.

Members of the Industry Advisory Council are:

- Mr. Bo Alexander, Mariculture Research and Training Center, University of Hawaii;
- Mr. David Barclay, Aquatic Culture and Design;
- Mr. David Bigger, Hawaii Aqua Seed;
- Mr. Dennis Bishop, Kona Mariculture;
- Ms. Mary Brooks, Pacific Aquaculture;
- Dr. Linden Burzell, Aquaculture International Inc.;
- Mr. Steve Chaikin, Molokai Sea Farms;
- Mr. Shinji Chibana, Palau Biotech Marine Tropicals;
- Mr. Michael Crisostomo, Kurumaya SeaHorse Restaurant;
- Mr. Richard Croft, Pohnpei Natural Products;
- Mr. Craig Emberson, Makauu Aquafarm;
- Ms. Linda Gusman, Island Aquaculture;
- Mr. Donald Heacock, Hawaii Division of Aquatic Resources;
- Mr. Steve Katase, Royal Hawaiian Sea Farms;
- Mr. Andrew Kuljis, Amorient Aqua Farms;
- Mr. Paul Lister, The Chamber of Commerce of Hawaii;
- Dr. Craig MacDonald, Hawaii State Ocean Resources Development;
- Mr. Jerry B. Norris, Pacific Basin Development Council;
- Mr. Ramsey Reimers, Robert Reimers Enterprises;
- Dr. Rick Spencer, Hawaiian Marine Enterprises {Council Chairman};
- Mr. Ray Tulafono, American Samoa Department of Marine and Wildlife Resources;
- Mr. Ron Weidenbach, Hawaii Fish Company;
- Dr. Leonard Young, Hawaii State Aquaculture Development Program.

Technical Committee

The Technical Committee's members represent participating research institutions and state extension services, other state or territorial public agencies as appropriate, and non-profit private research institutions. The Technical Committee provides research expertise to address priorities set by the Industry Advisory Council. Members are appointed by the Board of Directors for three-year, renewable terms.

The Technical Committee:

- prepares Problem Statements for priority areas identified by the Industry Advisory Council;
- participates as needed in project review panels, Program Review Delegations and other functions of the Center.

The members of the Technical Committee are:

- Dr. Harry Ako, University of Hawaii {Committee Chairman};
- Mr. Richard Bailey, Sea Grant Extension Service, University of Hawaii;
- Dr. James Brock, Hawaii State Aquaculture Development Program;
- Dr. Christopher Brown, Hawaii Institute of Marine Biology, University of Hawaii;
- Dr. John Brown, College of Agriculture and Life Sciences, University of Guam;
- Mr. David Coleman, Hamilton Library, University of Hawaii;
- Mr. David Crisostomo, University of Guam Cooperative Extension Service;
- Mr. Calistro Falig, Department of Natural Resources, Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands;
- Dr. Roger Fujioka, Water Resources Research Center, University of Hawaii;
- Dr. Gordon Grau, Hawaii Institute of Marine Biology;
- Mr. Marion Henry, Chuuk State Division of Marine Resources;
- Mr. Gerald Heslinga, Micronesian Mariculture Demonstration Center;
- Dr. Kevin Hopkins, University of Hawaii;
- Dr. Robert Howerton, Cooperative Extension Service, University of Hawaii;
- Mr. Tom Iwai, Anuenue Fisheries Research Center;
- Dr. Christopher Kelley, The Oceanic Institute;
- Mr. Steve Lindsay, College of Micronesia;
- Dr. Yung C. Shang, Department of Agricultural and Resource Economics, University of Hawaii;
- Dr. Ilse Silva-Krott, College of Agriculture and Life Sciences, University of Guam;
- Mr. Howard Takata, Sea Grant Extension Service, University of Hawaii
- Dr. Clyde Tamaru, Sea Grant Extension Service, University of Hawaii.

Effluent Discharge Program

Dates of Work

March 1988 through August 1995

Funding Level

$520,020

Participants

- Dr. Gary D. Pruder and Dr. David Ziemann, The Oceanic Institute;
- Dr. Jaw-Kai Wang, University of Hawaii

Project Objectives

The overall goal of this project is to reduce the uncertainty, time and cost of obtaining aquaculture effluent discharge permits and the cost of satisfying aquaculture effluent discharge regulations. The specific objective for the program's sixth year was to prepare and publish a report summarizing the findings from the first five years of the program and recommending regulatory action to the Hawaii State Department of Health.

Anticipated Benefits

Hawaii's regulations regarding aquaculture effluent discharge form one of the most critical obstacles to growth and success of the aquaculture industry. Reducing the uncertainty, time and expense involved in trying to satisfy these regulations would greatly benefit aquaculture farmers.

Progress and Principal Accomplishments

During the first year of the project, effluent discharge from commercial aquaculture facilities throughout Hawaii was characterized. In addition, relevant scientific literature on zones of mixing was reviewed, and effluent discharge issues and the costs of various treatment processes were analyzed.

During the second year of the project, a workshop was held to disseminate the results of the first year s work to commercial aquaculturists and other interested parties. At the World Aquaculture Society Meeting in 1990, investigators presented a paper on characterization of effluents in Hawaii, projected environmental impacts and conventional treatment technologies. They also participated in a panel discussion on

U.S. regulations of effluent. A list of organizations active in Hawaii environmental affairs was compiled.

During the third year of the project, case studies were developed documenting the experiences of three Hawaii facilities in obtaining National Pollution Discharge Elimination System (NPDES) permits. The case studies showed that the only commercial facility in Hawaii that got an NPDES permit spent more than $210,000 and four years to do so—an investment of time and money that exceeds the resources of most aquaculture producers. The effects of different feeds, feeding levels, water exchange rates and continuous versus batch mixing regimes were studied.

During the third year of the project, investigators participated in a national conference titled *Water Quality and the Environment: Aquaculture* in Washington, D. C., which was attended by representatives of the Food and Drug Administration and Environmental Protection Agency, directors of all five Regional Aquaculture Centers, and researchers and commercial producers from throughout the country. Information on injection wells, trenches, offshore pipes, slant drilling, polyculture, particle removal and recycling was collected and analyzed for their potential as alternatives to direct coastal discharge. The Hawaii state Department of Health's technical data and procedures for establishing Zones of Mixing were analyzed, and the quality of aquaculture effluent was compared with that of industrial and municipal wastewater facilities and state standards.

During the fourth year of the project, investigators helped launch an effluent discharge project that was undertaken cooperatively by the five Regional Aquaculture Centers. Interviews with recreational fishermen, divers and beach users showed that they associate improved fishing and increased levels of marine life with aquaculture discharge.

During the fifth year of the project, studies were conducted to determine effluent's effect on the growth of shrimp and fish. Data from a previous shrimp study using intensive round pond technologies clearly showed a pond water enhancement of shrimp growth with both medium and high quality feeds. This led to a projection that exposure to aquaculture effluent would enhance the growth of desirable species. Growth comparison studies of shrimp and fish were conducted in replicate indoor tanks supplied with flow-through shrimp pond water, well water or a mixture of half pond and half well water. The water was relatively poor quality when compared to the fully mixed waters of the intensive round pond used in the first study. In these trials, pond water suppressed shrimp growth rates compared to the shrimp growth rates achieved in well water. But the pond water had no detrimental effect on mullet growth, which was essentially the same in pond water, well water and the mixture of both.

Objective: The specific objective for the program's sixth year was to prepare and publish a report summarizing the findings from the first five years of the program.

A draft summary report was prepared and is being finalized. It raised a number of points about current effluent discharge regulations.

- Government regulation is a critical limitation to the success of the domestic aquaculture industry.
- Aquaculture effluent discharges are extensively regulated by a number of agencies at all levels of government. These regulations, especially at the state level, have significantly affected the rate and character of aquaculture development in Hawaii. Further, the regulations tend to have more severe effects on small entrepreneurs.
- Aquaculture effluents, though different depending on the type of crop and culture system, share many similarities. They are distinctly different from domestic sewage in nature and potential environmental impacts. The most notable difference is that aquaculture effluents contain no pathogenic microorganisms, pesticides, toxic chemicals or heavy metals, all of which are incompatible with successful production of aquaculture crops.
- Alteration of aquaculture diets and feeding practices is not a viable solution to the problem of effluent discharge regulations. Although changes in feeds and feeding practices can alter the amount of nitrogen, phosphorus and other materials in aquaculture effluents, no dietary formulation or feeding strategy has been found that significantly improves the possibility of meeting current regulatory standards.
- Limited discharges of aquaculture effluents in appropriate locations do not adversely affect the environment. In fact, aquaculture effluent has been shown to have positive biological effects in some environments. Data suggest that populations of commercially valuable near-shore sport fishes have increased in areas of effluent discharge while no adverse effects were seen in other near-shore biological resources.
- Effluent effects vary depending on the nature of the coastal environment.
- The potential impact of aquaculture effluents on coastal waters varies considerably depending on the characteristics of the nearshore environments. The Hawaii state system of classifying waters as "AA" or "A" bears little correlation to the potential risk to specific nearshore environments from aquaculture effluent discharges.
- The susceptibility of the coastlines of each inhabited Hawaiian island to environmental damage from aquaculture effluent was evaluated. The results provide a rational basis for directing future aquaculture development based on the ability of the coastal environment to tolerate effluent discharges.
- Few, if any, viable alternatives to direct ocean discharge exist. Alternatives to ocean discharge, including slant drilling, discharge wells

and shallow dispersion ponds, were evaluated in terms of cost and efficacy. None of the alternatives were economically feasible.

- A broad spectrum of wastewater treatment technologies was evaluated for applicability to aquaculture effluents. None would bring aquaculture effluents within existing state discharge standards without a Zone of Mixing. The Zone of Mixing costs are beyond the reach of most commercial aquaculture enterprises.
- The comprehensive revision of aquaculture effluent discharge regulations represents a great opportunity to develop new methods to resolve environmental issues.

Past discussions with government officials led investigators to believe that changing the state regulations regarding effluent discharge would be near impossible but that the Department of Health's water quality standards could be amended to address aquaculture. However, at a September 1995 meeting with Department of Health officials, investigators learned that changing the standards would also be nearly impossible and that waivers will not be issued for certain industries. However, the Department of Health official suggested that aquaculture industry members could use its new, streamlined administrative approach to Zones of Mixing, which relies on computerized models and minimal monitoring for industries that have best management practices plans in place.

Work Planned

The investigator is preparing a termination report that summarizes:

- the aquaculture effluent discharge controversy;
- the promise of commercial aquaculture;
- the reality of commercial aquaculture;
- constraints to achieving the promise of aquaculture;
- the principal constraint -- effluent discharge permits;
- technology application to improve effluent quality;
- failure to satisfy water quality standards -- the limits of treatment technology;
- social, political and environmental aspects of less stringent new regulations, water quality standards or both: massive resistance;
- the best option for Hawaii aquaculture is to pursue revised administrative procedures for Zones of Mixing in Class A waters. It would involve

  developing an industry-wide best management practices plan;
  a general computerized mixing zone model;
  and streamlined mixing zone compliance.

Impacts

This project compiled a large database of information on the impact and potential impact of aquaculture effluent on the coastal environment in Hawaii. The results will be used to educate and inform legislators, government regulators, environmentalists, scientists, farmers and the general public. In addition, this project stimulated the development of a national inter-regional initiative on aquaculture effluent discharge research that was undertaken by several of the regional aquaculture centers in 1992/1993.

Recommended Follow-Up Activities

The data gathered under this project should be used to develop a Best Management Practices Plan for commercial aquaculture in Hawaii and a computerized model of a Zone of Mixing that is general enough to include the various commercial aquaculture enterprises throughout the state. Those developments could be presented to the state Department of Health for use by commercial aquaculture facilities applying for Zone of Mixing permits.

Support

This project was funded by the Center for Tropical and Subtropical Aquaculture (CTSA).

Year	CTSA	Total Support
One	$180,000.00	$180,000.00
Two	$48,800.00	$48,800.00
Three	$127,120.00	$127,120.00
Four	$64,100.00	$64,100.00
Five	$65,000.00	$65,000.00
Six	$35,000.00	$35,000.00
Total	**$520,020.00**	**$520,020.00**

Publications, Manuscripts or Papers Presented

Pruder, G.D. 1991. An Overview of Aquaculture Water Quality Issues in the United States. *In:* Proceedings of a Conference on Aquaculture: Water Quality and the Environment. April 9-10, 1991. Washington, D.C.

Wang, J.K. 1990. Managing Shrimp Pond Water to Reduce Discharge Problems. *Aquacultural Engineering*. 61-73.

Ziemann, D. A., G. D. Pruder and J.-K. Wang. 1990. *Aquaculture Effluent Discharge Program: Year One Final Report*. Center for Tropical and Subtropical Aquaculture Publication #101. Waimanalo, Hawaii.

Ziemann, D. A., W.A. Walsh, E.G. Saphore and K. Fulton-Bennett. A Survey of Water Quality Characteristics of Effluent from Hawaiian Aquaculture Facilities. *Journal of the World Aquaculture Society*. 23 (3): 174-203.

Potential Drugs and Chemotherapeutants for Marine Shrimp Production: Selection, Evaluation and Approval

Dates of Work

March 1988 through August 1995

Participants

- Dr. Donald V. Lightner, Thomas Bell, Rodney R. Williams, Department of Veterinary Science, University of Arizona;
- Dr. John Controulis, John Controulis, Ph.D., Inc.;
- Dr. Roger Fujioka, Water Resources Center, University of Hawaii;
- Dr. James Brock, Aquaculture Development Program, State of Hawaii.

Reason for Termination

This project was terminated because all objectives were completed.

Project Objectives

The objective of this project was to identify and test compounds likely to be effective against shrimp diseases that have been identified as treatable. Compounds were selected based upon their reported efficacy, their potential to receive government approval under current federal regulations and the manufacturer's interest in sponsoring studies.

Progress and Principal Accomplishments

Objective: Identify and test compounds likely to be effective against shrimp diseases that have been identified as treatable. Compounds will be selected based upon their reported efficacy, their potential to receive government approval under current federal regulations and the manufacturer's interest in sponsoring studies.

To obtain Food and Drug Administration (FDA) approval for use of a compound to treat shrimp disease, a Master File must be submitted that shows the compound is effective against disease, safe for the animals and leaves no residue that could harm consumers. The Master File data must come from a number of studies conducted *in vitro*, or in test tubes, and *in vivo*, or on live animals. Master File requirements comprise the following:

- Minimum Inhibitory Concentration (MICs) trials, which determine the lowest concentrations of a compound needed to completely inhibit the growth of selected bacteria isolated from diseased shrimp;
- animal safety studies, which determine whether the compound is safe for the animals;
- palatability studies, which determine the concentration of a compound in the feed at which the animals stop eating;
- and residue studies, which determine how rapidly residues of a compound are depleted from the animals' tissue. The FDA requires that withdrawal periods be long enough so that the animals' tissues show no detectable level of the compound.

Investigators completed work and submitted a Master File on formalin. As a result, the FDA approved the use of the compound in penaeid shrimp nurseries and growout. During the fifth year of the project, Western Chemical, which manufactures formalin, applied to the FDA for a label extension for use of the compound in shrimp culture. The FDA approved Western Chemical to market formalin for that use. This achievement was especially noteworthy because it marked the FDA's first approval of a compound for use in the culture of marine shrimp.

Media were evaluated and selected for use in recovering bacteria from shrimp hatchery water and larvae. Dominant bacteria were identified and isolated from samples collected at various U.S. shrimp culture facilities. In addition, bacterial pathogens from Ecuador were identified and, upon screening, a large number were found to be sensitive to Chloramphenicol.

An extensive database was compiled on the bacteria isolated during the project. The database will allow researchers to compare isolates from different areas to determine which are associated with disease. The database included information on each bacteria's structure and form, biochemical reactions, drug sensitivities, collection sources, host species, host species' health status and other pertinent observations.

The results of pharmacokinetic, bioavailability and protein binding studies that were conducted on Mobay's enrofloxacin were analyzed. In addition, safety, palatability and preliminary elimination studies were completed on:

- Sarafin, the sarafloxacin manufactured by Abbott Laboratories. The studies indicated that neither palatability nor toxicity were problems even at 50 times the estimated treatment level of 200 mg per kilogram of feed. Elimination appears to be rapid, and a relatively short withdrawal period is indicated.
- Abbott's difloxacin with juvenile *P. vannamei.* The animals showed reduced palatability and survival when treated at levels two and four times higher than the estimated therapeutic level.
- Romet-30 with juvenile *P. vannamei.* Results indicated that up to 13,000 mg of the compound per kilogram of feed caused no ill effect to palatability and toxicity. However, because the FDA has expressed

concern about all sulfa compounds in animal feeds, Hoffmann-LaRoche placed tissue analysis on very low priority, so this data was not available.

Large-scale field trials of oxytetracycline were conducted on Texas shrimp farms. The studies included pond and cage trials and laboratory trials for four different treatment levels for comparisons of the two treatment environments. Data from the studies indicated that oxytetracycline is effective in controlling Necrotizing Hepatopancreatis (NHP), which was formerly referred to as Texas Pond Mortality Syndrome, if the compound is administered before the disease is established in a majority of the shrimp and before most of the organ damage is done.

- In ponds, treatment at 3.0 grams OTC per kilogram of feed proved effective.
- In cage trials, treatment levels from 2.25 - 4.5 grams OTC per kilogram of feed were not significantly different in increasing the survival percentage. This indicates that the lower concentration may be just as effective as higher doses in decreasing mortality.

A second cage and laboratory study was conducted with animals from a pond previously treated with 3.0 grams OTC per kilogram of feed. The animals had been taken off the medicated diet, and the incidence of disease had increased. The retreatment data indicated that levels of OTC as low as 0.5 grams per kilogram of feed were as effective in maintaining survival as higher levels. Investigators initiated a study to determine the storage stability of oxytetracycline-medicated feed. The FDA requires such a study prior to approval of the compound in feeds for juvenile to adult size shrimp.

Objective: With contractual and financial cooperation from one or more industry sponsors, obtain approval for the selected compound(s) from the appropriate federal government agency.

Plans to conduct *in vitro* efficacy studies on dinitroaniline herbicides, the class of herbicides to which trifluralin belongs, were dropped after investigators learned that trifluralin can be used without approval from the Environmental Protection Agency (EPA). After discussions with officials from the National Pollution Discharge Elimination System (NPDES) permitting office in Washington, D.C. and with officials from EPA Region Six, investigators determined that the most economical way to regulate use of this compound would be through the NPDES permitting process, which is usually handled by state agencies. In Hawaii, that agency is the Department of Health; in other states, it may be the state environmental protection agency.

An NPDES permit for trifluralin would be necessary even if national registration of the compound were possible. Thus, each facility planning to use trifluralin must obtain a permit, which would eliminate potential problems with FDA

inspectors. An application submitted to the NPDES permitting agency should include the following information on the compound:

- information on the current use practices in penaeid culture available in published scientific literature;
- data indicating that the animals would carry no detectable residues to harvest. This has been submitted for publication by investigators at the University of Arizona and is available from them in draft form;
- a complete description of the proposed usage;
- worst case projections on the amount of trifluralin reaching the environment;
- a copy of the letter stating that the EPA regulates the compound as a water quality agent.

Hawaii farmers who wish to pursue an NPDES permit for trifluralin should contact Dr. Leonard Young of the Hawaii State Aquaculture Development Program.

Impacts

Obtaining Food and Drug Administration approval for an agriculture drug has been estimated to cost $5 million to $10 million. The project funding, which resulted in approval of formalin for use in shrimp culture, represents a direct cost benefit of $4 million to $8 million. Safe, effective therapeutic compounds will help U.S. shrimp farmers to achieve higher production levels and to compete better against unregulated foreign producers.

Recommended Follow-Up Activities

Aquaculture industry members are urged to support the National Biological Service's Chemical Drug Registration Program and the National Coordinator for New Animal Drug Applications, Rosalie Schnick, who will coordinate Investigational New Animal Drug applications for the U.S. aquaculture industry.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture, the University of Arizona (UA), the University of Hawaii (UH) and the Hawaii State Aquaculture Development Program (ADP).

Year	CTSA	Other Support			Total Other	**Total Support**
		UA	UH	ADP		
One	$192,145	$12,086	$5,679	$5,329	$23,094	$215,239
Two	$165,704	$0	$0	$5,329	$5,329	$171,033
Three	$193,000	$0	$0	$5,329	$5,329	$198,329
Four	$165,000	$6,019	$0	$3,730	$9,749	$174,749
Five	$100,788	$2,216	$1,136	$1,066	$4,418	$105,206
Six	$155,667	$2,223	$1,136	$1,066	$4,425	$160,092
Total	**$972,304**	**$22,544**	**$7,951**	**$21,850**	**$52,345**	**$1,024,649**

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Library Aquaculture Workstation

Pacific Regional Aquaculture Information Service for Education (PRAISE)

Dates of Work

March 1988 through October 1995

Funding Level

$141,600

Participants

David E. Coleman (project coordinator), Randall Buettner, Kristen Anderson, Rachel Hu and Jue Wang, Hamilton Library, University of Hawaii.

Project Objectives

The overall goal of this project is to make scientific information more accessible to the aquaculture community. Specific year eight objectives related to that goal are to:

- expand the existing dial-up remote access information network in the Pacific Islands;
- evaluate the effectiveness of the dial-up remote access information network that was expanded to the Pacific Islands during year six;
- increase and ensure the continued usefulness of the PRAISE program through the use of CD-ROM database searching, telecommunications and new technologies as they develop, and disseminate information products as needed by the industry;
- increase the efficiency of PRAISE through interaction with other information agencies;
- establish a cooperative project to gather and disseminate Pacific Islands gray literature on aquaculture;
- increase the support base for the project through cooperative agreements with other agencies.

Anticipated Benefits

This project has improved the accessibility of scientific information throughout CTSA's region, much of which is undeveloped and would otherwise have no access to science journals or other published information on aquaculture.

Progress and Principal Accomplishments

In 1988-1989, the Center for Tropical and Subtropical Aquaculture provided funding to establish an aquaculture workstation operated and managed by the staff of Hamilton Library, University of Hawaii. That program is known as the Pacific Regional Aquaculture Information Service for Education, or PRAISE. The workstation is a computer equipped with a multi-disk CD-ROM player, fax and modem. The service subscribes to a number of CD-ROM databases, including Aquatic Sciences and Fisheries Abstracts (ASFA), CINAHL Nursing Index, AGRICOLA, and Biological Abstracts. These databases list articles on thousands of aquaculture topics from hundreds of scientific journals.

During the first two years of the project, those interested in conducting a search could either travel to Hamilton Library at the University of Hawaii Manoa campus or call David Coleman, who would then conduct the search and fax the results to the PRAISE patron. The patron then selected the desired articles, which Coleman photocopied and faxed or mailed to the patron. Initially, a limit of 10 articles was set, but that proved too restrictive and was eliminated. An average of 15 articles are sent to patrons who can't otherwise obtain them.

During the third and fourth years of the project, investigators compiled and published *A Union List of Aquaculture Journals in Hawaii*. The catalog listed science journals held at seven key libraries that have a large collection of aquaculture literature. The catalog assisted the aquaculture community with locating journal literature. In addition, PRAISE exchanged journal holdings data with the Scripps Institute of Oceanography, the California Academy of Sciences and the Pacific Island Marine Resources Information Service of the University of the South Pacific.

During the fifth year of the project, remote workstations were established at the CTSA office, the Hawaii Institute of Marine Biology, the Aquaculture Development Program office, the Sea Grant office, the Pacific Island Network office and the University of Hawaii at Hilo. From these remote workstations equipped with modems, users can dial into PRAISE to perform database searches 24 hours a day, 365 days a year. The remote sites increased the efficiency of the service, which was demonstrated by the vastly increased numbers of searches that have been performed since their establishment.

During the sixth year of the project, additional remote workstations were established at The Oceanic Institute's site at Keahuolu on the island of Hawaii, at Anuenue Fisheries Research Center, and at the Hawaii Institute of Marine Biology computer lab. A breakthrough in the Pacific Islands' ability to access scientific information came in August 1993, when two remote workstations were established on Guam. Users at the site at the offices of the University of Guam's Cooperative Extension Service and at the Guam Department of Commerce gained access to PRAISE through a toll-free telephone line. The investigator conducted training sessions at both locations.

The establishment of two remote workstations, from which users dial into PRAISE via a toll-free telephone number, marked the first time a toll-free line was established from the Pacific Islands for CD-ROM data transmission. The vendor, MCI, experienced a number of problems before instituting reliable service. The cost of establishing the line and monthly charges totaled $2,000. A total of 54 calls--an average of 3.9 calls per month--were made. The average call lasted 20 minutes and cost $1.85 per minute or $37 per call. Providing ready access to aquaculture information has proven to be useful to the aquaculturists of Guam. However, the service was quite costly, and the system continued to experience problems.

During the sixth year of the project, PRAISE submitted data to the U.S. Department of Agriculture Science and Evaluation Study Working Committee on Aquaculture. Results of the study showed that aquaculturists were particularly interested in sources of aquaculture information from various government agencies and educational facilities. Based on this information, the Joint Subcommittee on Aquaculture approved publication of the Resource Guide to Aquaculture Information. PRAISE participated in the creation of this publication.

Objective: Increase and ensure the continued usefulness of the PRAISE program through the use of CD-ROM database searching, telecommunications and new technologies as they develop, and disseminate information products as needed by the industry.

Use of the workstations at both Hamilton Library and remote sites continued to increase. Since establishing the electronic network, the total number of system uses increased from about 400 per year to more than 8,000 per year. The 2,000 percent rise in use of the service was accomplished with no increase in staff.

During 1994, PRAISE entered a cooperative agreement with the Pacific Education and Communications Experiment by Satellite, or PEACESAT, to improve information access for five Pacific Island sites. Under the agreement, residents of Guam, Saipan, Pohnpei, Belau and Majuro can directly access the Aquatic Sciences and Fisheries Abstracts (ASFA) database through an Internet connection between the local PEACESAT station and the mainland vendor. This system, which will cost $1,000 per year per locale, will be evaluated for one year. At the end of that period, if it is found to ineffective, the toll-free line to Guam will be re-established and other sites will be added as telephone service becomes available.

A wealth of reports containing valuable, unique information are produced throughout the Pacific but never integrated into journals and conference proceedings. The inaccessibility of gray literature is a particularly serious problem in the Pacific, where libraries and other organizations that collect and disseminate information are few. Also, important work done in the region is not shared with the rest of the scientific community, which means regional work does not get the recognition it deserves. The Pacific Islands Gray Literature project was established to address this

impediment to information. To date, more than 100 Pacific Islands publications have been gathered for inclusion in the Aquatic Sciences and Fisheries Abstract (ASFA) database. In addition, *Pacific Islands Gray Literature Project: A Bibliography* was published.

PRAISE hosted the 20th Annual Conference of the International Association of Marine Science Libraries and Information Centers in Waikiki from October 9-13, 1994. Participants from more than 12 countries, including Iceland, Malaysia and Russia, attended.

Objective: Increase the efficiency of PRAISE through interaction with other information agencies.

The Joint Subcommittee on Aquaculture (JSA) decided that legislative materials on the development and support of aquaculture should be included on AquaNIC, an Internet gateway to the world's electronic resources in aquaculture that is supported by the U.S. Department of Agriculture. David Coleman, a member of the JSA's Aquaculture Information and Technology Transfer Task Force, is attempting to gather relevant legislative materials from Hawaii and the Pacific Islands for AquaNIC. He met with AquaNIC coordinators in October 1995 to establish a procedure for downloading the information. Coleman gave a presentation on the cooperative project between PRAISE and PEACESAT and participated in discussions of Internet uses and procedures at the 1995 CYAMUS Marine Librarians Meeting.

Objective: Increase the support base for the project through cooperative agreements with other agencies and information facilities.

The cost to establish the remote workstations was shared by all the institutions that host a remote workstation. The work on the gray literature bibliography received additional funding from the Pacific Island Network, U.S.D.A.'s National Agricultural Library and the vendor for the ASFA database, into which the bibliography materials will be incorporated. The National Agricultural Library also provided co-funding to publish the bibliography. Additional base project funding was secured from the University of Hawaii, the Pacific Island Network and the University of Hawaii Sea Grant Extension Service.

Work Planned

The project will evaluate the cooperative agreement between PRAISE and PEACESAT to improve information access for five Pacific Island sites. In addition, the PRAISE server at Hamilton Library will be upgraded with new CD-ROM readers and equipment to allow improved access for users. The current system of searching from remote sites will continue, and project staff will continue to send documents to

users upon request. The Pacific Islands gray literature bibliography will be updated, and new sources of funding will be sought to broaden the support base for PRAISE.

Impacts

This project has increased the accessibility of scientific information throughout the Pacific region. In the last year, PRAISE users performed more than 8,000 searches, each of which lasted approximately 30 minutes. Commercial databases charge $102 per hour for connect time. Therefore, those searches would have cost approximately $408,000. The highest level of project funding from CTSA was $49,000 in Year Eight, which represents a savings of $359,000 in that year alone.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture (CTSA), the University of Hawaii (UH), Sea Grant Extension Service (SGES), the National Agricultural Library (NAL), the Center for Applied Aquaculture (CAA), the National Oceanic and Atmospheric Administration (NOAA) and jointly from the Pacific Island Network (PIN) and the Pacific Aquaculture Development Program (PADP).

		Other Support						Total	Total
Year	CTSA	UH	SGES	PIN/PADP	NAL	CAA	NOAA	Other	Support
Yr 1	$7,000	$13,400	$1,500	$0	$0	$0	$0	$14,900	$21,900
Yr 2	$6,700	$12,600	$0	$0	$0	$0	$0	$12,600	$19,300
Yr 3	$6,000	$12,600	$3,300	$0	$0	$0	$0	$15,900	$21,900
Yr 4	$7,000	$14,100	$4,000	$0	$2,500	$0	$2,500	$23,100	$30,100
Yr 5	$20,000	$44,175	$3,500	$10,800	$0	$15,000	$0	$73,475	$93,475
Yr 6	$17,900	$24,000	$0	$5,800	$0	$0	$0	$29,800	$47,700
Yr 7	$28,000	$12,600	$0	$5,500	$0	$0	$0	$18,100	$46,100
Yr 8	$49,000	$11,400	$0	$5,500	$0	$0	$0	$16,900	$65,900
Total	$141,600	$144,875	$12,300	$27,600	$2,500	$15,000	$2,500	$204,775	$346,375

Publications, Manuscripts or Papers Presented

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Aquaculture Extension and Training Support in the U.S.-Affiliated Pacific Islands

Dates of Work

August 1989 through October 1995

Funding Level

$572,470

Participants

Stephen Lindsay, College of Micronesia, Pohnpei, Federated States of Micronesia.

Project Objectives

The overall goal of this project is to provide extension and training support to private aquaculturists and to government fisheries and aquaculture staff to develop commercial and subsistence aquaculture crops within American Samoa, the Commonwealth of the Northern Mariana Islands (CNMI), the Federated States of Micronesia (FSM), the Republic of Belau and the Republic of the Marshall Islands (RMI). Specific objectives related to that goal are to:

- conduct training course in culture techniques and general biology of aquaculture species;
- provide extension support to private aquaculturists and government fisheries and aquaculture staff to develop commercial and subsistence aquaculture crops within the region;
- help develop and support hatcheries and growout farms for giant clams and other aquatic plant and animal species, including sponges, pearl oysters, seaweed, trochus and green snail;
- assist in reef reseeding programs and surveys for giant clams, sponges and other species as requested by local authorities;
- continue to act as the scientific and aquaculture advisor to the FSM National Aquaculture Center in Kosrae.

Anticipated Benefits

This project provides vital technical assistance in all phases of aquaculture to locales in CTSA's region that have little expertise in aquaculture but have great potential for its development. Both private and government aquaculture projects in

American Samoa, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, the Republic of Belau and the Republic of the Marshall Islands benefit from an aquaculture extension specialist without incurring the cost of employment, which these undeveloped areas cannot afford.

Progress and Principal Accomplishments

This project began in 1988, when the Center for Tropical and Subtropical Aquaculture funded an aquaculture extension specialist for the region comprising American Samoa, the CNMI, the FSM, Belau and the Marshall Islands. Additional funding has been provided by Sea Grant Extension Service, the Pacific Island Network, the Pacific Aquaculture Development Program, the College of Micronesia and the Federated States of Micronesia government.

Dr. Christine Crawford served as the extension specialist from 1989 to 1991, when Mr. Stephen Lindsay assumed the position. The extension specialist provided technical advice and assistance to establish the FSM National Aquaculture Center in Kosrae and established a demonstration ocean growout farm on the reef outside the National Aquaculture Center. The specialist assisted with development of the major field site, including building and deploying enough off-bottom culture racks to hold all the clams. A training course in giant clam culture was conducted, after which trainees induced spawning in *T. gigas* and in 6-year-old *Hippopus hippopus*. A project was conducted to encourage the women of Kosrae to grow clams on the reef outside their homes. The specialist continues to act as the scientific and technical advisor to the facility and makes site visits to all the giant clam culture facilities in the region upon request.

Training courses in all aspects of giant clam spawning and culture were conducted in various locations throughout the region. Assistance was provided with giant clam reef reseeding programs, and surveys for giant clams, sponges and other species were completed as requested by local authorities.

Objective: Conduct training courses in culture techniques and general biology of aquaculture species

Each year, the specialist conducts aquaculture training courses throughout his region. During the last year, the specialist conducted the following training courses in all aspects of aquaculture:

- Eight training courses in giant clam culture were conducted at various sites;
- Four black-lip pearl oyster growout training courses were conducted;
- Two sponge culture training courses were conducted;
- Two trochus and turbo culture training courses were conducted.

A series of lectures on aquaculture topics were presented to science classes at the American Samoa Community College, the FSM Community College and to groups of Peace Corps volunteers in the FSM. In addition, lectures on pearl farming and giant clam culture were given to staff of the American Samoa Department of Marine and Wildlife Resources and to staff of the Marshall Islands Development Authority.

Objective: Provide extension support to private aquaculturists and government fisheries and aquaculture staff to develop commercial and subsistence aquaculture crops within the region.

Literature and advice on aquaculture of various species were provided to private concerns and government agencies in the Republic of Belau, the Federated States of Micronesia, the Commonwealth of the Northern Mariana Islands, the Republic of the Marshall Islands and American Samoa.

- The species covered included mangrove crabs, pearl oysters, marine shrimp, freshwater prawns, marine sponges, live rock, soft coral, giant clams, mullet, grouper, trochus, eels, sea cucumbers, tilapia and ornamental species. Field site evaluations were done in several cases.
- Approximately 5 percent of those who requested information and advice initiated aquaculture projects.

All locations were provided with information on the documentation required under the Convention on International Trade in Endangered Species (CITES) and by U.S. Fish and Wildlife Service to allow the export of giant clam products.

- The Republic of Belau, the Republic of the Marshall Islands and the Federated States of Micronesia have completed the necessary steps and obtained permits to export giant clam products for non-food uses.

Objective: Help develop and support hatcheries and growout farms for giant clams and other aquatic plant and animal species, including sponges, pearl oysters, seaweed, trochus and green snails.

A giant clam demonstration farm was established in Pohnpei, FSM. Three sponge demonstration farms were established in various states of the FSM, and assistance was provided in marketing a colonial tunicate that grows on sponge farming lines. All giant clam culture facilities in the region received information on aquarium markets, local and international food markets and reef reseeding. A private giant clam wholesaler in Saipan was assisted with obtaining the necessary permits and provided with information on clam availability and pricing from hatcheries in the region.

Objective: Assist in reef reseeding programs and surveys for giant clams, sponges and other species as requested by local authorities.

A black-lip pearl oyster stock assessment was conducted in Arno Atoll, RMI, and three people were taught survey techniques.

Work Planned

The project will continue to provide extension support and training throughout the region. In addition, a manual and video explaining various value-added commercial uses of giant clam shells, such as book-ends and wasabi dishes, is being planned.

Impacts

This project has provided vital technical assistance in all phases of aquaculture to locales in CTSA's region that have little expertise in aquaculture but have great potential for its development. Both private and government aquaculture projects benefit from the expertise of an aquaculture extension specialist without incurring any costs for the assistance.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture (CTSA), the Federated States of Micronesia government (FSM), the Sea Grant Extension Service (SGES), the Pacific Island Network (PIN), the College of Micronesia (COM), the Pacific Aquaculture Development Program (PADP), and the United Nations Food and Agriculture Organization (FAO).

		Other Support						Total	**Total**
Year	CTSA	FSM	COM	SGES	PIN	PADP	FAO	Other	**Support**
One	$100,000	$24,000	$7,000	$5,000	$4,000	$10,000	$0	$50,000	$150,000
Two	$85,870	$26,700	$7,000	$4,500	$4,500	$4,500	$2,500	$49,700	$135,570
Three	$73,600	$27,754	$7,000	$10,800	$10,800	$21,000	$6,000	$83,354	$156,954
Four	$70,000	$15,000	$2,000	$0	$6,000	$4,000	$0	$27,000	$97,000
Five	$75,000	$0	$3,000	$0	$2,000	$10,000	$0	$15,000	$90,000
Six	$98,000	$0	$3,000	$2,000	$2,000	$16,000	$0	$23,000	$121,000
Seven	$70,000	$0	$3,000	$2,000	$2,000	$12,000	$0	$19,000	$89,000
Total	**$572,470**	**$93,454**	**$32,000**	**$24,300**	**$31,300**	**$77,500**	**$8,500**	**$267,054**	**$839,524**

Publications, Manuscripts or Papers Presented

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Crawford, Christine. 1991. *Giant Clam Mariculture Information Sheet Number 2: CITES Requirements for the Export of Giant Clams*. College of Micronesia. Kosrae, Federated States of Micronesia.

Crawford, Christine. 1991. *Giant Clam Mariculture Information Sheet Number 3: U.S. Food and Drug Authority Ruling on Giant Clams*. College of Micronesia. Kosrae, Federated States of Micronesia.

Crawford, Christine. 1992. *A Review of U.S. Food and Drug Administration Requirements to Market Giant Clam Meat in the United States of America*. CTSA Publication #109. Waimanalo, Hawaii.

Lindsay, S.R. 1991. Survival and Growth of Introduced Populations of the Giant Clam, *T. derasa*, on the Island of Yap Proper and the Outer Atoll of Woleai, FSM. Yap Marine Resources Division. Yap, FSM.

Expert System Disease Module for Hawaiian Aquaculture

Dates of Work

March 1991 through October 1995

Participants

- Dr. Stephen Itoga, Department of Information and Computer Sciences, University of Hawaii;
- Dr. Jim Brock, Aquaculture Development Program, State of Hawaii;
- David E. Coleman, Hamilton Library, University of Hawaii.

Reason for Termination

This project was terminated because all the objectives were completed.

Project Objectives

The objectives of this project are to:

- develop an expert system disease module, a computer software program that will help aquafarmers and extension personnel diagnose and manage diseases of tilapia cultured in Hawaii;
- redesign the major modules of the expert system to take advantage of the graphical user interface of Microsoft Windows® and implement the new design using that environment;
- implement the new design using the Macintosh development environment.

Progress and Principal Accomplishments

The goal for the first two years of work, initiated under the CTSA Fourth Annual Plan of Work, was to develop an expert system disease module, a computer software program that could help aquafarmers and extension personnel diagnose and manage diseases of tilapia cultured in Hawaii.

To start, investigators surveyed 94 groups involved in aquaculture, asking them to rank species for inclusion in the expert system. Based on the results of the survey, investigators selected tilapia for the program.

A list of diseases and syndromes of tilapia cultured in Hawaii was compiled, and published information on tilapia diseases was gathered and indexed. In addition, information on local disease problems was drawn from the files of Dr. Brock, a

veterinarian and state aquaculture disease specialist who has worked with cultured tilapia for more than 10 years.

A computer software program, PDC Prolog®, was tested and found suitable to be the basis of the expert system. Slides of animals showing various disease symptoms were digitized and incorporated into the software.

The expert system disease module was completed as Center for Tropical and Subtropical Aquaculture Publication Number 111. Titled *Hawaii Aquaculture Module Expert System*, the program runs in a Microsoft DOS® environment. It has five components:

- **Review Information**, which is divided into six sections:
  1. An Overview of HAMES,
  2. Reading Topics, Glossary,
  3. Laboratory Methods,
  4. Bibliography,
  5. Extension Assistance
  6. and Vendors;
- **Volume Determination**, a utility designed to compute the volume of a wide variety of containers;
- **Solve A Problem**, which uses observation and selected water parameter tests to help the tilapia farmer understand diseases that may affect tilapia in Hawaii. It is divided into four sections:
  1. Field Observations,
  2. Microscopy,
  3. Water Analysis,
  4. and Ammonia;
- **Treatment**, which contains seven sections:
  1. List of Chemicals,
  2. Ectoparasites,
  3. Anesthesia,
  4. Bacteria,
  5. Disinfection,
  6. Fungi
  7. and Algae Control;
- and **Control This Session**, which allows users to view data and information from the last session, save the current session, or print all the data and information in the current session.

The expert system comes complete with an instruction manual and is available on either 3.5" or 5.25" floppy diskettes. A $10 fee to cover the cost of the diskettes is charged for distribution outside the CTSA region. As of October 1995, more than 100 copies of the expert system had been requested and distributed.

Objective: Redesign the major modules of the expert system to take advantage of graphical user interface of Microsoft Windows and implement the new design using that environment.

Investigators have completed redesigning the program to operate in an Microsoft Windows® environment. The implementation is currently being refined and tested. The new program will contain enhanced graphics and a more "user-friendly" interface. The Windows program will be available by the end of 1995.

Objective: Implement the new design using the Macintosh development environment.

Investigators have implemented the design to operate on Macintosh computers. They are currently testing the implementation of the program. The Macintosh version of the software will be available by the end of 1995.

Impacts

The cost of developing a computer software program can be several hundred thousand dollars. The project funding therefore represents a cost benefit of at least $10 for each dollar spent.

Recommended Follow-Up Activities

After the program has been in use by farmers, its programming and technical information may need revisions and updating.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture, the Hawaii State Aquaculture Development Program (ADP) and the University of Hawaii (UH).

		Other Support			
Year	CTSA	ADP	UH	Total Other	Total Support
One	$16,709	$2,208	$5,000	$7,208	$23,917
Two	$27,849	$1,325	$5,000	$6,325	$34,174
Three	$30,000	$4,800	$5,000	$9,800	$39,800
Total	**$74,558**	**$8,333**	**$15,000**	**$23,333**	**$97,891**

Publications, Manuscripts or Papers Presented

Brock, J.A., S. Itoga, Y. Liu, H. Fujii and D. E. Coleman. 1992 . *Hawaii Aquaculture Module Expert System*. Center for Tropical and Subtropical Aquaculture Publication #111. Waimanalo, Hawaii.

Gill Discoloration in *Penaeus stylirostris*

Dates of Work

April 1994 through October 1995

Funding Level

$17,300

Participants

- Dr. Ilse Silva-Krott, College of Agriculture and Life Sciences, University of Guam;
- Dr. Jim Brock, State of Hawaii Aquaculture Development Program;
- Jeff Tellock, Guam Aquaculture Development and Training Center, Guam Department of Commerce.

Project Objectives

The objective of this project is to identify the causes of black gill discoloration in market-sized penaeid shrimp cultured in Guam.

Anticipated Benefits

In Guam, aquaculture farmers have found that their market-sized shrimp are afflicted with blackened gills, which makes the animals unsuitable for sale. This project will directly benefit Guam shrimp farmers by identifying the cause and means of preventing gill discoloration and by introducing ways to improve shrimp health. It will indirectly benefit Guam shrimp farmers by providing basic data about shrimp growth rates, shrimp health and water parameters in local ponds.

Progress and Principal Accomplishments

Objective: Identify primary and secondary causes of gill discoloration in market-sized penaeid shrimp in Guam.

Samples of bottom soil were taken from shrimp ponds and analyzed to assess acid/alkaline balance, phosphorus, potassium, sodium, calcium and magnesium. All were found to be within normal limits. Pond water samples were taken regularly and assessed for pH, oxygen saturation, salinity, ammonium contents and temperature. Results have shown elevated water temperatures.

Shrimp were sampled monthly at a commercial farm in Guam. The animals grew approximately 1 gram per week. Assessment of fresh gill samples revealed that up to 50 percent of the animals were afflicted with black gill disease to varying degrees of severity. Some fouling with protozoan organisms (*Zoothamium* spp.) was also found. Shrimp were also fixed for routine histopathology, which is in progress.

In December 1994, shrimp from the first pond investigated (Pond #1) were harvested. An examination of 25 fresh shrimp revealed no protozoa, but black gills were seen in two animals and a slight bluish gill discoloration in another seven. The shrimp had grown an average 1.17 grams per week. After harvest, the shrimp were washed in fresh water, put on ice and immediately transported to restaurants and stores. No problem arose during the sale of the crop.

Overall, the shrimp in Pond #1 grew at a normal rate. Review of histological preparations from larvae and four monthly samples revealed no serious disease problems. However, the results indicated increased gill discoloration, which occurred during dry weather in October 1994. During that period, water temperatures reached as high as 36°C and pH was higher than 8.8. The high water temperatures and high pH values were less than optimal for the shrimp and probably favored the growth of disease-causing organisms.

A second experiment was undertaken in a different earthen pond. Analysis of bottom soil samples taken before the pond was filled with water did not indicate any conditions adverse to shrimp culture. The pond was stocked in January 1995, but it was abandoned because problems with maintaining adequate water levels caused high shrimp mortalities. The study was switched to an adjacent earthen pond (Pond #2), which was stocked on March 7, 1995.

The shrimp in Pond #2 grew slowly, and 52 percent of the animals exhibited black gill disease in the second sample, which was taken June 9, 1995. Samples of these animals were sent for processing and histological examination.

Work Planned

Plans call for continued monitoring of Pond #2 and periodic sampling of the shrimp until harvest. Histological sections will be examined, and the results will be analyzed. Plans also call for production of an extension publication that recommends conditions for optimal shrimp growth in Guam, describes black gill condition and includes pictures of developing shrimp. Those bacteria present on shrimp gills will be grown so that the pathogens can be identified. That will provide investigators with a baseline record of bacterial species that occur in shrimp ponds in Guam.

Impacts

This study will start a baseline of data on water parameters in Guam shrimp ponds, assess bacterial flora on gills of shrimp and document the occurrence of black

gill disease and other pathogens. This information will be important for comparisons in case of future disease outbreaks. The extension publication will contain helpful information for local aquaculture farmers.

Support

This project, initiated under the Center for Tropical and Subtropical Aquaculture's (CTSA) Seventh Annual Plan of Work, received funding from CTSA, the University of Guam (UOG), the Hawaii State Aquaculture Development Program (ADP) and the Guam Department of Commerce (DOC).

		Other Support				**Total**
Year	CTSA	UOG	DOC	ADP	Total Other	**Support**
One	$17,300	$5,000	$3,000	$1,000	$9,000	$26,300
Total	**$17,300**	**$5,000**	**$3,000**	**$1,000**	**$9,000**	**$26,300**

Publications, Manuscripts or Papers Presented

None.

Mangrove Crab as a Model for Development of a Quarantine System to Screen Species for Aquaculture in Guam

Dates of Work

April 1994 through October 1995

Funding Level

$50,234

Participants

- Dr. Ilse Silva-Krott, Dr. John Brown, Dr. Robert Barber and David Crisostomo, College of Agriculture and Life Sciences, University of Guam;
- Dr. Jim Brock, Hawaii State Aquaculture Development Program.

Project Objectives

The overall goal of this project is to establish an aquatic animal quarantine area, which will be used to screen species for pathogens, at the University of Guam Marine Laboratory. Specific objectives related to that goal are to:

- construct an aquatic animal quarantine facility;
- capture local juvenile through adult mangrove crabs and transfer them into the quarantine area for pathogen and disease studies;
- screen incoming and enhancement-reared crabs for biotic agents;
- identify a list of pathogens, diseases and syndromes found in wild caught mangrove crabs;
- formulate pathogen and disease risk assessment for introduction of feral mangrove crab broodstock to the Guam Aquaculture Development and Training Center (GADTC);
- evaluate the economic feasibility of commercial scale mangrove crab production in Guam.

Anticipated Benefits

Guam aquaculture farmers need to increase the variety of species cultured in order to improve farm viability and profit margin. The island did not have a facility and equipment for safe quarantine of imported aquaculture species to ensure their health status before introduction to farmers' ponds or to the GADTC. This project establishes a quarantine facility that is adaptable for marine, brackishwater or

freshwater species. Guam imports several thousand live crabs per month for direct consumption. Locally produced mangrove crabs that could be sold fresh would be a high quality product for local restaurants and retail markets. The project includes a marketing component that will investigate economic factors to be considered in mangrove crab culture. Local wild crabs will be caught, held in the quarantine system and monitored for disease agents.

Progress and Principal Accomplishments

Objective: Establish an aquatic animal quarantine area at the University of Guam Marine Laboratory.

An area at the Marine Laboratory was identified for the quarantine facility. The area was fenced, and two 975-gallon tanks were installed. The tanks were connected to 5-micron and 1-micron cartridge water filters and a UV-sterilizer on both inflow and effluent water. An appropriate effluent water pump and a float valve were installed, and plywood covers were placed over the tanks to keep debris out. Holding baskets with plastic glass dividers were installed in the tanks. An official from the Guam Division of Aquatic and Wildlife Resources (DAWR) visited the facility and suggested several improvements that will be carried out. Project investigators are working closely with the DAWR in order to have the system approved within the next year.

Objective: Capture local juvenile through adult mangrove crabs and transfer them into the quarantine area for pathogen and disease studies.

A boat for setting crab traps was purchased. Nine crab traps were built and six more are being built. Four traps were deployed in the Ylig River, and two traps were deployed in Ylig Bay in early June. A total of 12 crabs were caught. Gross examination revealed no lesions or parasites. Two crabs were dissected for histopathology. The remaining crabs were placed in the holding baskets, which were abandoned after one week because the crabs destroyed them. The animals were transferred to individual buckets suspended under a drip water distribution system within the quarantine tank.

Objective: Identify a list of pathogens and disease syndromes found in wild caught mangrove crabs.

A pathology configuration microscope has been purchased and is being used for the histopathological studies on the mangrove crabs.

Objective: Evaluate the economic feasibility of mangrove crab production in Guam as a prelude to further work in the area.

The mangrove crab (*Scylla serrata*) reaches more than 20 centimeters in carapace width and more than two kilograms in weight. It naturally ranges from South Africa to Hawaii and from Japan to New Zealand and is indigenous to Guam. Due to a lack of habitat and strong local demand, Guam imports approximately 3,000 live crabs per month. The crabs retail for $8.25 to $8.75 per pound and have a ready market.

Investigators obtained mangrove crab production data from the Tungkang Marine Laboratories in Taiwan and the National Prawn Production Center in Malaysia and reviewed the literature on crab culture in the Philippines. They also visited crab farms, crab fattening operations and crab sellers in Malaysia and Taiwan. Based on the information gathered, investigators project that mangrove crabs could be commercially cultured in Guam assuming the following three points:

- crabs could be cultured in ponds along with milkfish. This would necessitate displacing the milkfish on a pound-for-pound basis with crabs in polyculture;
- the physical management of the pond would not need to be modified, so no additional costs would be incurred;
- commercial culture on Guam would use a maximum stocking density of one crab per square meter.

The investigators projected the following production parameters for Guam: 25-gram crabs would be stocked at a density of 1.0 crab per square meter, grown out for 180 days at an average rate of 1.75 grams per day to an average size of 340 grams. The projected survival rate is 75 percent and the project feed conversion ratio is 2.5. These estimates of the physical production parameters are derived from data from the other locations and have not been tested on Guam. However, given these points, investigators estimate that replacing 3,000 pounds of milkfish per acre of pond with mangrove crabs would yield a net gain of more than $9,000 per acre. Even using a stocking density of one crab per two square meters would result in a net gain of more than $4,500 per acre. In fact, the preliminary analysis indicates that the addition of mangrove crabs to milkfish ponds will always increase the profitability of the ponds.

Work Planned

Crabs caught in Guam rivers will be put into the quarantine system and screened for pathogens. In addition, studies of crabs' food preferences and captive growth rates will be conducted, after which a detailed economic feasibility analysis of mangrove crab culture in Guam will be performed.

Impacts

Aquaculture in Guam primarily produces tilapia, milkfish and shrimp. Diversification is necessary to develop the industry, but the Guam government has stringent regulations regarding importation of species. Guam currently has no facility in which aquatic animals can be quarantined and screened for pathogens, which is necessary to avoid introducing pathogens that could be dangerous to the carrier species as well as species already present on farms. This project provided a sorely needed quarantine facility at which imported aquaculture species can be held in order to ensure their health status prior to introduction to farms or the Guam Aquaculture Development and Training Center's hatchery. Mangrove crabs were used as a test species for the quarantine facility because they could potentially be a valuable aquaculture crop in Guam.

Support

This project is receiving funding from the Center for Tropical and Subtropical Aquaculture (CTSA), the University of Guam (UOG) and the Hawaii State Aquaculture Development Program (ADP).

		Other Support			**Total**
Year	CTSA	UOG	ADP	Total Other	**Support**
One	$50,234	$18,000	$1,000	$19,000	$69,234
Total	**$50,234**	**$18,000**	**$1,000**	**$19,000**	**$69,234**

Publications, Manuscripts or Papers Presented

None.

Disease Management for Hawaiian Aquaculture

Dates of Work

April 1993 through October 1995

Funding Level

$159,670

Participants

- Dr. James Brock, Hawaii State Aquaculture Development Program;
- Dr. Brad LeaMaster, Department of Animal Sciences, University of Hawaii;
- Dr. Rick Spencer, Hawaiian Marine Enterprises.

Project Objectives

The objectives of this project are to:

- provide aquaculture health management extension support to commercial farms;
- identify contributing factors that may be important to the occurrence of bacterial disease during growout of Chinese catfish (*Clarias fuscus*);
- field test a preventive strategy to mitigate losses of cultured Chinese catfish (*Clarias fuscus*) during growout in Hawaii due to two bacterial diseases, *Aeromonas hydrophila* and *Edwardsiella tarda* septicemia;
- screen juvenile and adult cultured Chinese catfish and tilapia (*Oreochromis mossambicus*) for potential pathogenic fish viruses;
- assess the infectivity of IHHN virus in feces after passage through the digestive tract of a species of water bird;
- provide diagnostic and health management support to the CTSA-funded project titled “Ornamental Aquaculture Technology Transfer” and implement management practices and standard disease treatment strategies to improve fish survival and reduce the abundance of pathogenic parasites in imported groups of freshwater tropical aquarium fish;
- document the principal ectoparasites and assess their effects on cultured tilapia and mullet in a traditional Hawaiian fishpond;
- assess samples of *Gracilaria* spp. for the presence of *Gracilaria* Gall Syndrome (GGS), determine how the syndrome is transmitted, and identify potential chemical controls for it.

Anticipated Benefits

This project focuses on problems that either directly affect production of crops in Hawaii's aquaculture farms or relate to assistance to other CTSA-funded projects. Examples include activities that address application of procedures for control of bacterial diseases in cultured Chinese catfish, initial investigation of a serious new disease in cultured seaweed, a study to increase the understanding of transmission of selected viruses in cultured shrimp, documentation of ectoparasites on fish cultured in Hawaiian fishponds, and work focusing on disease control in ornamental fish culture in Hawaii. These efforts will improve production of Hawaii aquaculture facilities or procure new information that will eventually lead to improved health management strategies for improved aquaculture productivity in Hawaii.

Progress and Principal Accomplishments

Objective: Provide aquaculture health management support to commercial farms.

Investigators made 80 site visits to 10 farms to provide health management extension assistance under this project. In May 1994, a serious disease outbreak occurred in farmed *Penaeus vannamei* in Kahuku, Hawaii. It caused mortality rates higher than 95 percent within 14 to 30 days of stocking. Studies initiated to determine the cause and a means of controlling the disease led to the discovery of a new shrimp virus in Hawaii. The virus was thought to be the Taura Syndrome agent, which was confirmed in subsequent studies by other laboratories. Additionally, this study found that *P. stylirostris* is largely resistant to Taura syndrome. The Hawaii farm that was affected by Taura syndrome then began culturing *P. stylirostris* and has achieved production levels equal to or greater than those achieved with *P. vannamei.*

*Objective: Identify contributing factors that may be important to the occurrence of bacterial disease during growout of Chinese catfish (*Clarias fuscus*) and develop practical strategies for the control of bacterial diseases during their growout.*

Scientists in Thailand who have experience with disease management in freshwater aquaculture fishes in Asia were contacted for information. They forwarded a series of publications on the culture, environmental quality and disease problems for *Clarias* spp. The publications provided comparative information on diseases that have been a problem in Hawaii.

A study was initiated to determine the occurrence and severity of disease episodes in Chinese catfish reared in tanks. The study tracked the occurrence and severity of disease episodes in six tanks of catfish given the same feed. Fourteen dead fish were retrieved from the six tanks during the first sampling period. Those fish and, to a far lesser degree, the fish sampled for weighing showed physical changes that

suggested internal bacterial infection, such as swelling of the abdomen over the anterior lobes of the kidney or small skin sores.

Investigators collected a set of water specimens from the six tanks and measured bacterial levels. The bacterium *A. hydrophila* was retrieved in samples from five of the tanks; the bacterium *E. tarda* was not identified from any of the samples.

Skin scrapings from a sample of five fish per tank were done to monitor the prevalence and the relative abundance of ectoparasites. The scrapings showed two types of ectoparasites, *Tricodina* sp. and *Gyrodactylus* sp., that are commonly associated with cultured Chinese catfish in Hawaii. The findings suggest that *Tricodina* sp. infestation had declined in the older groups of fish. *Gyrodactylus* sp. were found in fish from only one tank.

An initial database was developed on the physical and chemical water quality parameters in Chinese catfish culture tanks. Water samples were collected four times over approximately 24 hours. The samples were evaluated for temperature, dissolved oxygen, pH, carbon dioxide, hydrogen sulfide, secchi disc turbidity, hardness, alkalinity, chloride, total ammonia, nitrite, nitrate and ortho-phosphate.

Water quality and commercial diet factors were evaluated in relation to the onset of disease episodes in Chinese catfish populations under farm conditions. The initial sample findings suggested that juvenile Chinese catfish can tolerate large diurnal variations in temperature, dissolved oxygen, carbon dioxide and pH without the occurrence of high mortality episodes of bacterial or ectoparasitic disease. However, evaluation of the physical and chemical measurements during disease outbreaks suggested a positive correlation between occurrence of disease and elevated levels of ammonia or nitrate. Elevated levels of these compounds were associated with one of two factors: either the water supply is temporarily lost due to mechanical or electrical failure, or the phytoplankton/biological filtration community in the culture tank failed.

Bacterial pathogens were isolated from dead Chinese catfish during disease outbreaks. *A. hydrophila* accounted for an average of 80 percent of viable bacteria in the water samples. *E. tarda* rarely was isolated from catfish culture tank water. In addition, the bacterial pathogen *A. hydrophila* is the dominant flora in the water of these catfish culture tanks during periods of minimal losses to bacterial infection. This suggests that the animals are normally exposed to relatively stable numbers of *A. hydrophila* continuously throughout the culture period and that disease events involving this pathogen involve the contribution of more etiological variables than the bacteria and the host fish.

Objective: Field test a preventive strategy to mitigate losses of cultured Chinese catfish during growout in Hawaii due to two bacterial diseases, Aeromonas hydrophila *and* Edwardsiella tarda *septicemia.*

A. hydrophila was isolated and will be grown for use in a vaccination trial. The ultimate goal of this effort is development of a vaccine to prevent the disease.

*Objective: Screen juvenile and adult cultured Chinese catfish and tilapia (*Oreochromis mossambicus*) for potential pathogenic fish viruses.*

Sixty tilapia of various ages and sizes were collected from five Oahu locations for a virus isolation study. Evaluation of various organ tissues revealed no viruses. These results support findings from previous tilapia disease cases on Oahu. Both wild and cultured tilapia (*Sarotherodon melanotheron* and *Oreochromis mossambicus*) populations have been afflicted by a previously unrecognized syndrome that causes high mortalities and has negatively affected production at several Oahu farms. Analysis of dying tilapia from various Oahu sites suggests that the cause is an intracellular rickettsia-like organism (RLO).

Dead and dying Chinese catfish from an Oahu farm that has a history of chronic disease problems were evaluated by cell culture methods for viruses. Evaluation of various organ tissues showed no evidence of an infectious virus.

Objective: Field test an approach for IHHNV decontamination of shrimp ponds.

Six ponds at the site of the former Amorient Aquafarm in Kahuku, Hawaii, were selected for the study. All six ponds were drained, and the soil's moisture content and pH balance were measured. The three control ponds were refilled with water within three days of draining. The surfaces of the three remaining ponds were spread with a layer of lime at a rate of 2,500 pounds per acre and were left undisturbed for two weeks.

Investigators sampled soil from the limed ponds weekly to determine the moisture content and pH level. The lime distribution was uneven, so the pH rose to 11 in some areas while remaining unchanged in other areas. After two weeks, the limed ponds were refilled and stocked at a per-acre rate of 60,000 *Penaeus vannamei* and 10,000 *P. stylirostris*; the latter are highly susceptible to IHHNV. Results were very disappointing. *P. stylirostris* survival and shrimp production levels were no better in the limed ponds than in the control ponds.

Objective: Assess the infectivity of IHHN virus in feces after passage through the digestive tract of a species of water bird.

Two cages were constructed to hold the two juvenile night herons obtained for the study. The birds have adapted well to captivity and readily eat fish and fresh shrimp.

Objective: Provide diagnostic and health management support to the CTSA-funded project titled "Ornamental Aquaculture Technology Transfer," and implement management practices and standard disease treatment strategies to improve fish survival and reduce the abundance of pathogenic parasites in imported groups of freshwater tropical aquarium fish.

Eight groups of freshwater tropical fish, imported for the CTSA-funded project titled "Ornamental Aquaculture Technology Transfer," were evaluated and found to be free of diseases.

Diagnostic assistance was provided to three farmers who were losing fry and juvenile discus (*Symphysodon discus*) stock. Parasite and water quality problems were found. Parasite treatments were suggested and solutions to the water quality problems were recommended. Water quality monitoring data on temperature, dissolved oxygen, pH, carbon dioxide, alkalinity, hardness, chloride, total ammonia, nitrite and nitrate are being gathered at one of the ornamental fish farms. The data will help in determining appropriate water quality parameters for tropical fish culture in Hawaii.

Objective: Document the principal ectoparasites and assess their effects on cultured tilapia and mullet in a traditional Hawaiian fishpond.

Two species of tilapia (*Oreochromis mossambicus* and *Sarotherodon melanotheron*) and mullet (*Mugil cephalus*) from a traditional Hawaiian fishpond were examined for ectoparasites. Tilapia exhibited the following ectoparasites and pathogenic infections:

- *Caligus* sp.,
  Neobenedenia melleni,
- *Trichodina* sp.,
- *Scyphidia* sp.

Mullet exhibited the following ectoparasites and pathogenic infections:

- Digenetic trematode metacercaria,
- Epitheliocystis,
- *Trichodina* sp.,
- *Scyphidia* sp.,
  Myxobolus equisquamalis,
- *Eimeria* sp.

Objective: Assess samples of Gracilaria *spp. for the presence of* Gracilaria *Gall Syndrome (GGS), determine how the syndrome is transmitted, and identify potential chemical controls for it.*

A cooperating commercial seaweed farmer constructed a greenhouse for on-site experiments with infected *Gracilaria*. A series of observations on the farm led to the suspicion that the fresh water might be a potential source of GGS. In March, a two-month experiment was undertaken to compare the onset and severity of GGS in *Gracilaria* exposed to different freshwater treatments. Two replicates were done of each of the following experiments:

- seaweed held in seawater and rinsed in unsterilized freshwater every three days;
- seaweed held in a mixture of 80 percent seawater and 20 percent unsterilized freshwater;
- seaweed held in a mixture of 80 percent seawater and 20 percent UV-sterilized freshwater;
- seaweed held in full strength seawater with no exposure to freshwater.

The effect of adding penicillin to seawater containing GGS-positive seaweed was tested. Preliminary observations suggest that penicillin reduces or eliminates GGS symptoms, which supports previous tests in flask cultures of GGS-positive *Gracilaria*. This finding implies that a bacterial agent may cause GGS.

Impacts

Hawaii aquafarmers have seen their Chinese catfish crops devastated by bacterial diseases and their penaeid shrimp crops hit hard by IHHNV and Taura Syndrome in the past two years. By determining methods to control such disease problems, this project could save crops worth hundreds of thousands of dollars yearly.

Support

Support was provided by the Center for Tropical and Subtropical Aquaculture (CTSA), the University of Hawaii (UH) and the Hawaii State Aquaculture Development Program (ADP).

Year	CTSA	Other Support			Total Support
		UH	ADP	Total Other	
One	$41,638	$15,988	$5,329	$21,317	$62,955
Two	$68,116	$10,658	$5,329	$15,987	$84,103
Three	$49,916	$13,323	$5,329	$18,652	$68,568
Total	**$159,670**	**$39,969**	**$15,987**	**$55,956**	**$215,626**

Publications, Manuscripts or Papers Presented

None.

Investigation of Mullet Net-Pen Stocking Densities in Coastal Fishponds for a Stock Enhancement Nursery Program

Dates of Work

April 1992 through October 1995

Funding Level

$88,700

Participants

- Dr. Kenneth Leber, The Oceanic Institute;
- Dr. Robert Nishimoto, Department of Aquatic Resources, Hawaii State Department of Land and Natural Resources;
- Mary Brooks, Hawaiian Island Sea Farms.

Project Objectives

The overall goal of this project, which received funding under the Center for Tropical and Subtropical Aquaculture's Fifth and Seventh Annual Plans of Work, was to determine whether traditional Hawaiian fishponds and other in-ocean ponds could play a role in improving inshore fisheries by serving as nursery facilities for stock enhancement efforts. Specific objectives related to that goal are to:

- synthesize available literature and data on Hawaii fishponds in reference to socioeconomic feasibility issues related to their use as a stock enhancement resource;
- develop transport methods to transfer mullet from the hatchery to the coastal fishponds;
- determine the optimal stocking density for juvenile mullet in net pens;
- determine the optimal net-pen design for mullet nursery culture in coastal fishponds;
- compare growth and survival of juvenile mullet in net-pens with land-based tank culture;
- establish preliminary economic data for use in analysis of the cost of net-pen operations and production.

Reason for Termination

This project was terminated because all the objectives were completed.

Principal Accomplishments

Objective: Synthesize available literature and data on Hawaii fishponds in reference to socioeconomic feasibility issues related to their use as a stock enhancement resource.

A report on general conditions in coastal Hawaiian fishponds similar to Heeia Fishpond, which is the site of this project, was compiled. Fishponds played an important historical role in Hawaii, but in modern times, a long period of neglect, disuse and lack of appreciation for their potential reduced their number from 360 to approximately 70. In the past ten years, state, federal and private efforts began fishpond restoration and operation projects.

Hawaiians built several types of fishponds, which are typically shallow, with a muddy, sandy or rocky substrate and soft bottom overlying the fringing coral reef. Larger ponds are often found within embayment areas that provide wave protection. Heeia Fishpond is a type of fishpond known as "loko kuapa," which are from 300 to 600 years old. These fishponds are marine enclosures in which a section of fringing reef is fully surrounded by a wall built of rock and coral. The walls usually extend to the edge of the reef and are adjacent to deeper marine waters and currents. Water and fish pass from ocean to pond through gates called makahas. Tides and currents frequently create water exchange rates of 100 percent per day. Loko kuapa were used to raise primary herbivores, such as mullet and milkfish, and to hold excess fish from abundant ocean catches.

Objective: Determine effective and efficient net-pen designs for mullet nursery systems in shallow coastal fishponds.

A survey of fish containment systems was completed. A special pen, which combined the best features and eliminated the disadvantages of fixed and free-floating systems, was developed. Eighteen of the 2-cubic-meter cages, built of hard plastic, quarter-inch mesh with a unique mooring system that allowed them to float at high tide and be supported off the bottom in extremely shallow water at low tide, were deployed and stocked.

The cages remained stable during 40-mile-per-hour wind gusts. However, the small-gauge mesh necessary to contain the juvenile mullet proved to be an ideal surface for rapid, abundant growth of filamentous algae. The algae restricted water flow, was difficult to remove and seemed to be a factor in chronic, low-grade mortality across all stocking densities within the trial population. Because of these problems, different containment systems were designed and tested.

A 200-square-meter, rectangular, escape-proof fenced pen was built. It was initially built with a fence of 1/8-inch mesh surrounded by a 1-inch mesh fence; both were attached to the pond bottom. To control algal fouling, the inner fence can be

removed and replaced with clean fencing of a slightly larger mesh size. The prototype was stocked with 15,000 juvenile mullet in two shipments from The Oceanic Institute. Fish from one of the stocking shipments were stressed during transport because dissolved oxygen concentrations fell to extremely low levels. Thus, the second year of the project developed transport methods that ensured the healthy condition of fish transported from the hatchery to the fishpond.

Observations of mullet behavior in the test pen showed that the fish schooled and fed regularly, grew rapidly, had easy access to the bottom substrate and appeared to resist parasitic outbreaks, which were very prevalent in the first cage design. The higher water volume in the new pen appeared to reduce rapid deterioration of water quality and resulted in a more stable culture environment. However, the rectangular shape and nearshore location presented distinct disadvantages. First, the fish tended to group in the corners of the rectangle, making fish maintenance and sampling more difficult. Second, the nearshore location prevented adequate water circulation. For these reasons, investigators modified the pen design to an octagonal-shape and placed it farther from shore.

A large-scale, octagonal pen, 40 feet in diameter, underwent testing to determine if any design refinements were needed before three pens were stocked for the year-two growout trial. In August 1994, the octagonal pen was stocked with 20,000 25- to 35-millimeter mullet postlarvae for growout trials. The pen was located farther from shore to ensure a high water turnover rate and prevent fouling. Trial results showed that this size and style pen is conducive to high survival and growth. The pen style was also easy to maintain, operate and harvest and prevented predator entry and crop escape. This design was economical and efficient to construct, could be used for other species and locations, and could be easily enlarged.

Objective: Determine the optimal stocking density for juvenile mullet in net-pens.

In the trials using nine cages of the original design, fish were stocked at three densities: 1 fish per liter, 1.5 fish per liter, and 2 fish per liter. Results indicated that growth and survival were independent of the three stocking density treatments. Survival rates ranged from a low of 3 percent in the high density cage to a high of 34 percent in the low density cage. Although the final fish count from each of the nine cages varied considerably, overall survival and growth rates were independent of stocking density.

Objective: Develop transport methods to transfer mullet from the hatchery to the coastal fishponds.

A key objective of this project was to develop fish transport methods that would assure the healthy condition of striped mullet postlarvae on arrival at coastal ponds after transport from the hatchery. If postlarvae are healthy when stocked in the pond, they can more easily resist stress-mediated disease and early mortality.

Transport techniques for shipping stage-one fingerlings are being adapted to shipping postlarvae both intra-island by truck and interisland by barge or air freight.

Postlarvae ranging from 25 mm to 35 mm were packed in aerated plastic boxes within boxes and transported from The Oceanic Institute to Heeia Fishpond by truck. The plastic bags were then hand-carried directly to experimental net-pens and stocked.

Researchers also set up a tank system for conducting experiments designed to establish an interisland barge transport capability. A 1,476-liter live fish transport tank was fitted with a battery-powered oxygen system consisting of an oxygen tank, regulators, dissolved oxygen meter and diffusers. The tank was also fitted with a circulation and aeration system with bioactive filters, agitators and carbon dioxide to ensure water quality. The entire system was on a portable platform. The refinement of the system produced a viable, cost-effective method to transport fish interisland by barge.

Objective: Compare growth and survival of juvenile mullet in net-pens with land-based tank culture.

Growth and survival rates in the original cages were far poorer than those obtained in the land-based tanks at The Oceanic Institute. However, the newly designed net-pens appeared promising as cost-effective systems for growing out juvenile fish in fishponds for aquaculture or stock enhancement purposes. Results from the final harvest in mid-July showed variable survival and slow growth. The investigators concluded that using this system for mullet aquaculture was not economically viable.

Objective: Establish preliminary economic data for use in analysis of the cost of net-pen operations and production.

Because problems with the year one cage design resulted in poor fish survival and growth, an economic analysis of operations and production is not viable based on year one economic data. However, cost data collected during the growout trials indicated that the unit and operations costs per fish produced related directly to the scale of operation. Generally, costs are lower per fish with larger cage units.

Results from the first year of the project showed that cage cleaning methods had the greatest impact on operating expenses. The redesigned pen used in the second year of the project employed a mesh removal and replacement system to control algal fouling rather than the manual cleaning methods that were necessary with the year one cage design. Thus, cleaning expenses were minimized. However, the poor growth rates and survival of the mullet in the growth trials showed that this system is not economically viable for aquaculture of mullet. It may be viable for other species.

Impacts

This project developed a unique net-pen system for use in traditional Hawaiian coastal fishponds. The associate investigator plans to use private funding to test the net-pen with other species, including Pacific threadfin (*Polydactylus sexfilis*), which is a highly valued local food fish.

Support

This project was funded by the Center for Tropical and Subtropical Aquaculture (CTSA).

Year	CTSA	Total Support
One	$28,700	$28,700
Two	$60,000	$60,000
Total	**$88,700**	**$88,700**

Publications, Manuscripts or Papers Presented

None.

Development of Threadfin (*Polydactylus sexfilis*) Fry Production Technology

Dates of Work

April 1993 through October 1995

Funding Level

$204,500

Participants

- Dr. Anthony Ostrowski and Dr. Kenneth Leber, The Oceanic Institute;
- Dr. Christopher L. Brown, Hawaii Institute of Marine Biology, University of Hawaii;
- Michael Fujimoto, Anuenue Fisheries Research Center.

Project Objectives

The overall goal of this project, initiated under the Center for Tropical and Subtropical Aquaculture's Sixth Annual Plan of Work, is to develop the hatchery and nursery culture technology for Pacific threadfin (*Polydactylus sexfilis*). Specific objectives related to that goal are to:

- resolve bottlenecks in threadfin seedstock production, which will involve reducing mortality due to cannibalism by active and passive grading and by preventing cannibal development with optimal culture protocols during the larval rearing and Stage One nursery phases;
- resolve bottlenecks in threadfin quality, including opercular deformities;
- demonstrate and document threadfin fingerling and fry mass production technology.

Anticipated Benefits

This project will benefit the development of commercial aquaculture by providing a mass seedstock production technology for Pacific threadfin that can be applied to other high-value marine fishes. Industry will be able to establish a market for commercially cultured marine fishes in Hawaii, creating economic benefits for commercial producers throughout the state.

Progress and Principal Accomplishments

Objective: Resolve bottlenecks in threadfin seedstock production.

The first step in resolving the seedstock production technique is to secure a sufficient quantity of high-quality eggs from captive broodstock. In the first year of the project, investigators conducted a total of 148 spawns that produced 164,907,506 eggs with an average fertilization rate of 78.7 percent.

In an effort to overcome the high mortality rate of larvae during the first 15 days after hatching, investigators conducted 15 larval rearing (Days 0 to 25) experiments in year one. The first trial examined growth rate data from the rotifer feed stage (Days 1 to 11). Cannibalism does not appear possible up to Day 11. Seven trials compared survival and growth rates of larvae stocked at two different densities 10 eggs per liter and 30 eggs per liter. These trials were inconclusive, producing widely varying harvest densities and larval sizes.

Two trials compared the standard diet provided after Day 15 with a diet composed of ground squid, smelt and krill. Five trials examined whether threadfin larvae would accept a pelleted feed diet between Days 15 and 20. Efforts to wean these larvae from live feeds with four different types of pelleted feeds were unsuccessful. To date, weaning has taken place only after Day 26.

A third goal under this objective was to develop a rearing technology with less than 1 percent mortality per day within the cannibalistic period (Days 25 to 50). Investigators conducted a number of Nursery Stage One (Days 26 to 40) and Nursery Stage Two (Days 41 to 60) experiments that examined the effects of grading, feeds and rearing systems on survival. These trials found that cannibalism is a phenomenon that occurs primarily during Nursery Stage One (Days 26 to 40). Given optimum conditions of diet and rearing systems, cannibalism can be controlled, and survival rates of 90 percent or more can be achieved consistently during both nursery stages at stocking densities of at least 2 to 3 kilograms of fish per cubic meter.

Nursery Stage One experiments examined the effects of size grading on survival to Day 40. The results provided clear evidence that cannibalism can be significantly reduced by size grading. Ideally, the fish should be graded before Day 26; however, grading even at Day 26 significantly improved the survival rate during this stage.

Growth rates greater than 20 percent per day in Nursery Stage One and 10 percent in Nursery Stage Two at feed conversion ratios approximating 1-to-1 can be obtained on pelleted, practical feeds. That means that for each kilogram of feed that a fish eats, the fish will grow one kilogram.

Another set of Nursery Stage One trials compared four diets, which were Rangen Nippai Brine shrimp flake feed (RNB); Rangen Salmon Elite (RAN); Oceanic

Institute Mahimahi Nursery Diet (OIM); and Moore-Clarke Mahimahi diet (MCM), and three rearing systems, round tanks, oval raceways and doughnut-shaped circular tanks.

Overall survival was highest for fish raised in oval raceways -- 86 percent compared to 71 percent in doughnut tanks and 60 percent in round tanks. The combination of the OIM diet with the oval raceway resulted in a 63 percent improvement in fish survival compared to those raised in either round tanks and fed either the RNB or RAN diets.

Objective: Resolve bottlenecks in threadfin production and quality, including opercular deformities.

Experiments conducted at Anuenue Fisheries Research Center (AFRC) examined the cause of the deformed operculum condition in juvenile threadfin. The experiment sought to:

- identify and document the types of deformities that occur when juvenile threadfin are fed different commercial diets;
- determine whether these deformities occur at a specific period of development;
- and determine whether a particular age is critical to normal opercular development.

Results of the experiments indicated that deformities may be caused by differences in the formulation of weaning diets. Although 23- to 26-day-old threadfin postlarvae readily accepted commercial semi-moist feeds formulated for salmon and trout (Bioproducts Biostarter and Biogrower Diets, respectively), these fish had more operculum deformities of various kinds by Day 40 than fish that were fed a dry diet formulated for mahimahi (Moore-Clarke Mahi Diet). Fish given the semi-moist diets exhibited not only flared and reduced operculum but also

- lordosis;
- scoliosis;
- crooked lower jaw;
- dimple head, which is suspected to indicate an early stage of lordosis;
- cataracts;
- and popeye.

The deformed fish were removed at Day 40, but deformities continued to occur throughout the Nursery Stage Two (Day 41 through Day 60). These results suggested either a lack of a nutrient or a reaction to the diet formulation or to the quality of an ingredient.

Another trial examined the effect of dietary Vitamin C levels on the incidence of operculum deformities. Results were inconclusive because of problems attaining prescribed treatment levels in the commercial feeds tested. Other trials indicated that

water quality also plays a role in the occurrence of operculum deformities in threadfin. Fish raised in oxygen concentrations above 80 percent saturation show a dramatic decrease in the incidence of flared operculum. Fish populations raised in water with less than 65 percent oxygen saturation have high incidences of flared operculum. Although mild operculum flaring is reversible, severe flaring is not. Fish with severely flared operculum also become more easily stressed during anesthetization. Therefore, it is recommended that juvenile threadfin be cultured under nearly oxygen-saturated conditions, that tanks be cleaned daily to remove feces and uneaten feed and that densities be reduced if oxygen levels begin to fall below 80 percent saturation.

Objective: Demonstrate and document mass production technology for threadfin fry.

During the first phase of the project, development of mass production techniques progressed rapidly. Based on a standard model developed at The Oceanic Institute, producing a 40-day-old juvenile threadfin costs an average of $0.58 per fish. During this reporting period, a series of small tank trials were conducted at The Oceanic Institute to reduce juvenile production costs by reducing the cost of producing live feeds in the hatchery. Results of the trials, which used 30-liter and 1.5-cubic-meter tanks, indicated that the optimum live feed regimen in the hatchery employs rotifers until the threadfin larvae are 15 days old and then employs *Artemia* from that point. *Artemia* did not appear to substitute well for rotifers in larval rearing, and adding them early in the feeding regimen did not offer any advantage. This finding provides a substantial savings on the cost of these live food items.

Attempts to introduce pelleted feed on Day 15 of the larval rearing cycle were inconclusive due to unusually high mortality in both the live-feed control groups and the treatment groups. The mortalities probably were caused by a combination of the small size of the tanks (30 liters) and an inability to control temperature.

Impacts

Diversification of aquaculture crops will provide a better economic base for the industry. Because Pacific threadfin are a high-value fish, perfection of technology to culture this species will offer farmers an opportunity to improve their overall profitability.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture (CTSA), The Oceanic Institute (OI), the Hawaii state Aquaculture Development Program (ADP) and the Anuenue Fisheries Research Center (AFRC).

Year	CTSA	Other Support				**Total Support**
		OI	ADP	AFRC	Total Other	
One	$42,000	$87,000	$15,000	$10,000	$112,000	$154,000
Two	$92,500	$50,000	$15,000	$10,000	$75,000	$167,500
Three	$70,000	$50,000	$15,000	$10,000	$75,000	$145,000
Total	**$204,500**	**$187,000**	**$45,000**	**$30,000**	**$262,000**	**$466,500**

Publications, Manuscripts or Papers Presented

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Kelley, C. D., P. Bass, K. Leber. 1995. The production of Pacific threadfin fry for stock enhancement and aquaculture. Aquaculture '95: Proceedings of the 1995 World Aquaculture Society meeting. February 1 - 4, 1995. San Diego, California.

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Ostrowski, A. C. 1995. Nursery and Growout Production Techniques for the Mahimahi (*Coryphaena hippurus*) and Pacific Threadfin (*Polydactylus sexfilis*). *In*: Main, K. L., and C. Rosenfeld, eds. Culture of High-Value Marine Fishes in Asia and the United States: Proceedings of a Workshop. August 8 - 12, 1994. Honolulu, Hawaii.

Ostrowski, A. C., et al. In review. "Nursery production techniques for Pacific threadfin (*Polydactylus sexfilis*). *Aquaculture*. 1995.

Commercial Feasibility of Giant Clam Mariculture in American Samoa

Dates of Work

March 1989 to October 1995

Participants

Henry Sesepasara, Ray Tulafono, Bonnie Ponwith, Lui Bell, Pio Gaisoa, Dominique Gebauer, John McConnaughey, Fa`asega Kuresa, Ioelu Seve and Fa`atauvaa Lam Kitiona, American Samoa Department of Marine and Wildlife Resources (DMWR).

Reason for Termination

This project was terminated because all objectives were completed.

Project Objectives

The overall goal of this five-year project, initiated under the Center for Tropical and Subtropical Aquaculture's Second Annual Plan of Work, is to establish a giant clam culture demonstration station to be used for training, extension and economic feasibility studies. Specific objectives for the fifth and final year of the project related to that goal are to:

- produce giant clam juveniles for distribution to local farmers;
- develop and establish participation of the private sector in giant clam farming on the intertidal and near intertidal zones;
- investigate and develop local markets in American Samoa for giant clams;
- conduct a business feasibility study of giant clam hatchery and lagoon farming in American Samoa;
- develop an aquaculture education and training extension program that will target farmers, villages and government leaders and complement existing DMWR education program.

Principal Accomplishments

During the first year of the project, a project investigator obtained training in giant clam spawning and culture techniques from the Micronesian Mariculture Demonstration Center (MMDC) in the Republic of Belau. Investigators negotiated a lease for a hatchery site. In July 1990, Lui Bell, senior fisheries biologist for the

government of Western Samoa, was hired and assumed management of the project. By October 1990, enough of the hatchery facility was built so that spawning inductions could be conducted on *Tridacna derasa* imported from the MMDC. *T. derasa* was chosen as the target species for the project because broodstock and seed were readily available from the MMDC.

Investigators also continued to monitor growth, development and survival of clams in the Nuuuli lagoon growout nursery, which were planted in 1987 under a DMWR project. Predation by *Cymatium* snails was the biggest cause of mortalities. In June 1991, investigators constructed PVC racks fitted with cages to hold trays of clams for growout. This hanging method was found to reduce mortalities from *Cymatium* snail predation.

The first successful spawning inductions were conducted in January 1991. Through trial and error, investigators determined that the intensive method of larval culture was best suited to conditions at the facility. In addition, providing shade to reduce algal blooms during the juvenile stage was necessary. Investigators established a total of eight ocean growout nurseries, three of which were managed by private citizens who had been trained in nursery management techniques at the DMWR hatchery and nursery. According to DMWR statistics, giant clams were unavailable in the market place in American Samoa after 1988, probably because wild clam stocks were so depleted. However, DMWR records showed that clam meat had nearly tripled in price from 1982 to 1988.

School classes from grade one through college took field trips to the hatchery and nursery sites. During these visits, investigators lectured on clam taxonomy, general biology, the status of local giant clam species and giant clam culture methods and constraints. These educational efforts were intended both to make the students more environmentally aware and interest them in aquaculture.

Objective: Produce giant clam juveniles for distribution to local farmers.

Investigators built a new pump house and saltwater intake line and installed a new water pump. Tests showed the pump could achieve flows of 150 gallons per minute, more than double the rate required to fill all the raceways twice daily. The salt water intake line was extended to deeper water further from shore because of poor water quality conditions near shore.

In October 1994, the new hatchery manager, John McConnaughey, received training in spawning and larval rearing techniques from the regional aquaculture extension specialist. During the project's fifth and final year, the hatchery shifted its emphasis from production of *T. derasa* to *Hippopus hippopus,* a species better-suited to conditions in American Samoa. Although *T. derasa* grows slightly faster, *H. hippopus* is more resistant to the predator snail *Cymatium,* which is the major cause of clam mortalities in American Samoa.

Investigators attempted to induce spawning in approximately 120 broodstock *H. hippopus* and *T. derasa* over seven consecutive days in late October. However, significant quantities of viable eggs and sperm were not released, and the broodstock that were sacrificed for gonads had very regressed gonads. Whether this was due to seasonal factors or the broodstock being spawned too many times is unclear.

In December 1994, *T. derasa* broodstock spawned spontaneously. On the following day, approximately 3 million eggs were filtered, concentrated, moved to indoor settling tanks and reared according to protocol described in the giant clam manual by Heslinga et al. (1990). Zooxanthelle extracts were added to all tanks. The clams exhibited good survival rates and normal growth rates. In March, samples from two raceways showed the average clam had reached 3.0 mm in one raceway and 5.4 mm in another. Several hundred clams were transferred to the Nuuuli nursery site and to two private farms and continue to grow well.

T. maxima broodstock collected from the wild were induced to spawn on two occasions in 1995, and the resulting larvae are being grown out. *T. derasa* and *H. hippopus* broodstock spawned spontaneously every week from July through September 1995 when brought to the adult holding tank from the ocean nursery.

Adult nudibranches introduced to raceways with 100-day-old clams appeared to be effective at controlling algae, which had been a problem at the facility. However, as of June 1995, algae growth slowed considerably at the same time that a small, bright red annelid worm appeared in the tanks. Clam larval survival has improved as a result.

Security has been a major concern for the project, with numerous clams having been stolen. The situation improved with the installation of security gates in the access road.

Objective: Develop and establish participation of the private sector in giant clam farming on the intertidal and near intertidal zones.

Four individuals in three villages expressed interest in starting giant clam farms, and three of the areas were surveyed. Two sites in Nuuuli are expected to provide a habitat similar to the project's nearby nursery site. The third site, located in Maicata, was determined to be less than ideal because the reef is only about 200 meters wide, has no barrier and is exposed to high wave conditions.

Announcements were made on local television and in newspapers to recruit potential clam farmers. Sixteen individuals responded and received training in clam nursery culture. They were then assisted with starting their own small, private ocean farms and each given 25 3.5-year-old clams. The farmers are responsible for routine care of the clams. Project personnel visit each farm monthly to collect growth and survival data. Four of the 16 farms were destroyed by high waves in July.

Objective: Develop an aquaculture education and training extension program that will target farmers, villages and government leaders and complement existing DMWR education program.

An experimental nursery is being established at the American Samoa Community College's new marine science laboratory. The nursery will be stocked with 25 - 50 *T. derasa*. In addition, a number of how-to pamphlets are being developed for private farmers in Samoa.

Objective: Investigate and develop local markets for giant clams in American Samoa.

In February 1995, project personnel took *T. derasa* to several fish markets and restaurants to evaluate market acceptance. Market and restaurant owners said they would be interested in purchasing the clams and suggested prices they would be willing to pay (Table 1).

Table 1. Results of Preliminary Survey of Restaurant and Fish Market Owners

Date Clams Were Spawned	April 1991	June 1992
Age of Clams	3.8 years old	2.6 years old
Average Size of Clam	204 mm	133 mm
Acceptable Price Range for Whole Clams	$2 to $4 per clam	$1.75 to $2.50 per clam

Two taste tests and a clam marketing study designed by the University of Hawaii's Pacific Business Center Program were conducted. Data analysis and reports are being prepared and should be available by the end of the year. In addition, project personnel conducted another market study through which farmers have the opportunity to market clams and determine the prices they are likely to obtain. The farmers purchase clams for $1 per pound and then sell them at the times, locations and prices of their choosing.

Impacts

This project has started three giant clam growout nurseries that are run by private citizens and 12 additional ocean growout nurseries, thus providing diversification to the narrowly based economy and protecting the remaining wild stocks of clams. In addition, educational efforts help to increase young people's awareness of the status of American Samoa's wild giant clam stocks and interest in mariculture.

Recommended Follow-Up Activities

None.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture (CTSA), the Pacific Aquaculture Development Program (PADP) and the American Samoa Department of Marine and Wildlife Resources (DMWR).

Year	CTSA	Other Support PAA/PADP	DMWR	Total Other	Total Support
One	$17,300	$0	$17,900	$17,900	$35,200
Two	$15,000	$0	$23,500	$23,500	$38,500
Three	$20,000	$11,200	$22,410	$33,610	$53,610
Four	$29,000	$23,000	$28,100	$51,100	$80,100
Five	$29,000	$15,000	$47,900	$62,900	$91,900
Total	**$110,300**	**$49,200**	**$139,810**	**$189,010**	**$299,310**

Publications, Manuscripts or Papers Presented

None.

Differential Growth Rate Studies in Cultured Commercial Sponges

Dates of Work

April 1993 through October 1995

Funding Level

$100,126

Participants

- Richard Croft, College of Micronesia;
- Dr. Michelle Kelly-Borges, Natural History Museum, London, UK.

Project Objectives

The objectives of this project, initiated under the Center for Tropical and Subtropical Aquaculture's Sixth Annual Plan of Work, are to:

- improve the efficiency and production of commercial sponge farms by determining the factors responsible for variable growth rates in cultured sponges;
- and maintain the existing demonstration nursery.

Anticipated Benefits

Sponges grow very slowly, taking at least two years to reach market size. However, sponge growth rates vary widely; even sponges planted side by side grow at different rates. By determining the cause of growth rate variations, this project could improve the efficiency of sponge farms, thereby increasing the profitability to farmers.

Progress and Principal Accomplishments

Objective: Improve the efficiency of commercial sponge farms by conducting several simultaneous studies at the demonstration farm in Pohnpei, Federated States of Micronesia.

From April through December 1993, the sponges were selected, cut, tagged and planted for use in the experiments.

Experiment #1

The first study is examining the large differences in growth rates of cultured commercial sponges. The hypothesis in this study is that the variation in growth rates are a result of certain areas of the parent sponge growing more rapidly than others. This is based on data showing that one sponge cutting may grow 3 percent per month while a cutting planted three feet away on the same line may grow 18 percent per month.

One hundred thirty-eight large, wild sponges were collected. Each was cut into three disks: one from the top of the parent sponge, one from the middle and one from the bottom. The disks were then divided into two groups—one from the outside edge of each disk and the other from the inside edge. These sections were divided into cuttings larger than 200 grams and tagged. This resulted in six groups of tagged cuttings, which were planted by group.

A second component to this experiment is to examine the differences in growth rates between cuttings taken from various sections of bowl-shaped and ball-shaped parent sponges. Ball-shaped and bowl-shaped parent stock were each cut into a top layer, a middle layer and a bottom layer. The center of each layer was cut out, resulting in a donut-shaped outside section and a disk-shaped inside section (although the top layer of a bowl-shaped sponge does not have an inside section.) The resulting 1,100 cuttings were then segregated into 11 groups, tagged and planted together. The first 12 months of growth data are summarized in Tables 1 and 2.

Table 1. Cuttings from Ball-Shaped Sponges

	Top Layer		Middle Layer		Bottom Layer	
	Inside	Outside	Inside	Outside	Inside	Outside
Average Size	324 g	346 g	354 g	353 g	323 g	389 g
Maximum Size	555 g	475 g	575 g	490 g	705 g	580 g
Minimum Size	190 g	250 g	240 g	255 g	220 g	270 g
Ave. Monthly Increase	4%	5%	6%	6%	4%	7%
Range of Growth Rates	-2% to 12%	1% to 11%	1% to 15%	2% to 14%	1% to 16%	2% to 15%

Table 2. Cuttings from Bowl-Shaped Sponges

	Top Layer		Middle Layer		Bottom Layer	
	Inside	Outside	Inside	Outside	Inside	Outside
Average Size	Top layer does not have any inside cuttings	326 g	315 g	323 g	320 g	324 g
Maximum Size		695 g	480 g	515 g	505 g	465 g
Minimum Size		240 g	220 g	240 g	235 g	255 g
Average Monthly Increase		5%	4%	5%	5%	5%
Range of Growth Rates		1% to 18%	1% to 12%	2% to 13%	1% to 12%	2% to 11%

- Tagged sponges from both the bowl-shaped and ball-shaped parent stock grew an average of 4 to 7 percent monthly. The growth rates of all 11 groups of sponge cuttings range widely: from a low of -2 percent to a high of 18 percent. This may be attributed to the die-back of portions of some of the cuttings. If so, the lower growth rates should climb during the next 12 months, and the range of growth rates should narrow.
- At least twice as many cuttings from the inside section of the top, middle and bottom sponge layers showed negative growth as cuttings from the outside layer. This may be because the inside cuttings do not have any of the black "skin" that covers the outside of sponges and probably protects the cuttings.

Experiment #2

The second study is examining whether sponges with high growth rates will retain those high growth rates after being cut into smaller pieces. From the existing nursery, 35 sponges that have shown growth rates higher than 15 percent per month and now weigh more than 1,000 grams were selected. Each large sponge was divided into four cuttings, which were tagged, measured and planted. During the 17 months since planting, most of the cuttings grew at the same rate or at higher rates as their parent stock, and many of these cuttings reached the minimum sale size of 600 grams live, wet weight (Table 3). Data indicate that these would be the sponges that farmers would use to replant and expand their farms.

Table 3. Cuttings from High-Growth Rate Sponges	
Average Size	539 grams
Maximum Size	815 grams
Minimum Size	385 grams
Average Monthly Growth Rate	11%
Range of Monthly Growth Rates	7% to 20%

Experiment #3

The third study is examining whether cutting sponges with low growth rates stimulates their growth. The principal investigator selected 80 cultured sponges that weighed 400 grams or more and had exhibited growth rates of less than 5 percent per month. These sponges were divided into two or more cuttings of at least 200 grams each. The resulting 197 cuttings were tagged, weighed and planted. These cuttings grew at monthly rates ranging from 3 to 9 percent and averaging 5 percent (Table 4).

Table 4. Cuttings from Low-Growth Rate Sponges	
Average Size	324 grams
Maximum Size	520 grams
Minimum Size	170 grams
Average Monthly Growth Rate	5%
Range of Growth Rates	3% to 9%

Objective: Maintain the existing demonstration farm.

A colonial tunicate continued to foul the sponge growing lines and the sponges, causing them to be irregularly shaped. The tunicate was cleaned off the sponges and lines monthly. Broken growing lines and main suspension lines were replaced as needed. Sponges in Areas A and B were replanted on heavier weight growing lines than was originally used.

Objective: Obtain additional biological data.

A sponge systematist and ecologist who was hired as a project consultant identified the sponge being cultured for the project as *Coscinoderma mathewsi*. The Pohnpei lagoon is home to four wild sponge morphotypes: the ball-shape, the bowl-shape, the ring-shape and the digitate. An experiment is being conducted to examine whether the final morphology of cultured sponges is determined by the morphology of the parent stock or by the physical and biological environment of the cuttings during the culture period. For statistical purposes, at least three parent sponges of each type were required for replication, and at least 10 cuttings were taken from the six areas of each parent sponge. The 800 to 900 resulting cuttings were tagged, the circumference of each was measured and the live, wet weight of each was determined, and they were planted on growing lines.

Work Planned

Investigators will continue to gather and analyze growth and morphometric data.

Impacts

The data collected thus far indicate that cuttings grow at the same rate as their parent sponge. If this hypothesis is borne out, farmers can harvest and sell slow-growing sponges as soon as they are ready for market and hold back some fast-growing sponges with which to replant and expand their farms. This will ensure that sponges reach market size as rapidly as possible, increasing profitability of farms.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture (CTSA), the College of Micronesia (COM), Pohnpei Marine Resources Division (PMRD) and the principal investigator (P.I.).

		Other Support				**Total**
Year	CTSA	COM	PMRD	P.I.	Total Other	**Support**
One	$30,380.00	$75.00	$625.00	$990.00	$1,690.00	$32,070.00
Two	$39,746.00	$75.00	$475.00	$7,535.00	$8,085.00	$47,831.00
Three	$30,000.00	$75.00	$550.00	$1,990.00	$2,615.00	$32,615.00
Total	**$100,126.00**	**$225.00**	**$1,650.00**	**$10,515.00**	**$12,390.00**	**$112,516.00**

Publications, Manuscripts or Papers Presented

None.

Improvement of Tilapia Stocks in Hawaii Phase I: Collection and Identification of Present Stocks

Dates of Work

April 1994 through October 1995

Funding Level

$49,180

Participants

Dr. Kevin Hopkins and Dr. Leon Hallacher, University of Hawaii at Hilo.

Project Objectives

The objectives of this project are to:

- review the international, national and Hawaii technical and regulatory status of tilapia stocks and strains related to improvement of the tilapia aquaculture industry in Hawaii;
- morphometrically and genetically assess the status of farmed stocks from 12 sites and wild tilapia stocks from 12 sites on six Hawaiian islands;
- determine growth characteristics of existing farmed tilapias and compare the data with the available scientific literature;
- recommend measures to improve existing stocks with the available stocks or to propose importations of new tilapia strains or species based upon review of the collected information.

Anticipated Benefits

This project will provide the local tilapia industry and the regulatory community with the information required to make informed decisions regarding the need to import new strains or species of tilapia. Additionally, the project will provide information that can be used by local industry in estimating growth rates and yields for various populations of tilapia in Hawaii.

Progress and Principal Accomplishments

Objective: Review the international, national and Hawaii technical and regulatory status of tilapia stocks and strains related to improvement of the tilapia aquaculture industry in Hawaii.

The scientific literature both on introductions of tilapia into Hawaii and on the impact of tilapia introductions worldwide was reviewed.

Objective: Morphometrically and genetically assess the status of farmed stocks from 12 sites and wild tilapia stocks from 12 sites in Hawaii.

All known tilapia farmers in Hawaii were interviewed to determine the history of their tilapia stocks. On the basis of these interviews, the sampling design was revised to minimize duplication and ensure that all possible stocks would be sampled. Tilapia were collected in two separate samples from the commercial and field sites shown in Table 1.

Table 1. Sites From Which Tilapia Samples Were Taken

Island	Location	Tentative Field Identification
Hawaii	UH-Hilo farm	*Oreochromis macrochir* hybrid
	Jervis Fish Farm	Red *O. mossambicus*
	Okamura Fish Farm	*O. macrochir* hybrid
	Royal Hawaiian Sea Farms	Red *O. mossambicus*
		Sarotherodon melanotheron
Molokai	Kualapuu Reservoir	*O. mossambicus*
Kauai	Hanapepe River	*O. mossambicus*
	Nagao Farm	*Tilapia rendalli*
		O. mossambicus x O. hornorum hybrid
		S. melanotheron
	Amao Reservoir	*T. rendalli*
Maui	Maui Plantation	*O. mossambicus*
	Kealia Fish Farm	*O. mossambicus*
		T. rendalli
		O. macrochir
Oahu	UH Mariculture Research and Training Center	*O. aureus*
		Red *O. mossambicus*
	Waianae Coast Community Development Authority	Red *O. mossambicus*
	Nuuanu Reservoir #3	*T. rendalli*
		T. zillii
	McKinley High School	Red *O. mossambicus*
	Wahiawa Reservoir	*S. melanotheron*
	Anuenue Fisheries Research Center	Red *O. mossambicus*
	Honolulu Harbor	*S. melanotheron*
	Heeia Fish Pond	*S. melanotheron*
Philippines	Central Luzon State University, Republic of the Philippines	*O. niloticus*

The sampled fish were photographed and measured. Eye, muscle, fin and liver tissue from the collected fish were sampled and shipped to Genetic Analyses, Inc. in Smithville, Texas, for electrophoretic analyses. The collected fish were then fixed in formalin and transferred to alcohol for long-term storage. Meristic counts and taxonomic measurements were completed on all the preserved fish. Measurements taken included the number of gill rakers, the shape and size of the bone at the top of the gill arch, jaw length relative to body length, eye size and fin size.

Work was completed on the first phase of the electrophoretic analyses, which examined the protein structure of sampled tissues to determine the species of tilapia. Based on results of this work, 15 isozymes were selected for closer analysis in the second phase. This work, when completed, will enable investigators to determine the purity of local tilapia stocks. With that information, fish breeders will have some indications regarding the suitability of using local fish for breeding stock.

Objective: Determine growth characteristics of existing farmed tilapias and compare the data with the available scientific literature.

A computer database was created for entry of data collected during the project. The database, currently on a Macintosh® computer, uses a software program called Foxpro® that readily transfers across platforms, so it will be available for use on personal computers. Morphometric and meristic data were coded and transferred into a computerized database. Using this database, preliminary estimates of each characteristic (e.g., the number of scales in the lateral line, relative length of the head, etc.) were calculated and are now being compared to values published in scientific literature. Analyses of meristic and morphometric data should be finished by late September.

Work Planned

This project has been extended through December 31, 1995. Investigators will complete the electrophoretic analyses and the data analyses and prepare the project reports.

Impacts

As data analysis is still in the early stages, the impact of the findings has been limited to date. A major observation has been the widespread emergence of *S. melanotheron* as the dominant tilapia species in wild populations. In some cases, other tilapia species appear to have been completely displaced.

Support

This project was funded by the Center for Tropical and Subtropical Aquaculture (CTSA) and the University of Hawaii (UH).

Year	CTSA	Other Support UH	Other Support Total Other	**Total Support**
One	$49,180	$40,981	$40,981	$90,161
Total	**$49,180**	**$40,981**	**$40,981**	**$90,161**

Publications, Manuscripts or Papers Presented

None.

Ornamental Aquaculture Technology Transfer

Dates of Work

April 1993 through October 1995

Funding Level

$250,200

Participants

- Dr. Clyde Tamaru, Dr. Bruce Miller, Paul Olin, Richard Bailey and Brian Cole, Sea Grant Extension Service, University of Hawaii;
- Dr. Christopher Brown, Hawaii Institute of Marine Biology, University of Hawaii;
- Dr. Frank Chapman, University of Florida.

Project Objectives

The overall goal of this project is to establish consistent production and marketing of ornamental fish on existing Hawaii aquaculture farms. Specific objectives relating to that goal are to:

- obtain an assessment of the U.S. ornamental market;
- hire and retain an expert in commercial ornamental fish culture to support development of an ornamental production industry in Hawaii;
- import and evaluate the culture potential of selected ornamental fish species;
- evaluate the production economics of breeding and growout in selected species;
- establish ornamental fish in commercial production on cooperating aquaculture farms in Hawaii;
- provide seedstock and technical support to farmers;
- conduct a business feasibility analysis in conjunction with the Pacific Business Center, University of Hawaii.

Anticipated Benefits

The worldwide market for ornamental fish is about $1.4 billion per year. The United States alone imports approximately $40 million worth of tropical fish, and Florida's ornamental culture industry generates revenues of about $50 million annually. Hawaii's resources -- clean, plentiful fresh and salt water, competitive air freight costs, and a warm climate with no freezes -- could provide a competitive

advantage in the ornamental fish culture market and further diversify the economic base of the aquaculture industry in the islands.

Principal Accomplishments

This project includes objectives from the second year of the project titled *Introduction of New Species for Biological Culture Assessment Year Two*, which was initiated under the Center for Tropical and Subtropical Aquaculture's Fifth Annual Plan of Work as well as objectives from the project titled *Ornamental Aquaculture Technology Transfer*.

Objective: Obtain an assessment of the U.S. ornamental market and conduct a business feasibility analysis in conjunction with the Pacific Business Center, University of Hawaii.

The market assessment was completed. It found that ornamental fish are kept principally by households in the U.S.A., Canada, Europe and Japan. The U.S. market for ornamental fish is consistently growing, as are imports of ornamental fishes, which reached $45.2 million in 1993, and the net trade deficit. Most ornamental fishes sold through the pet trade are farm-raised freshwater species imported from Southeast Asia; wild-caught ornamentals from South America account for the second largest number of imports. Florida is the major domestic source of farm-raised ornamental freshwater fishes. The principal source of saltwater ornamental fishes is collection from the wild; the Philippines and Indonesia are the main exporters of these fishes. In the United States, saltwater ornamentals are collected from the coastal waters of Florida and Hawaii. Freshwater fishes account for 80 percent of the value of U.S. ornamental fish imports. Of the 1,539 species declared as ornamental fish, only 32 species -- all freshwater animals -- dominate the trade. The neon tetra and the guppy are the most popular ornamental fish in U.S. households, but a greater variety of species tends to penetrate the market as they become available. The average prices paid for imported ornamental freshwater fishes were 45 cents for egg layers and 22 cents for live-bearers. Patterns of import and export trade activities indicate that the major ports for U.S. distribution of ornamental fishes are Los Angeles, which accounts for 39 percent of all trade activity, Miami, which accounts for 22 percent, New York, which accounts for 16 percent, and Tampa and Honolulu, which each account for 6 percent.

The Pacific Business Center submitted a report titled *A Business Analysis of the Ornamental Fish Market for Hawaii*. Investigators drew the following generalizations from the report:

- Profit margins for each species vary, but the ready markets and easy culture requirements of live-bearing species that fall in the middle of the profit spread make them good candidates for culture.
- Ornamental fish culture can be profitable in Hawaii by following patterns established in the successful Florida industry.

- Hawaii farmers will enjoy a distinct advantage by targeting Seattle for ornamental fish marketing because neither Florida nor Singapore can send farmed fish directly to Seattle, which serves growing markets in British Columbia.

In order to do the business analysis, the investigators developed an interactive software program to analyze the potential profitability of various mixes of ornamental fishes on Hawaii aquaculture farms. The software comprised a series of linked spreadsheets that evaluated the relative profit potential of various species, the best species mix for growout production, the best commitment of space and resources at a particular site, the best mainland markets for Hawaii farmers to target, production and shipping costs, landed prices and overall profit potential. Reviewers recommended that the work group consider revising the software package to make it more user-friendly before distributing it to aquaculture farmers.

Objective: Hire and retain an expert in commercial ornamental fish culture to support development of an ornamental production industry in Hawaii.

Investigators hired Brian Cole, who has more than 10 years experience in ornamental fish production, including management of production systems, spawning induction, and disease diagnosis and treatment. Mr. Cole has provided farmers interested in ornamental fish culture with technical assistance in the form of

- public presentations on Oahu and the Big Island,
- site visits,
- hatchery design,
- and generating production data to be used in the development of business plans.

He has also developed and manages the demonstration ornamental fish culture facility at Windward Community College. This included

- installing a water treatment facility that impounds and aerates water to eliminate excess chlorine from the well water source,
- installing PVC liners in each of the ponds,
- and constructing an enclosed breeding facility equipped with 40 10-gallon aquariums that are being used for production of high health, F_1 tiger barbs.

Objective: Import and evaluate the culture potential of selected ornamental fish species.

Demonstration growout trials in cages and tanks were completed at the Windward Community College facility for a number of ornamental species. Results indicate that increasing stocking densities inhibits growth or causes significant

problems related to fin conformation or disease resistance. Subsequent trials will evaluate higher densities as fish become available.

Objective: Establish ornamental fish in commercial production on cooperating aquaculture farms in Hawaii.

Investigators evaluated the imported fish stocks for pathogens using wet-mount and standard histological methods. The animals found to be free of specific pathogens are used to produce high health F_1 offspring, which will serve as founder broodstock for commercial producers. Dr. James Brock of the Hawaii State Aquaculture Development Program examined and certified the fish listed below as specific pathogen-free.

Common Name	Latin Name
jewel cichlids	*Hemichromis bimaculatus*
rosy barbs	*Barbus conchonius*
neon swordtails	*Xiphophorus helleri*
sunset swordtails	*Xiphophorus helleri*
red wag swordtails	*Xiphophorus helleri*
tinfoil barbs	*Barboides shwanenfeldi*
rainbow sharks	*Labeo erythrurus*
albino rainbow sharks	*Labeo erythrurus*

Investigators stocked ornamental fish into ponds at two sites. In May 1994, ponds at Hanohano Farms were stocked with sunset swordtails, neon swordtails, high-fin rosy barbs, pineapple swordtails and jewel cichlids. Temperature, water flow and water quality were monitored regularly. As of mid-October, excellent spawning and growth rates had been observed in all but one pond. Harvesting and marketing began in mid-October.

In July 1994, one pond at Fong's Plantation was stocked with rosy barbs, sunset swordtail broodstock and catfish fry. Survival, growth and reproduction have been good to excellent for both ornamental species. A second pond will be stocked with neon swordtail broodstock, F_1 tinfoil barbs and F_1 tiger barbs. Rainbow sharks and tinfoil barbs will be separately stocked into two additional ponds. Four ponds at the Hawaii Aquaculture Group site in Kahuku were stocked with rosy barbs, swordtails and albino rainbow sharks.

Objective: Establish the consistent production of five species of high health ornamental fish at commercial farm locations in Hawaii.

Fong’s Plantation has produced neon swordtails, sunset swordtails, green swordtails, fancy goldfish, koi, rosy barbs and feeder guppies at levels far higher than expected and has sold them in local and mainland markets. Current sales have been estimated at $20,000 to $25,000 per year and rising. Fong’s is also growing broodstock tinfoil barbs, tiger barbs and rainbow sharks for future production.

Hanohano Farms received assistance in establishing commercial production of three varieties of swordtails, rosy and tiger barbs and two species that are discussed under the reverse osmosis objective (below). Additional funding from the Hawaii state Aquaculture Development Program provided fancy guppies, and project personnel have actively assisted in culture of that species.

Another commercial farm on Oahu and a farm on Molokai joined the project as cooperating sites in August 1995. The project also provided extension assistance in tropical fish culture to 22 entities, including other commercial farmers, various fish hobbyist clubs and corporations on five Hawaiian islands.

Objective: Provide seedstock and technical support to farmers.

Investigators established a standardized production unit system for intensive culture of live-bearing, ornamental fish. The production units comprise two 12-foot, circular tanks outfitted with breeding cages and a series of growout cages in ponds. A breeding cage in one tank is stocked with 1,000 females and 200 male broodstock swordtails, which produce 7,500 fry over 15 days. Then the caged broodstock are moved to the second tank for another 15-day spawning cycle.

At that point, the 15- to 30-day-old fry from the first cycle are stocked into growout cages in ponds. Each production unit in the ponds has nine growout cages, from which the older fish are continually harvested and sorted for marketing. After an initial three-month period, each production unit should be able to attain a marketing target of up to 15,000 fish per month. Data on the cost, productivity and problems encountered with these production units will be compiled during the project's third year.

Objective: Reproduce Amazon Basin fish using reverse osmosis technology.

Based on the findings of the business feasibility analysis, investigators began work on this objective in mid-October 1994. This technology is most effective for production of discus and angelfish, two of the four most profitable species identified in the analysis. An environmentally controlled, enclosed reverse osmosis production room was established at the Hawaii Institute of Marine Biology. Attempts to breed cardinal tetras have been unsuccessful but are continuing.

Hanohano Farms established an enclosed production room with environmental controls and a reverse osmosis water treatment system patterned after the facility at the Hawaii Institute of Marine Biology. Established breeding pairs of several varieties of angelfish and discus fish were introduced to the facility. The angelfish produced 3,000 marketable fry within four months after their introduction to the facility; the fry were sold for $0.40 each, for a total of $1,200.

Work Planned

Investigators plan to continue providing extension support to farmers interested in growing ornamental fishes and to produce an ornamental culture manual.

Impacts

This project will help to diversify the aquaculture industry in Hawaii and give farmers an inroad into the U.S. ornamental fish industry, which imported ornamental fish valued at $23.6 million in the first half of 1993. Most U.S. ornamental fish production is in Florida; few of those fish are shipped west of the Rocky Mountains, where demand is high. In addition, Japan and Canada are strong export markets for the U.S. ornamental industry. Hawaii will enjoy a distinct shipping advantage to the U.S. West Coast and Japan.

Support

This project received funding from the Center for Tropical and Subtropical Aquaculture (CTSA), Sea Grant Extension Service (SGES), the Hawaii state Aquaculture Development Program (ADP) and the Hawaii Institute of Marine Biology (HIMB).

Year	CTSA	Other Support				Total Support
		SGES	ADP	HIMB	Total Other	
One	$58,000	$2,050	$2,050	$0	$4,100	$62,100
Two	$122,200	$2,050	$2,050	$0	$4,100	$126,300
Three	$70,000	$7,022	$7,022	$6,082	$20,126	$90,126
Total	**$250,200**	**$11,122**	**$11,122**	**$6,082**	**$28,326**	**$278,526**

Publications, Manuscripts or Papers Presented

Brown, C. L. 1995. *Raising the Silver Arowana* (Osteoglossum bicirrhosum*).* Center for Tropical and Subtropical Aquaculture Publication #117. Waimanalo, Hawaii.

Publications

Dates of Work

March 1990 through October 1995

Funding Level

$103,000

Participants

Dr. Kevan L. Main and Patti Killelea-Almonte, Center for Tropical and Subtropical Aquaculture, The Oceanic Institute.

Project Objectives

The overall goal of this project is to disseminate information on aquaculture. Specific objectives related to that goal are to:

- publish a quarterly newsletter to communicate information about the activities of the Center for Tropical and Subtropical Aquaculture and its funded projects and the latest information about aquaculture from the nation and the region;
- develop and publish a biannual technical bulletin to communicate the status and progress of current activities to the CTSA Board of Directors, Industry Advisory Council and Technical Committee. The bulletin will also be sent to aquaculturists in the Pacific region and upon request to other interested parties;
- produce and publish final reports of selected CTSA-funded projects. These publications will be distributed free of charge to commercial producers, aquaculture researchers, extension agents and other interested parties throughout the Pacific region, with limited distribution in the United States;
- duplicate and distribute the other Regional Aquaculture Centers' videos and publications to information networks throughout the Pacific region.

Anticipated Benefits

In many locations in the Center for Tropical and Subtropical Aquaculture region, access to information is extremely limited, which handicaps the development of aquaculture. This project helps to overcome that obstacle by disseminating research results and other information that bears directly on commercial aquaculture production.

Progress and Principal Accomplishments

Objective: Publish a quarterly newsletter to communicate information about the activities of the Center for Tropical and Subtropical Aquaculture and its funded projects and the latest information about aquaculture from the nation and the region.

In August 1989, the Center developed and published the inaugural issue of its quarterly newsletter, *CTSA Regional Notes*. The staff handles all aspects of production for the Center's newsletter, including interviewing, researching and writing articles, and shooting or obtaining photos. *Regional Notes* provides the latest information on Center activities and aquaculture throughout the Pacific region. Published four times per year, it is distributed to approximately 1,000 individuals, organizations and universities worldwide. In 1990, the newsletter was expanded by one-third and began carrying two regular columns:

"PRAISE Pages" is a bibliography of journal articles; the column is prepared by David E. Coleman, coordinator of the CTSA-funded *Pacific Regional Aquaculture Information Service for Education.* In each newsletter issue, Coleman compiles a bibliography on a specific topic of interest to *Regional Notes* readers;

- "Aquatips" provides recommendations and suggestions on specific aquaculture topics and problems from researchers and extension agents.

The newsletter also features news on CTSA-funded projects, government assistance programs for aquaculture, publications and various information services that are available. In addition, it provides profiles of individuals and positions who provide services to aquaculturists, job openings in the region, and announcements about training courses.

Objective: Develop and publish a biannual technical bulletin to communicate the status and progress of current activities to the CTSA Board of Directors, Industry Advisory Council and Technical Committee. The bulletin will also be sent to aquaculturists in the Pacific region and upon request to other interested parties.

In February 1990, the Center staff developed and published its first set of *Project Updates*, technical bulletins that are published twice a year and distributed to the CTSA Board of Directors, Industry Advisory Council and Technical Committee and to extension agents and other interested parties upon request. Each set of *Project Updates* contains separate bulletins from one to six pages long on each active, funded project. Each bulletin provides details on the principal accomplishments for each objective and the principal investigators. In addition to writing and editing the bulletins, the staff does the artwork, layout and design and works with printers to produce the final publication.

The Publications project produced a 70-minute movie titled *CTSA Video Project Update.* Center staff assisted with writing the script and shooting the background footage for the video. The staff worked closely with the Sea Grant Communications director on the editing and final production of the video. The *CTSA Video Project Update* was prepared to provide the CTSA Board of Directors, Industry Advisory Council and Technical Committee with the latest results from 12 Center-funded projects. The video was shown at the Industry Advisory Council meeting in March 1995 and at the Technical Committee meeting in April 1995 and was distributed throughout the region.

Objective: Produce and publish final reports of selected CTSA-funded projects. These publications will be distributed free of charge to commercial producers, aquaculture researchers, extension agents and other interested parties throughout the Pacific region, with limited distribution in the United States.

The Center staff assists with publication of selected project final reports. Staff assistance includes editing the grammar and style of the reports, proofreading and designing them and working with printers to produce the final documents.

During 1995, the Center staff assisted with publication of a bibliography developed under the two-year, Center-funded project titled "Exploratory Study of Hawaii and Guam as High Health Aquaculture Stock Centers." The bibliography, titled *A Bibliography of Specific Pathogen-Free Organisms*, was published as CTSA publication number 116 in April 1995. The Center staff also assisted with publication of an extension fact sheet developed under the Center-funded project titled "Ornamental Aquaculture Technology Transfer." The fact sheet, titled *Raising the Silver Arowana* (Osteoglossum bicirrhosum*)*, was published as CTSA publication number 117 in May 1995.

Objective: Duplicate and distribute the other Regional Aquaculture Centers' videos and publications to information networks throughout the Pacific region.

The Center staff duplicated 11 videos produced by the other Regional Aquaculture Centers and distributed them to extension agents, libraries and aquaculture concerns throughout the region. The Center staff also maintained a library of all videos produced by the Regional Aquaculture Centers and loaned them to interested parties upon request. In addition, the Center staff distributed publications produced by the other Regional Aquaculture Centers to extension agents and libraries throughout the region.

Work Planned

The Center staff will continue to produce the quarterly newsletter, the biannual technical bulletins and selected project final reports.

Impacts

This project aids in disseminating aquaculture research results and information throughout the region in order to enhance viable and profitable U.S. aquaculture production that will benefit consumers, producers, service industries and the American economy.

Support

This project was funded by the Center for Tropical and Subtropical Aquaculture (CTSA) through grants from the U.S. Department of Agriculture.

Year	CTSA	Total Support
One	$10,000	$10,000
Two	$10,000	$10,000
Three	$12,000	$12,000
Four	$15,000	$15,000
Five	$38,000	$38,000
Six	$18,000	$18,000
Total	**$103,000**	**$103,000**

Administrative Support 1995

Dates of Work

January through December 1995

Participants

Dr. Kevan L. Main, Director; Patti Killelea-Almonte, Research Assistant; Alcian Clegg, secretary, Center for Tropical and Subtropical Aquaculture, The Oceanic Institute.

Project Objectives

The objectives of this project are to:

- establish and operate a regional center that will conduct aquaculture research, development and demonstration for the enhancement of a viable and profitable commercial aquaculture industry in the United States;
- develop and maintain a national program of cooperative and collaborative research, extension and development activities among public and private institutions;
- provide support for the development and implementation of projects of the Center for Tropical and Subtropical Aquaculture.

The Center for Tropical and Subtropical Aquaculture (CTSA) is jointly administered by the University of Hawaii and The Oceanic Institute. The Center's administrative activities are overseen by the Executive Committee of the CTSA Board of Directors. The Executive Committee includes the designated representative of the University of Hawaii and The Oceanic Institute. In 1987, The Oceanic Institute was designated as the site of the CTSA Administrative Center. In this capacity, The Oceanic Institute will disburse funds to other participating institutions and serve as a legal and physical agent in the receipt and disbursement of funds.

Anticipated Benefits

The mission of the Center for Tropical and Subtropical Aquaculture is to support aquaculture research, demonstration and extension education to enhance viable and profitable U.S. aquaculture production that will benefit consumers, producers, service industries and the American economy.

Progress and Principal Accomplishments

The Center for Tropical and Subtropical Aquaculture Administrative Center staff provided a variety of support services to the Board of Directors, the Industry Advisory Council, the Technical Committee, various project review panels and delegations and project work groups during 1995. The Administrative Center staff has processed eight Annual Plans of Work and is currently processing the ninth. The support services provided in 1995 are described below.

The Administrative Center staff provided support for the completion of the 12 projects funded under the Fifth Annual Plan of Work, nine projects funded under the Sixth Annual Plan of Work, 12 projects funded under the Seventh Annual Plan of Work and 11 projects funded under the Eighth Annual Plan of Work. That support included monitoring project status and progress, preparing subcontracts, tracking budget expenditures, reviewing progress reports and assisting principal investigators with problems.

In support of the Ninth Annual Plan of Work, the Administrative Center staff assisted Technical Committee groups in preparing problem statements and prepared the Preliminary Plan of Work. The staff then solicited proposals and assisted work groups in preparing the documents. The Center staff also solicited external and CTSA panel reviews of the proposals and drafted the Ninth Annual Plan of Work.

The Administrative Center staff functions as the work group for the project titled *Publications*. Work under that project included producing a quarterly newsletter, biannual technical bulletins, project final reports and a video. Details on the work completed under that project are provided in the chapter titled "Publications."

In addition, the Center staff continued to reproduce and distribute a computer software program and accompanying instruction manual that was developed under the Center-funded project titled "Expert System Disease Module for Hawaiian Aquaculture." The software program, titled *Hawaii Aquaculture Module Expert System*, was published as CTSA publication number 111 in March 1994. The Center staff also distributed other publications by CTSA and the other Regional Aquaculture Centers upon request.

Work Planned

During 1996, the CTSA Administrative Center Staff will continue to provide all these forms of support for the Center's regional aquaculture projects. Further, the Center staff will:

- coordinate the review of annual reports,
- prepare the U.S.D.A. grant package for fiscal year 1996,
- organize and provide documentation and assistance for CTSA meetings,

- visit Pacific Island project sites to review the status of currently funded projects and assist in the development of proposals for the tenth year program,
- participate in the National Coordinating Council,
- and work with other fisheries and aquaculture agencies throughout the region.

Finally, the Administrative Center staff will prepare the Tenth Annual Plan of Work for submission to the U.S. Department of Agriculture.