AQUACULTURE DEVELOPMENT FOR HAWAII

ASSESSMENTS AND RECOMMENDATIONS

AQUACULTURE PLANNING PROGRAM

Center for Science Policy and Technology Assessment

Department of Planning and Economic Development

State of Hawaii

1978

This report has been catalogued as follows:

Hawaii. State Center for Science Policy and Technology Assessment.
Aquaculture development for Hawaii: Assessments and recommendations. By Aquaculture Planning Program, Center for Science Policy and Technology Assessment. Honolulu: Dept. of Planning and Economic Development, State of Hawaii, 1978.

1. Aquaculture-Hawaii. I. Hawaii. Department of Planning and Economic Development.
SH325.H3H393 (x fr. Hawaii. State Center for Science Policy and Technology Assessment. Aquaculture Plan. Prog.)

GOVERNOR'S MESSAGE

In my State-of-the-State Address to the 1978 Legislature, I noted that aquaculture is one of the fastest growing industries in Hawaii. *Aquaculture Development for Hawaii* represents a major step towards achieving this industry's enormous potential. We have closely followed both existing and soon-to-be-established Federal programs so that the objectives of our State program will blend with Federal planning. As Hawaii is the first State to develop a comprehensive aquaculture development program, it is our hope that these efforts may be of value to other states planning their aquaculture programs.

Hawaii's success in pioneering techniques for the mass-culture of freshwater prawns clearly demonstrates that the State can and must continue to provide support services to aquafarmers and develop new species. Existing State aquaculture activities, such as the loan programs, marketing studies, disease control, and extension/advisory services, must be expanded to include other services as needs arise.

Hawaii also has a significant role to play in assisting other U.S. Pacific islands and the newly-developing countries of the Asia-Pacific Basin in building their aquaculture industries. Thus, we have the opportunity to become an important focal point for research, development and training as well as a center of commercial production.

Aquaculture is in harmony with the State goals expressed in the Hawaii State Plan passed by our 1978 Legislature, with our Coastal Zone planning, and with the culture and traditions of our people. With the continued support and cooperation of all key State Departments, the University of Hawaii and private industry, *Aquaculture Development for Hawaii* is certain to accelerate our progress and bring many benefits to our State and the nation.

We must seize the opportunities that lie ahead so that aquaculture may develop into one of Hawaii's major industries, providing increased revenue and new and better employment opportunities for the people of our Islands.

George R. Ariyoshi
Governor, State of Hawaii

FOREWORD

While the cultivation of fish in ponds has always been a part of Hawaii's heritage, modern scientific aquaculture is a relatively new and rapidly growing industry in the State. A 1976 assessment of statewide aquatic resources published by the State Department of Planning and Economic Development (DPED) indicated that aquaculture has the potential to become a major industry in Hawaii. As a result, the Eighth State Legislature appropriated $150,000 to the DPED for developing a comprehensive aquaculture program for Hawaii. The University of Hawaii Sea Grant College Program provided $25,000, office space, and student support for the start-up phase of the project.

The success of this program would not have been possible without the efforts of various national and international research organizations, seafood brokers, wholesalers, retailers and restaurateurs, and other private commercial enterprises throughout the world. We are particularly grateful for the input to, and review of the report by those individuals of the Aquaculture Planning Program Advisory Committee, and the Aquaculture Advisory Council and Liaison Committee, and their organizations, listed on the following pages. In addition, we wish to recognize the generous assistance of the U.S. Army Corps of Engineers, the Fish and Wildlife Service of the U.S. Department of the Interior, the National Marine Fisheries Service and the Office of Sea Grant of the U.S. Department of Commerce, the Subcommittee on Merchant Marine and Fisheries of the U.S. House of Representatives, the University of Hawaii Sea Grant College's Marine Option Program and Marine Advisory Program, the Coastal Zone Management Program, the Hawaii Regional Water Resources Program, and the Pacific Urban Studies and Planning Program. On the Federal level, Hawaii's Congressional delegation was extremely helpful in keeping the program advised of the many legislative and administrative activities.

Special appreciation is extended to those staff members of the aquaculture programs—both past and present—who worked in a full- or part-time capacity for varying lengths of time. A list of these individuals appears on page vi.

Aquaculture Development for Hawaii, prepared under the direction of Richard T. Gibson, assesses sites, technical resources and the economic benefits to the State. It identifies the steps necessary to develop all phases of an aquaculture industry in Hawaii, and recommends actions needed to achieve the highest possible degree of expansion. Supporting assessments and studies—too detailed to include in this volume—are being planned for publication under separate cover. One such study, *Permits and Environmental Requirements for Aquaculture in Hawaii*, was published in 1977.

In addition to work on this report, our aquaculture staff has responded to Legislative and Administrative requests, answered numerous inquiries concerning starting aquaculture businesses in Hawaii, and assisted visitors to the State in touring aquaculture facilities. The staff also prepared and coordinated articles for an issue on Hawaii of the leading trade journal of the industry, participated in marine exhibitions, and—perhaps most important—reviewed and funded aquaculture research proposals. This latter activity was made possible by some $425,000 provided by the Ninth State Legislature in 1977 for staff support, for the freshwater prawn program of the State Department of Land and Natural Resources, and for research on baitfish, marine agronomy, marine shrimp, oysters, and opihi.

The Ninth State Legislature responded further to Administrative requests in 1978 by appropriating $750,000 to fund the development program, and $1,250,000 for State aquaculture facilities. Needed informational materials, including a slide show and film on prawn farming, are in preparation. A full-time veterinarian has also been hired to provide aquatic disease identification, treatment and prevention services.

These forward-looking actions augur well for the future of aquaculture in Hawaii. Our programs will support both commercial development and research and training in aquaculture. We look forward to merging our local programs with Federal and international efforts to promote a major growth of aquaculture in Hawaii, the nation and the world.

HIDETO KONO, Director
Department of Planning and
Economic Development

HAWAII AQUACULTURE PLANNING PROGRAM
ADVISORY COMMITTEE
(July 1, 1976 – June 30, 1977)

Mr. Takuji Fujimura
Chief Biologist
Anuenue Fisheries Research Center
Department of Land and Natural Resources

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

Dr. Eugene Grabbe, Manager
Center for Science Policy and Technology Assessment
Department of Planning and Economic Development

Dr. Philip Helfrich, Associate Dean
Office of Research Administration
University of Hawaii

Dr. Kenneth Kato, President
Pacific Aquaculture Corporation

Mr. John Keppeler, Managing Director
County of Hawaii

Mr. Hideto Kono, Director
Department of Planning and Economic Development

Dr. James Kumagai
Deputy Director of Environmental Programs
Department of Health

Mr. James Kurita, Director
Office of Economic Development
County of Kauai

Mr. Ronald Linsky, Acting Director
Sea Grant College Program
University of Hawaii

Dr. Robert May, Assistant Marine Biologist
Hawaii Institute of Marine Biology
University of Hawaii

Mr. Richard Morimoto, Head
Farm Loan Division
Department of Agriculture

Dr. Colin Nash
Director of Research and Vice-President
The Oceanic Institute

Mr. Howard Pennington
Office of the Marine Affairs Coordinator
State of Hawaii

Dr. Robert Shleser, Coordinator
Hawaii Aquaculture Planning Program

Mr. Eric Soto, Coordinator
Department of Economic Development
County of Maui

Mr. Robert Stengle, President
Brewer Chemical Corporation

AQUACULTURE ADVISORY COUNCIL AND LIAISON COMMITTEE
(Effective July 1, 1977)

Dr. John Bardach, Director
Hawaii Institute of Marine Biology
University of Hawaii

Dr. Linden Burzell, Vice-President
Aquatic Farms, Ltd.

Mr. William Coops
Director of Administration
Research Corporation of the
University of Hawaii

Dr. Jack Davidson, Director
Sea Grant College Program
University of Hawaii

Mr. John Farias, Jr.
Chairman of the Board
Department of Agriculture

Mr. Takuji Fujimura, Chief Biologist
Anuenue Fisheries Research Center
Department of Land and Natural Resources

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

Dr. Philip Helfrich, Associate Dean
Office of Research Administration
University of Hawaii

Mr. Robert Hughes,
Executive Vice-President
C. Brewer and Co., Ltd.

Dr. Stanley Swerdloff,
Assistant Coordinator
Office of the Marine Affairs Coordinator

Representative Richard Kawakami
House of Representatives
Ninth State Legislature

Mr. John Keppeler, Managing Director
County of Hawaii

Mr. Hideto Kono, Director
Department of Planning and Economic
Development

Dr. James Kumagai
Deputy Director for Environmental Programs
Department of Health

Mr. James Kurita, Director
Office of Economic Development
County of Kauai

Mr. Ronald Linsky
Assistant to the Dean on Aquaculture Programs
College of Tropical Agriculture
University of Hawaii

Dr. Colin Nash
Vice-President and Director of Research
The Oceanic Institute

Mr. Richard Power, President
The Oceanic Institute

Mr. Eric Soto, Coordinator
Department of Economic Development
County of Maui

Senator T. C. Yim
Senate
Ninth State Legislature

AQUACULTURE PROGRAM STAFF

Present Staff of the Aquaculture Development Program

Richard T. Gibson, Manager
John Corbin, Aquaculture Specialist
Justin Rutka, Aquaculture Economist/Analyst
C. Richard Fassler, Scientific/Technical Writer
Debra Takeuchi, Information Specialist
Randall Nishimura, Marketing Specialist
Cynthia Baca, Secretary
Uaaree Matsuda, Clerk Typist
Raymond Young, Cartographer
Gregory Chu, Assistant Cartographer

Former Staff of the Aquaculture Planning Program and Aquaculture Development Program

Robert Shleser, Coordinator
Samuel Kwok, Computer Specialist
Susan Morita, Marketing Specialist
Michael Santerre, Aquaculture Specialist
Judith Houtman, Administrative Assistant
Nora Chun, Typist
Student Researchers
- Guy Anzai, Marine Option Program
- David Coleman, Graduate Student
- Douglas Davis, Marine Option Program
- David Garcia
- Kathleen Hoff, Marine Option Program
- Shellie Kodama, State Executive Internship Program
- Donna Noborikawa, Marine Option Program
- Mark Suiso, Marine Option Program
- Joseph Kwok

Student Helpers
- Michael Hoyer
- Karen Ikei
- Lynne Kobashigawa
- Earlene Lofstrom
- Gail Mack
- Patricia Murzyn
- Terri-lynn Ozaki

PREFACE

This report is the culmination of nearly two years' efforts to assess the potential of aquaculture in Hawaii and recommends State actions to enhance and accelerate its growth. The project was managed by DPED's Center for Science Policy and Technology Assessment. In addition to containing recommended actions, this report provides a brief summary of several major assessments in the form of findings and conclusions. The publication of a series of technical assessments in the following areas is being considered:

Assessment of Technical Resources Relating to Aquaculture

Aquaculture's Role in Hawaii's Future—Some Potentials and Alternatives

The Selection and Development of Cultured Aquatic Species for Hawaii

Individual Assessments of Species for Culture in Hawaii (A Series)

Markets for Hawaii's Cultured Aquatic Species

Legal Constraints to Aquaculture Development in Hawaii

TABLE OF CONTENTS

LIST OF TABLES

Tables

Pages

LIST OF FIGURES

Figures *Pages*

SUMMARY

Hawaii is an excellent location for aquaculture. The State has warm year-round temperatures, sufficient land for fresh, brackish, and salt water aquaculture, and a tradition of fishfarming that extends back to the ancient Hawaiians. Yet, economic development over the past 100 years has centered on the exploitation of agricultural rather than aquatic resources. Only within the last decade has a concerted effort been made to identify these resources and opportunities, and to estimate the benefits that may be derived from a thriving aquaculture industry.

Preliminary evaluations have been favorable, and scientific research on a number of aquatic species has produced encouraging results. However, the most compelling reasons for optimism have sprung from the early successes of the State's freshwater prawn farming program which, in a few short years, has established Hawaii as the world leader in the culture of this species. *Aquaculture Development for Hawaii*, the most comprehensive assessment of a State's resources for aquaculture ever undertaken in the United States, confirms the economic potential of the industry and underscores the necessity of reducing or eliminating certain key constraints in order to achieve that potential.

Purposes

The purposes of this report are:

- To assess Hawaii's resources for aquaculture and identify the most important constraints to development.
- To recommend State goals for aquaculture development in Hawaii.
- To define the objectives and policies necessary to realize these goals.
- To recommend programs, an effective organization, management strategies, and a budget and timetable for the achievement of these objectives and policies.

Findings

The report finds that the expansion of aquaculture in Hawaii can help to achieve broad State goals by providing a greater number and wider range of employment opportunities; contributing to the balance of trade by increasing exports of aquatic products and substituting locally-farmed aquatic products for imports; diversifying the economies of all islands leading to self-reliance in food production; maintaining open spaces, reducing development pressure on prime agricultural lands; preserving the life-styles of rural residents; and maintaining the quality of life in the Islands through the wise use of the State's natural and human resources.

The assessments section of the report reveals numerous important resources for practicing aquaculture in Hawaii. The most significant findings include:

- There are two distinct, yet highly interrelated, economic sectors of Hawaii's aquaculture industry: the commercial production sector and the research, training, and technology transfer sector. Both have significant economic potential and, because they are compatible and complementary, they are expected to gain from each other's activities.

- There are more than 135,000 acres of primary lands and nearly 500,000 acres of secondary lands suitable for aquaculture.

- There is now, and will continue to be, competition for fresh water in certain locations of Oahu, Maui, and the Big Island. However, there is sufficient fresh water for the immediate expansion of aquaculture production in many other areas of all Islands and a longer term potential for utilizing existing agricultural water resources.

- There is an abundance of warm, unpolluted seawater, but there are limitations to open-ocean and near-shore mariculture.

- There are well-staffed and equipped laboratory research facilities for aquaculture in the State University System, at the Anuenue Fisheries Research Center, and at such private organizations as the Oceanic Institute, but outdoor research and demonstration facilities are badly needed.

- Legal and environmental considerations pose major constraints to aquaculture development, but various courses of action to help remove these constraints have been identified, and in several cases, implemented.

- There are a number of promising aquatic species that can be developed to achieve commercial profitability and compete successfully in Mainland and foreign markets.

- As approximately 30 million pounds of seafood are consumed annually in Hawaii, there appears to be a substantial local market potential for species cultured in the State.

- Since the State's financial resources are limited, Hawaii must seek Federal and non-State sources of funds to support developmental activities.

- Aquaculture is expected to compete favorably with agriculture for the use of land, and make a considerable contribution to other sectors of Hawaii's economy.

Furthermore, this report concludes that aquaculture can become a major industry in Hawaii if specific constraints can be eliminated. These emerge at all stages of the aquaculture process and include technical, economic, and legal/institutional considerations. Institutional constraints are by far the most crucial, as they involve the establishment of an organization–a lead agency–to direct, coordinate, plan and implement aquaculture activities. The lack of a lead agency has been identified as the single most important impediment to the development of aquaculture in Hawaii. Accordingly, the majority of recommendations summarized on the following pages address this concern.

Table i. Summary of Recommended Actions

Recommended Action		Action Agency	Timing	
			Begin	Duration
1.	UNIFIED APPROACH			
a.	*Assign responsibilities for aquaculture development to either the DOA or DLNR* as the lead agency to implement the recommended actions of this report. Assure that the administration of those aquaculture facilities currently housed at the AFRC be a function of the lead agency. Appropriate necessary operating funds.	Legislature	1979	one-time
b.	*Actively pursue national, international and private funds* . . . and assist the University of Hawaii and other groups in their grant development activities. . . .	Lead agency	ongoing	continuing
c.	*Establish a hatchery revolving fund.* . . .	Legislature	1979	continuing
d.	*Interact with other State and County agencies* to insure that aquaculture is considered in planning and development decisions.	Lead agency	ongoing	continuing
e.	*Regularly assess producers' needs for support services* so that the State can consider providing those services not available from the private sector.	Lead agency	1978	continuing
f.	*Establish appropriate existing and new aquaculture facilities* as jointly designated lead agency/University of Hawaii facilities	Lead agency and U H	1979	continuing
g.	*Establish cooperative programs* in research and extension and determine the most appropriate procedures for joint appointment of the lead agency and University of Hawaii	Lead agency and U H	1979	continuing
h.	*Establish program review panel* to provide input from producers, distributors, researchers, funding sources, feed suppliers and lenders, and to perform external review of State-supported aquaculture activities.	Governor	1979	continuing
i.	*Appropriate funds for the construction of experimental research and training facilities.* . . .	Legislature	1978	one-time

Table i. Summary of Recommended Actions (cont'd)

Recommended Action		Action Agency	Timing	
			Begin	Duration
j.	*Plan, design and construct outdoor experimental research and training facilities.*	Lead agency and UH	1978	two years
k.	*Appropriate funds for the construction of additional experimental research and training facilities. . . .*	Legislature	1981	one-time
l.	*Plan, design and construct additional experimental research and training facilities. . . .*	Lead agency and UH	1981	two years
2.	BUSINESS CLIMATE			
a.	*Provide assistance to prospective aquafarmers regarding . . . permit and environmental requirements . . . .*	Counties and lead agency	ongoing	continuing
b.	*Increase awareness and understanding among Federal, State, and County regulatory agencies* of the activities and processes involved in aquaculture production. . . .	Lead agency	1978	continuing
c.	*Establish simplified administrative approval procedures* . . . through enabling legislation.	Legislature	1979	one-time
d.	*Establish a central permit coordinating agency* with one master permit application form and consolidated notices and hearings at the State level.	Legislature	1979	continuing
e.	*Review the Aquaculture Revolving Loan Fund* periodically and, when necessary, make additional appropriations to the fund.	Legislature	1978	as needed
f.	*Provide lenders with information* on the costs of construction and operation of various types of aquaculture systems.	Lead agency	1979	continuing
g.	*Provide such support services* as disease diagnosis and prevention,* stocking material,* water chemistry** and soil analyses,** as well as advice on site selection,* permits,* business management,** and pond management*	Lead agency and UH	*ongoing **1979-81	continuing
h.	*Provide property and excise tax incentives* to aquaculturists for a specified period.	Legislature	1979	five years

Table i. Summary of Recommended Actions (cont'd)

	Recommended Action	Action Agency	Timing	
			Begin	Duration
i.	*Provide long-term leases of State lands* to aquaculturists at reasonable rates.	DLNR	1978	continuing
j.	*Continually identify and publicize through brochures and bulletins significant risks* associated with operating aquaculture enterprises.	Lead agency	1979	continuing
k.	*Establish additional agriculture/aquaculture parks* in a common location. . . .	DOA and DLNR	1979	continuing
l.	*Interact with economic, land- and water-use, and other resource planning efforts. . . .*	Lead agency	1978	continuing
m.	*Establish aquaculture activities as permitted uses within conservation districts.*	DLNR	1978	one-time
n.	*Consider the feasibility of restoring representative Hawaiian fishponds. . . .*	Legislature	1979	one year
o.	*Continue to assess sites for aquaculture* with particular attention to sites suitable for coastal or open-sea mariculture as well as unutilized and underutilized lands.	Lead agency	ongoing	continuing
p.	*Establish and maintain a reporting activity* for Hawaii's cultured aquatic products.	Lead agency	1980	continuing
q.	*Assist producers in the timely implementation of product development projects* for freshwater prawns and other cultured products. . . .	Lead agency and DPED	1978	continuing
r.	*Assist in the establishment of high quality standards* for Hawaii's cultured aquatic products.	Lead agency	1978	continuing
s.	*Monitor national and international levels and prices of production, sales and inventories* which affect aquatic products cultured in Hawaii.	Lead agency	1980	continuing
t.	*Work with other agencies to provide assistance to commodity associations and/or cooperatives.*	Lead agency and HCES/UH	1978	continuing
u.	*Support directed research* to reduce production costs and increase yields of species currently under culture in Hawaii.	Lead agency	ongoing	continuing

Table i. Summary of Recommended Actions (cont'd)

	Recommended Action	Action Agency	Timing	
			Begin	Duration
3.	NEW ECONOMIC OPPORTUNITIES			
a.	*Support the demonstration, under local conditions, of the commercially viable culture of species or species-groups* . . . whose culture technologies have been developed elsewhere.	Lead agency	ongoing	continuing
b.	*Provide funds for research on a cost-sharing basis* aimed at providing a basic understanding of life cycle and environmental requirements of promising species.	Lead agency	ongoing	continuing
c.	*Provide funds for testing the applicability of using aquaculture technologies* as components in Ocean Thermal Energy Conversion (OTEC) and biomass energy systems.	Lead agency	1979	continuing
d.	*Provide funding to investigate the technical and economic feasibility* of using aquaculture for livestock waste recovery and wastewater recycling and/or disposal.	Lead agency	1978	continuing
e.	*Provide funding to determine the potential of aquaculture effluents* for terrestrial crop fertilization and irrigation.	Lead agency	1979	continuing
f.	*Demonstrate the feasibility of using various cultured species as bait* for pole-and-line (skipjack tuna) and long-line fishing as well as for recreational fishing.	Lead agencies for fisheries and aquaculture development	ongoing	continuing
g.	*Study the potential of enhancing natural populations* of popular sport fishes. . . .	Lead agencies for fisheries and aquaculture development	ongoing	continuing
4.	EXCELLENCE IN RESEARCH AND DEVELOPMENT, TRAINING AND TECHNOLOGY TRANSFER			
a.	*Bring aquaculture meetings* . . . etc., to Hawaii, and support the participation of Hawaii's aquaculture community when these gatherings are held out-of-State.	Lead agency, DPED, UH and EWC	1979	continuing

Table i. Summary of Recommended Actions (cont'd)

Recommended Action		Action Agency	Timing	
			Begin	Duration
b.	*Initiate advanced training programs* for foreign government administrators, technicians, instructors and advisors involved in aquaculture development.	U H and EWC	1979	continuing
c.	*Develop cooperative programs* with other leading universities or organizations. . . .	U H	1978	continuing
d.	*Develop interdisciplinary programs* which would encourage lateral movement of specialists in traditional disciplines in other areas of investigation into the field of aquaculture.	U H and EWC	1978	continuing
5.	VOCATIONAL TRAINING AND FORMAL EDUCATION			
a.	*Develop a curriculum plan* in aquaculture for the entire University of Hawaii system. . . .	U H	1978	three years and continuing
b.	*Include the subject of aquaculture* in vocational agricultural or marine science studies at the secondary educational level. . . .	DOE	1980	continuing
c.	*Initiate training programs* to meet the specific needs of Hawaii's aquaculture technicians and managers for refinement of skills.	Lead agency and U H	1979	continuing
6.	INFORMATION CENTER			
a.	*Establish an aquaculture information center* for compiling and exchanging information . . . to assure early application of most recent results, and to avoid duplication of efforts.	Legislature, lead agency and U H	1979	continuing

ABBREVIATIONS USED IN THIS REPORT

AACLC	Aquaculture Advisory Council and Liaison Committee
ADP	Aquaculture Development Program
AFRC	Anuenue Fisheries Research Center
APP	Aquaculture Planning Program
BIFAD	Board for International Food and Agriculture Development
BLNR	Board of Land and Natural Resources
BOA	Board of Agriculture
CDUP	Conservation District Use Permit
CP	Commercial Production
CSPTA	Center for Science Policy and Technology Assessment
CTA	College of Tropical Agriculture
DLNR	Hawaii State Department of Land and Natural Resources
DOA	Hawaii State Department of Agriculture
DOH	Hawaii State Department of Health
DPED	Hawaii State Department of Planning and Economic Development
DOT	Hawaii State Department of Transportation
EIS	Environmental Impact Statement
EWC	East-West Center
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FLD	Farm Loan Division
HAES	Hawaii Agriculture Experiment Station
HCES	Hawaii Cooperative Extension Service
HIMB	Hawaii Institute of Marine Biology
HNEI	Hawaii Natural Energy Institute
ICLARM	International Center for Living Aquatic Resources Management

LUC	Land Use Commission
MAP	Marine Advisory Program
MCSD	Marketing and Consumer Services Division
MOP	Marine Option Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OI	Oceanic Institute
OSG	Office of Sea Grant
OTEC	Ocean Thermal Energy Conversion
RT&TT	Research, Training and Technology Transfer
SCS	Soil Conservation Service
SEAFDC	Southeast Asian Fisheries Development Center
SGCP	Sea Grant College Program
SMA	Special Management Area
UH	University of Hawaii
UNDP	United Nations Development Program
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USDOC	U.S. Department of Commerce
USDOI	U.S. Department of Interior

CHAPTER I

INTRODUCTION

Aquaculture: The propagation and cultivation of aquatic animals and plants for profit or social benefit.

Increasing population pressures on the world's limited food resources, coupled with escalations in energy costs, have emphasized the necessity of developing new methods of food production. An additional concern is the recent emphasis on industries that are environmentally clean, yet able to provide tax revenues and employment opportunities, particularly for communities that traditionally have been agricultural. Aquaculture, the systematic cultivation of aquatic plants and animals, has demonstrated the potential to meet these needs.

World aquaculture production in 1975 amounted to six million metric tons (only 10 percent of the total world fish catch), but this is expected to reach 50 million metric tons annually by the year 2000 (*Aquaculture in the United States, Constraints and Opportunities,* 1978). Without this production from aquaculture and with the population continuing to increase at present rates, the shortage of fisheries products is likely to worsen.

In the United States, seafood imports have grown steadily as traditional fisheries resources approach near maximum yield levels. The demand for seafood is expected to become critical within the next 10 years, resulting in shortages and higher prices (*NOAA Aquaculture Plan,* 1977). Aquaculture production on the U.S. Mainland, which began more than 100 years ago, reached 65,000 metric tons in 1975, yet provided less than three percent of the seafood consumed. With proper support, this figure could expand to one million metric tons by the year 2000 (*Aquaculture in the United States, Constraints and Opportunities,* 1978).

* * * * * * * * * * *

Coastal fishponds, such as these, have been used for hundreds of years. Aquaculture played an important role in the society of the ancient Hawaiians.

Kahaluu Fishpond, Kahaluu, Oahu.

Kaloko Fishpond.
(Courtesy of National Park Service.)

Aquaculture has particular significance for Hawaii. The State has a tradition of fishfarming that reportedly extends back some 600 years. There were approximately 360 fishponds in the Islands prior to the arrival of Captain James Cook in 1778, with a total annual production calculated to be over two million pounds (Kikuchi, 1976). The practice experienced a drastic decline in the early part of this century due to such factors as natural erosion, lava inundations, destruction by tidal waves, and land-filling for shoreline expansion. Aquaculture persisted, however, gradually assuming a renewed significance in the late 1960's with the importation and commercial testing of the Malaysian prawn by the State's Anuenue Fisheries Research Center (AFRC). The AFRC program, which provided juveniles and extension/advisory services to farmers at no cost, established Hawaii as the world leader in the culture of freshwater prawns, and pointed to the enormous potential of aquaculture for the State.

Opportunities for Aquaculture in Hawaii

As the only State with year-round climatic conditions favoring the growth of tropical as well as temperate-zone aquatic species, Hawaii has the opportunity to achieve leadership and excellence in both commercial aquaculture production and aquaculture research, training and technology transfer activities. The State has unused or underutilized lands that are ideal for fresh, brackish, and saltwater aquaculture, and air temperatures that fall within the optimal range for culturing numerous economically important species.

Aquaculture opportunities exist in two separate, yet highly interrelated sectors: the commercial production sector (CP) and the research, training, and technology transfer sector (RT & TT). Both share the common goal of developing aquaculture and are consistent with broad State goals. Although the two sectors differ on some objectives, both will bring revenues to the State and create jobs. Perhaps most important, both sectors are compatible and complementary, and stand to benefit greatly from each other's mutual expansion.

The commercial production sector. There are essentially three levels at which commercial aquaculture is practiced in Hawaii and throughout the world. These are:

1. The part-time family-run operation which supplements the farmer's food and income needs.

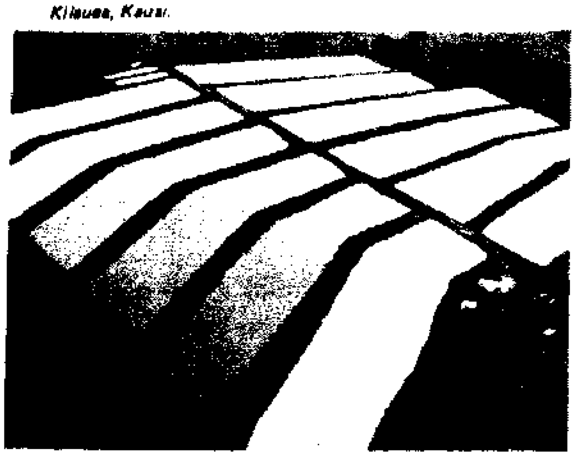
2. The small-scale commercial operation with hired employees.

3. The large-scale commercial operation which is associated with, or owned by, a large local, national or international company.

The physical layout, the amount of financial investment, and the technology involved in these operations generally increase with the scale of operation. All three levels of commercial aquaculture are practiced in Hawaii and are expected to continue to thrive because of: (1) the diverse nature of aquaculture, (2) the demand for different product forms of a given species, and the ability to provide these, (3) the existence of a variety of distribution channels, (4) opportunities for the formation of producer cooperatives and associations, and (5) provisions for State-supported services, including marketing and product promotion, extension/advisory, seed stock supply, credit and financing, and water quality testing.

Ota's Pond, Punaluu, Oahu—the first commercial prawn farm in Hawaii. (Courtesy of AFRC.)

Kilauea Agronomics (C. Brewer & Company), Kilauea, Kauai.



Kahuku Seafood Plantation, Kahuku, Oahu. (Courtesy of Kahuku Seafood Plantation.)

Modern commercial aquaculture is one of Hawaii's fastest growing industries. A wide range of opportunities exists—from the earthen pond culture of freshwater prawns to the intensive land-based mariculture of oysters and clams.

Commercial aquaculture production in Hawaii has grown rapidly in recent years. Gross sales of aquatic products in 1978 are expected to show a 500 percent increase over 1977 sales, with 35 commercial operations raising freshwater prawns, oysters, brine shrimp, seaweed, catfish and a few species of marine finfish (Table 1). Total acreage under production for aquacultured species is predicted to reach 426 acres in 1978, a 74 percent increase over the 1977 figure. According to the *Hawaii State Plan* (1977), aquaculture has the potential to produce gross sales worth $84 million to $336 million per year by 1990, and directly and indirectly employ as many as 12,000 people. The projections contained in this report (Chapter II, section G) are somewhat more conservative, but nonetheless favorable.

The research, training and technology transfer sector. The research, training, and technology transfer sector (RT & TT) has both a national and international emphasis. At present, RT & TT is a rather small sector in Hawaii, but there are strong indications that substantial growth could take place in the next few years. Although several public institutions are intimately involved in RT & TT,[1] many activities are also currently located in the private sector among consulting firms, agri-business corporations, and non-profit institutions.

Although this sector's main objective is the development of expertise and the transfer of technology to lesser-developed countries, it must be emphasized that a large portion of non-State funds will be expended within the State. This will create jobs and increase the demand for goods and services.

The high degree of interest in three recently established Federal programs intended to fund RT & TT points to considerable potential for this industry. Title XII of the Foreign Assistance Act (1975), Section 406 of the Food for Peace Act (1976), and the Comprehensive Farm Bill (1977) could provide as much as $6 million to $10 million a year to Hawaii's aquaculture RT & TT sector by 1985, and directly and indirectly employ as many as 300 to 400 people. The University of Hawaii's College of Tropical Agriculture is submitting proposals that will place the University in a favorable position to receive these Federal funds for both agriculture and aquaculture activities. Through subcontracts, several other State agencies and private firms are expected to participate.

* * * * * * * * * * *

The above projections for the commercial production and RT & TT sectors indicate that aquaculture can make a substantial contribution to Hawaii's economy. The State's economic base is presently limited. In 1976, only four sources (tourism, Federal defense expenditures, sugarcane, and pineapple) accounted for 42 percent of the gross State product (*State of Hawaii Data Book*, 1977). This problem is compounded by a high reliance on imports, coupled with rising fuel and fertilizer costs, so that once productive agricultural areas have become uneconomical or marginal. Moreover, only non-polluting industries are able to satisfy State, County, and Federal standards and permit requirements. State policy documents have, therefore, stressed the need for new industries, such as aquaculture, which will diversify the economy, provide additional employment opportunities, and preserve the environment.

---

[1]For example: the University of Hawaii, the East-West Center and the Anuenue Fisheries Research Center of the State Department of Land and Natural Resources.

Table 1. Commercial Aquaculture Production in Hawaii

Species	1976 No. of Farms	1976 Pounds	1976 Acres	1976 Wholesale Value	1977 No. of Farms	1977 Pounds	1977 Acres	1977 Wholesale Value	1978 Projections No. of Farms	1978 Projections Pounds	1978 Projections Acres	1978 Projections Wholesale Value in 1977 Dollars
Freshwater Prawn: *Macrobrachium*[a]	6	41,480	26.6	$145,180[b]	13	51,800	35.6	$181,300[b]	20	175,000	117	$ 616,000[b]
Oysters: Kahuku Sea Food Plantation[c]	-	-	-	-	1	16,666	4	$ 20,000[d]	1	112,000	22	$ 134,400[d]
Aquatic Farms[e]	-	-	-	-	1	-	-	-	1	88,000[f]	1.5	$ 105,600[d]
Mullet[g]	4	2,222	191.5	$ 3,915	4[h]	5,268[h]	191.5[h]	$ 9,996[h]	4[i]	5,268[i]	191.5[i]	$ 9,996[i]
Catfish	2	31,040	17	$ 39,870	2	31,040	17	$ 39,870	2	101,040	17	$ 126,300
Milkfish, *Ulua*, *Aholehole*, *Awaawa*, *Kaku*, *Moi*, *Oio*[g]	4	12,227	191.5	$ 9,094	4	13,226[h]	191.5	$ 13,662[h]	4[i]	13,226[i]	191.5[i]	$ 13,662[i]
Total	11[j]	86,969	235.1[k]	$198,059	20[j]	118,000	248.1[k]	$264,828	27[j]	494,534	349[k]	1,005,958

[a] Anuenue Fisheries Research Center (DLNR) data.
[b] Based on the wholesale price: one pound = $3.50.
[c] Kahuku Sea Food Plantation data.
[d] Based on the wholesale price of oysters, one pound = $1.20.
[e] Aquatic Farms data.
[f] First harvest expected in March, 1978.
[g] Division of Fish and Game (DLNR) data. Mullet is generally raised with other species.
[h] Data available through June, 1977; June - December projected.
[i] Assumes that figures will equal those for 1977.
[j] Several farmers raise more than one species. This number indicates the total number of different operations.
[k] As mullet are raised with milkfish, *ulua*, *aholehole*, *awaawa*, *kaku*, *moi*, and *oio*, 191.5 acres is counted only once in the total acreage.

Expanded aquaculture development can help to achieve the economic, social, and environmental goals of the State by providing a greater and wider range of employment opportunities, contributing to the balance of trade by increasing exports of aquatic products and substituting locally-farmed aquatic products for imports, diversifying the economies of all Islands, leading to self-reliance in food production, maintaining open spaces, reducing development pressure on prime agricultural lands, and preserving the life-styles of rural residents and the quality of life of all citizens by the wise use of Hawaii's natural and human resources.

Constraints to Development

Hawaii's considerable resources for aquaculture development were pointed out above. The numerous benefits to the State from expanded research and commercial production industries were also indicated. Why, then, hasn't aquaculture achieved a higher rate of growth? Why, for example, has aquaculture production in Hawaii lagged behind other areas of the world with far fewer resources?

The history of modern aquaculture in Hawaii parallels the growth of the industry in the United States where the "rate of development is slower than had been generally expected and has led to disappointment in aquaculture's contribution to U.S. food production" (*Aquaculture in the United States, Constraints and Opportunities*), and "While world aquaculture production has doubled during the last five years, U.S. production has remained static" (*NOAA Aquaculture Plan*, 1977). The U.S., for example, ranked only 16th in the world in the culture of finfish in 1975 (Pillay, 1976).

The reasons for the slow rate of aquaculture development in both Hawaii and the U.S. can be attributed to the existence of major constraints, many of which are not found in areas with greater aquaculture production. These constraints can be divided into three categories: (1) technical, including biological and production problems, (2) economic, and, perhaps most important, (3) legal-institutional. In many cases, the synergetic effects have been more of a limiting factor than the direct influence of each factor on the industry. The recommendations of this report address both present and anticipated constraints.

Technical constraints. Effective growout systems management is crucial to commercial success in aquaculture. An important technical constraint in Hawaii has been a lack of large-scale growout experimentation facilities to solve growout systems management problems and demonstrate the feasibility of culturing a species. The performance of fresh, brackish, and salt water species cannot be adequately evaluated without testing in a facility that will approximate actual commercial conditions.

The importance of this constraint is recognized in countries with large-scale aquaculture operations. In Japan, for example, the central government cooperates with the prefectural governments to apply research results to commercial-scale operations on an experimental basis. One research program increased fisheries resources on a "gigantic" scale through massive artificial seed production and stocking (Asono, 1976).

Biological constraints to aquaculture in Hawaii have developed from the selection of appropriate species for research, and the subsequent concentration of effort on those species. Species selection has tended to reflect the scientist's interest in biological problems rather than the species' potential for commercial culture. This is understandable in light of the fact that no coordinated system has existed for identifying and encouraging developmental research on the most important species for commercial

Aquaculture research, training, and technology transfer (RT & TT) can become a significant industry. These research centers are playing a key role in the development of aquaculture in the State, but additional facilities—such as an outdoor research and demonstration complex—are necessary.

The Hawaii Institute of Marine Biology (University of Hawaii), Kaneohe, Oahu. (Courtesy of HIMB.)

The Oceanic Institute, Makapuu Point, Oahu.

The Anuenue Fisheries Research Center (DLNR, Sand Island, Oahu).

Department of Agricultural Engineering (University of Hawaii—Manoa).

production in the State. Considering the Japanese experience once again, the central government enacted a law in 1971 to establish an aquaculture policy that would designate certain species of marine plants and animals for aquaculture promotion (Asono, 1976).

An additional constraint has been the lack of mechanisms for the transfer of technology to Hawaii. The State's aquaculture researchers need to observe and study technology developed elsewhere in order to apply the results to local conditions.

Economic constraints. Financing is necessary to begin an aquaculture venture. To make a profit, an aquafarmer must sell his product at a price which exceeds his production costs. Thus, financing, production economics, and market development play important roles in determining the farmer's economic viability.

Credit availability relates to the degree of success expected from the enterprise, the "track record" of the applicant, the anticipated market for the product, adequate down payment or front money, etc. Private financing can be augmented by public sector sources. An important constraint to credit has been the lack of experimental facilities to not only test and evaluate species, but to provide a demonstration of commercial feasibility. Without this demonstration, loan officers and entrepreneurs are often reluctant to loan money to, or invest in, aquaculture businesses.

A further obstacle to obtaining financial assistance has been the general failure of aquaculture to qualify for the programs of the U.S. Department of Agriculture and the Small Business Administration. The aquaculturist should be able to receive the same tax, credit, insurance, depreciation, etc., benefits that are currently available to persons engaged in agriculture and small businesses. The establishment of the Aquaculture Loan Fund in the Hawaii State Department of Agriculture in 1972 was an important step in this direction.

The most serious constraint to lowering aquaculture production costs in Hawaii has been—once again—the lack of an experimental facility. Because most forms of aquaculture are labor-intensive, research on reducing labor costs through mechanization is needed. Because of high feed and fertilizer costs, it will be necessary to develop cost-effective alternate strategies for nutrient utilization and recovery.

The production of aquatic products in Hawaii is still relatively small, so significant market constraints have not yet emerged. However, projections indicate that the production of certain species—freshwater prawns and oysters, for example—may increase rapidly in the next few years (Chapter II. B). Market development activities, focusing on local and export markets and the timing of these marketing activities to coincide with production, will be essential to the expansion of aquaculture in the State.

Legal/Institutional constraints. A major constraint to aquaculture development in the United States has been the lack of a lead agency to be responsible for directing, planning and coordinating aquaculture activities. "Poor coordination, lack of leadership, and inadequate financial support have traditionally characterized programs relating to aquaculture" (*Aquaculture in the United States, Constraints and Opportunities*, 1978). The NOAA Aquaculture Plan assessed the results of this situation:

> Coordination, if any has been primarily to avoid undesirable overlap rather than to define goals and agree on responsibility for their achievement. Far more serious than overlap are the number of gaps in the

research and development effort. Many severe problems that impede commercial success are not being attacked, or the efforts are inadequate (*NOAA Aquaculture Plan*, 1977).

Efforts to develop aquaculture in Hawaii have experienced similar problems.[2] Responsibilities and authorities for aquaculture currently exist in five separate State agencies. If aquaculture is to develop to its fullest potential in this State, a lead agency must be designated to effectively coordinate State resources in the planned research, development, support and promotion of the industry. Within the lead agency, an organizational infrastructure should be established that will allow for a maximum of human creative effort. This is needed to address the numerous biotechnical problems that limit expansion.

Of the many constraints that a lead agency should attempt to remove, the legal and environmental restrictions to starting an aquaculture venture in Hawaii are among the most important.[3] Rigid permit requirements, created to prevent the spread of pollution-causing industries to scenic areas, now apply equally—in some cases, unfairly—to aquafarms. Public regulations are many and varied, and may demand a considerable investment in time and money before operations can begin. The establishment of a simplified, coordinated permit procedure that would expedite agency processing of permit applications should be one of the first priorities of the lead agency.

An additional constraint which may have serious effects on the future of aquaculture in Hawaii involves water rights and availability. Complex legal problems are raised by State and Federal regulations in such areas as State vs. private water rights, stream flow diversion and minimum stream flow rates, water transfer, ground and surface water use, and historic agricultural uses of water.

Aquaculture Development for Hawaii

In order to realize the opportunities for aquaculture in Hawaii, the constraints discussed above must be systematically and effectively eliminated or reduced by specific State actions in a planned, integrated, and coordinated effort. The initial step in this process is an assessment of resources to determine limits, constraints and competitive uses.

Before 1974, the State Department of Planning and Economic Development (DPED) published three studies which contained assessments of, and recommendations for, aquaculture in Hawaii: *Hawaii and the Sea–1969*, *The Legal and Administrative Aspects of an Aquaculture Policy for Hawaii* (1972), and *Hawaii and the Sea–1974*. In 1975, a Hawaii State Senate resolution (SR 68) requested the DPED to report to the 1976 Legislature on the progress of current aquaculture programs, the resources committed to them, and their appropriate organizational placement. The study that emerged, *Aquaculture in Hawaii–1976*, provided detailed assessments which included such areas as species researched, the nature and amount of funding involved in this research, public and private sector involvement in aquaculture, and physical, institutional and human resources for aquaculture. Among the recommendations offered was one which suggested

---

[2]See Appendix B, "A Lead Agency for Aquaculture Development in Hawaii."
[3]See *Permits and Environmental Requirements for Aquaculture in Hawaii*, 1977.

a "long-range aquaculture plan" to be prepared by the State which would set State goals and objectives and levels of funding, and include information from existing studies on aquaculture, land use, water use, economics, etc.

The 1976 Legislature and the University of Hawaii Sea Grant College Program responded to the recommendation of *Aquaculture in Hawaii–1976* by co-funding a Statewide aquaculture planning program. The project, which began in July, 1976, was under the direction of the DPED's Center for Science Policy and Technology Assessment.

* * * * * * * * * *

Aquaculture Development for Hawaii incorporates information from previous assessments, and adds a wide range of material to provide a comprehensive treatment of aquaculture in the State. The purposes of this report are to (1) assess Hawaii's resources for aquaculture and identify constraints to development, (2) set a State goal for aquaculture development in Hawaii, (3) define the objectives and policies necessary to realize this goal, and (4) recommend programs, an effective organization, management strategies, and a budget and timetable for the achievement of these objectives and policies.

Other aquaculture studies[4] have made assessments and established goals and policies, but they have generally stopped short of recommending actions; that is, they have hesitated to answer such questions as "What should be done to achieve these goals?", "How?", "Who should do this?", "When?", and "How much money will be needed?" *Aquaculture Development for Hawaii*, however, provides specific answers to these questions. This functional approach is reflected in the methodology of this report, which follows this sequence:

1. The assessments identified both constraints and opportunities for development.
2. From the constraints, six broad objectives could be stated.
3. A set of policies could be formulated for each objective.
4. The policies, in turn, pointed to specific recommended actions.
5. Related actions, in concert with appropriate resources, could be grouped to form programs.
6. Related programs could be grouped to form an organization with the proper stature and placement to carry them out.
7. Once the organization was established, management strategies for the efficient, responsive administration of programs could be devised.
8. Once the programs, organization and management strategies had been created, a budget and timetable could be postulated.

---

[4]For example, the *NOAA Aquaculture Plan* (1977), *Aquaculture in the United States, Constraints and Opportunities* (1978), *Planning for Aquaculture Development–An Introductory Guide* (1974), and *Prognosis and Prescription for Development of Commercial Aquaculture in the United States* (1976)

The resulting information, formulated from execution of the foregoing sequence, is offered in four chapters: Summaries of Assessments (Chapter II), Guidelines for Development (Chapter III), Implementation (Chapter IV), and Budget and Timetable (Chapter V). A brief summary of each of these chapters follows.

Chapter II: Summaries of Assessments. The principal purpose of Chapter II is to assess Hawaii's resources for aquaculture in order to identify opportunities and determine the most important constraints to development. The following subject areas are summarized: Natural Resources, Technical Resources, Legal and Environmental Considerations, Species Selection, Marketing, Funding and Financing, and Economics and Future Considerations. These assessments are based on previously published material, survey questionnaires, personal interviews, and letters to U.S. corporations currently investing in, or engaged in aquaculture. A more detailed discussion of legal and environmental constraints, *Permits and Environmental Requirements for Aquaculture in Hawaii*, was published by the DPED in June, 1977. The Natural Resources section contains tables which indicate the amount of acreage suitable for aquaculture on the major Hawaiian Islands. A set of color-coded maps identifying primary and secondary lands for aquaculture on these Islands will be found in the back inside cover of this report. The Species Selection section is divided into two parts: selection and assessment. The first part discusses favorable and unfavorable characteristics of 20 species with potential for aquaculture development in Hawaii. The second part assesses the eight most promising species on this list. The market section includes a chart which indicates the estimated potential markets for Hawaii's cultured aquatic products. Funding and Financing indicates sources of funding for both public and private aquaculture activities. The final section, Economics and Future Considerations, discusses the effect of future developments on the growth of aquaculture in Hawaii. Projections for employment and revenue from the aquaculture industry extend to the year 2000. The assessments in this chapter represent brief summaries of detailed technical papers which are being planned for publication at a later date.

Chapter III: Guidelines for Development. Chapter III offers guidelines for aquaculture development in the form of a State goal, objectives, and policies, and suggests specific actions to achieve these. The goal is presented first, together with other compatible State goals. The six objectives listed evolve from the constraints discussed in Chapter II. There are six headings to indicate the nature of the objectives: (1) Unified Approach, (2) Business Climate, (3) New Economic Opportunities, (4) Excellence in Research and Development, Training and Technology Transfer, (5) Vocational Training and Formal Education, and (6) Information Center. Each objective includes a statement of rationale, a set of policies to provide long-term guidance on how to achieve the objective, a series of recommended actions, a suggested agency or agencies to implement these actions ("action agencies"), and a schedule for implementation.

Chapter IV: Implementation. Chapter IV indicates *how* the "action agencies" suggested in Chapter II can most effectively carry out the actions (recommended in that chapter) for accelerating the rate of aquaculture development in Hawaii. The action agencies are grouped as follows: (1) the Governor and the Legislature, (2) the various State and County agencies, (3) the University of Hawaii, and (4) the yet-to-be-designated aquaculture lead agency. The majority of this chapter focuses on how the 30 actions recommended for the lead agency can best be implemented. A State aquaculture program, under the direction of the lead agency, is recommended. This program is divided into three program areas: (1) Management, (2) Support Services, and (3) Species Development. Each of these areas contains functional elements. These are described,

A pivotal point for large-scale aquaculture in Hawaii: Governor George Ariyoshi (center) joins U.S. Congressman Daniel Akaka (center left) and Mr. John Buyers, President of C. Brewer & Company, in the first commercial harvest of Brewer's Kilauea, Kauai, prawn farm. The facility–300 acres when completed–will be one of the largest of its kind in the world. (Courtesy of C. Brewer & Company.)

together with major activities. The Species Development program area presents a step-wise procedure for identifying, testing, and developing new species from candidacy to commercial culture. Throughout the chapter, the need for joint programs, appointments, and facilities is stressed.

Chapter V: Budget and Timetable. The purpose of Chapter V is to present a five-year budget and timetable for State funding of the aquaculture development program discussed in Chapter IV. Fiscal policies and guidelines are offered with a description of opportunities for, and constraints to, further growth. Several assumptions are presented. Among the most important is the recognition that this budget reflects a steadily-increasing Federal contribution to aquaculture development.

* * * * * * * * * * *

This chapter has discussed constraints and opportunities for the development of aquaculture. The constraints have caused considerable disappointment because of the aquaculture industry's failure to progress more rapidly. Disappointment has also resulted because hope and optimism have been created without recognizing the appropriate time needed to remove these hindrances. For example, the commercial demonstration of an undeveloped species may take from five to eight years or more to realize. This period may be shortened by transferring culture practices and technologies developed elsewhere to Hawaii. However, even if this proves to be possible, three to five years may be necessary. Therefore, the expansion of aquaculture in Hawaii will require both a State commitment of money and resources to eliminate major constraints, and time to implement the recommendations of this report.

Aquaculture Development for Hawaii offers a pragmatic, conservative course of action that recognizes the State's resource limitations. Public support activities, needed for enlarging existing activities (freshwater prawns, oysters, and catfish) and the identification and economic demonstration of new opportunities (marine shrimp, freshwater finfish, baitfish, etc.), will be initially provided. However, expanded services and programs should be funded on a "pay-as-you-go" basis as the industry grows and increased needs for services emerge. This approach may not stimulate as rapid a rate of growth as a program with greater funding requirements, but, at this time, it will produce a more favorable cost/benefit ratio to the State.

When the recommendations of this report are implemented, the continued rapid development of the aquaculture industry will be greatly enhanced. Hawaii can then look forward to substantial benefits in terms of increased employment opportunities, and a growing and more diversified economy, while at the same time, maintaining its quality of life.

CHAPTER II

SUMMARIES OF ASSESSMENTS

This chapter presents the summaries of assessments of the following subject areas:

A. Natural Resources

B. Technical Resources

C. Legal and Environmental Constraints

D. Species Selection and Assessment

E. Marketing

F. Funding and Financing

G. Economic Projections and Future Considerations

The publication of even a small portion of the material available for each of the above areas would constitute a lengthy report. This chapter, therefore, condenses this information in order to present a concise and meaningful assessment of Hawaii's resources, opportunities and constraints. For additional details, the reader is urged to consult the references at the end of this report. A series of detailed, technical assessments in the aforementioned subject areas is being planned for publication under separate cover at a future date.

A. Natural Resources

Land-based freshwater aquaculture is considerably more advanced than mariculture for a variety of biotechnical and legal reasons, and is expected to make a more significant contribution to the growth of aquaculture in Hawaii during the next decade. Because of this, the assessment of areas physically suitable for aquaculture was limited to identifying and mapping land areas. Factors considered in the statewide land assessment included: (1) elevation, (2) slope of the land, (3) type of soil, (4) identification of surface and ground water sources, and (5) acreage summations of suitable lands of each Island by major drainage basins. State land-use districts and lands within military reservations were the institutional factors considered.

Factors

Elevation. Lands 3,000 feet above mean sea level were eliminated from aquaculture consideration because of cloud cover and lower temperatures. For every 1,000-foot rise in elevation, the decline in mean monthly temperature is about 3°F. Generally, temperatures above 3,000 feet would be less than optimal for the growth of all but a few temperate species, such as trout.

Slope. Lands with a slope greater than five percent were eliminated because of high earthwork costs for farm construction, together with erosion and siltation problems.

Soils. Low soil permeability is a requisite condition for traditional earthen pond aquaculture. Three soil types were identified from maps produced by the U.S. Department of Agriculture's (USDA) Soil Conservation Service (SCS) and the University of Hawaii's Hawaii Agricultural Experiment Station (UH/HAES) (1969). Clay, clay-loam, and loam soils were selected as the prime soils for unlined pond aquaculture because of their water-retaining properties. Soils of other types are suitable for artificially sealed, lined, or otherwise constructed culture units.

Surface and ground water sources. Perennial streams, reservoirs, ponds and groundwater sources were identified by mode of occurrence from various sources and drawn on the base maps of each Island. Mapped information of groundwater sources was obtained from the U.S. Geological Survey Water Supply Paper 2041, 1977.

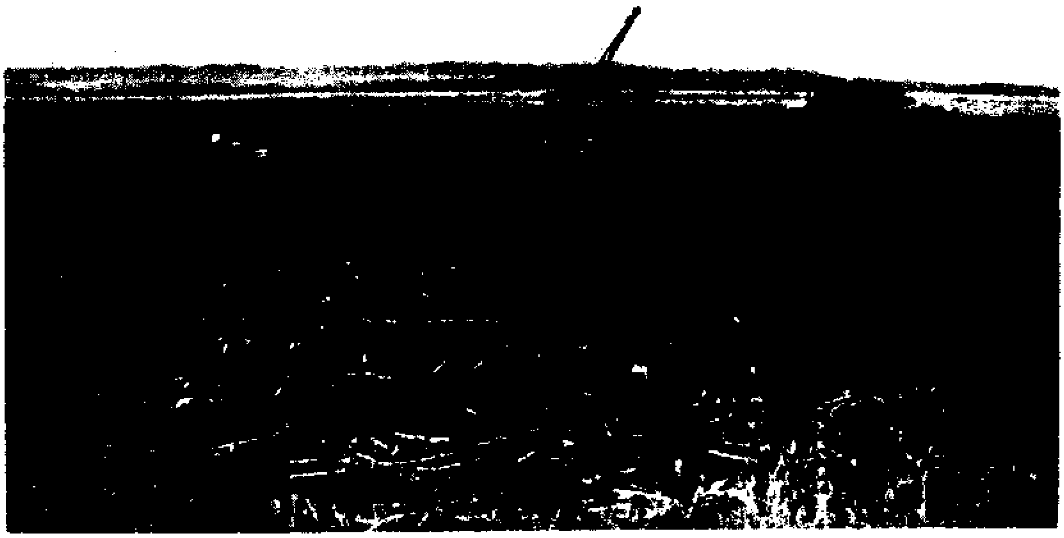
State land-use districts. Lands placed within urban districts by the State Land Use Commission (LUC) were eliminated from the aquaculture acreage assessments. Urban districts include lands presently in urban use with reserve areas of undeveloped lands to accommodate foreseeable urban growth. Some undeveloped urban areas may be suitable for aquaculture development, but high land values, taxes, and the problem of securing long-term leases are reasons why they were not considered for aquaculture.

Military reservations. Sizable land areas on Oahu and Kauai are under military ownership. Since some of these areas may revert back to State control, military reserves were included in the assessment as potential areas for aquaculture development and singled out in the acreage summations.

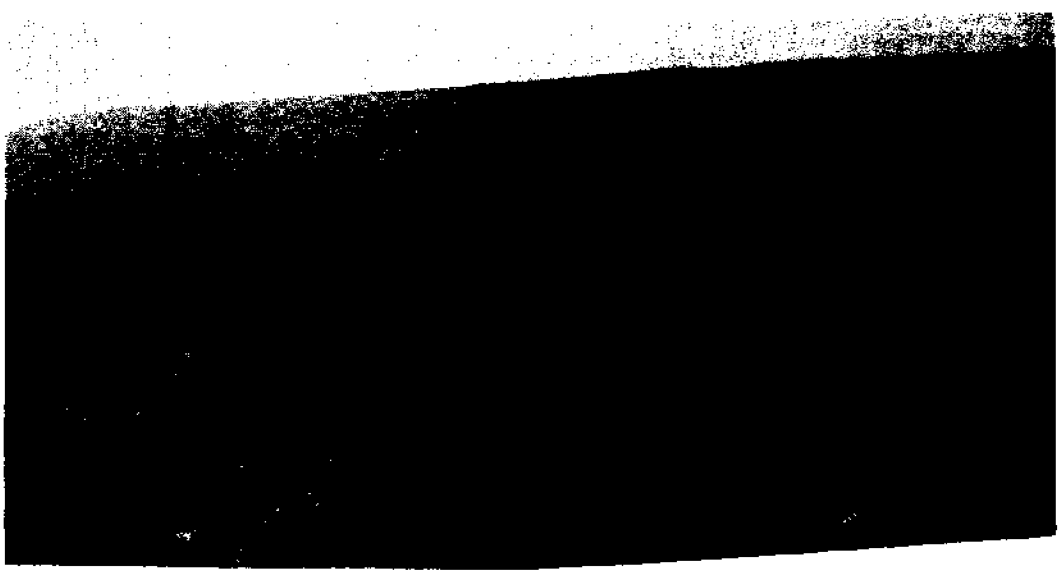
Definition of primary and secondary aquaculture lands. Primary lands that are suitable for aquaculture development are defined as meeting all of the following criteria: (1) lands below an elevation of 3,000 feet, (2) lands of clay, clay-loam, or loam soil type, (3) lands with a slope of not more than five percent, and (4) lands outside of Urban Districts. Secondary aquaculture lands have the same characteristics but include all soil types other than clay, clay-loam, or loam.

Acreage assessments. Acetate overlays for each of the aforementioned factors were prepared for superimposition on base maps of each Island. The boundaries of primary and secondary aquaculture lands were measured by planimeter, and acreage figures were computed from the planimeter measurements.

Hawaii has an abundance of land suitable for aquaculture—over 135,000 acres of primary lands and more than 500,000 acres of secondary lands.



A sugarcane plantation—an example of primary land for aquaculture.



A volcanic pahoehoe *area—secondary land for aquaculture.*

Hydrographic regions. Primary and secondary aquaculture lands for each Island were computed by hydrographic regions which represent the major drainage basins adopted from the *Hawaii Water Resources Plan* (1977). Within each hydrographic region, acreages of primary and secondary aquaculture lands were divided into two categories: 0 to 100 feet, and 101 to 3,000 feet above sea level. Lands bounding the 0 to 100-foot elevation contour were judged to be suitable for coastal water source (salt or brackish water) aquaculture. The cost of the energy needed to pump seawater beyond the 100-foot elevation was considered prohibitive.

Acreage summations. There are more than 135,000 acres of primary lands in the State which are exceptionally suited for aquaculture development (Table 2). Most of the primary lands are currently in agricultural production, principally for sugarcane and pineapple. Aquaculture expansion could extend to the lands currently in agriculture production by the 1990's. Oahu has the largest amount of primary lands, followed by Kauai and Maui. The Island of Hawaii has by far the largest amount of secondary lands. Many of these lands are currently under low-intensity use, chiefly for grazing. Some of these areas appear to be well-suited for saltwater aquaculture projects.

Tables 3 through 8 present acreage statistics of primary and secondary lands for each of the six largest islands according to elevation bands and major drainage basins (hydrographic regions). Comprehensive information on water resources within each hydrographic area, together with statewide assessments of water needs, problems and opportunities expected to emerge by the year 2000 can be found in the *Hawaii Water Resources Plan* (1977).

Maps

Color-coded maps identifying primary and secondary lands for each Island will be found in an envelope affixed to the inside back cover of this report. While the tabular acreage assessments exclude urban district lands, the maps do indicate the major urban centers. Additional features presented on the maps include: (1) groundwater sources by mode of occurrence, (2) perennial streams, reservoirs, and ponds, (3) elevation and rainfall contours, (4) major highways, and (5) boundaries of the hydrographic regions.

Future area assessments

All of the aforementioned factors which were used to determine the acreages of primary and secondary lands were overlayed on 1:24,000 scale base maps. These are on file with the Aquaculture Development Program. As resources allow, acetate overlays will be prepared for the following features: (1) existing uses of both primary and secondary lands, (2) land ownership, (3) subzoning within each State Land Use District, (4) location of solar intensity stations, and (5) possible sources of water pollutants. This information should be of value to prospective aquaculturists interested in selecting sites for commercial operations.

B. Technical Resources

The assessments of Hawaii's technical resources are summarized according to the following key subject areas: (1) effectiveness of past research, (2) development of freshwater prawn farming, (3) laboratory research facilities, (4) outdoor research and demonstration facilities, (5) extension/advisory services, (6) analytical services, (7) education and training, (8) information transfer, (9) complementary programs, and (10) private

Table 2. Summary of Acreages Suitable for Aquaculture in Hawaii

Description of Lands	Kauai	Oahu	Molokai	Lanai	Maui	Hawaii	Total
Primary lands[1]	31,520	47,170	10,060	5,570	29,100	16,940	140,360
Military reserve	--	5,140	--	--	--	--	5,140
Secondary lands[2]	34,880	26,160	11,390	11,710	24,290	414,880	523,310
Military reserve	2,230	5,390	--	--	--	--	7,620
Total primary and secondary lands	66,400	73,330	21,450	17,280	53,390	431,820	663,670
Total military reserve	2,230	10,530	--	--	--	--	12,760
Total primary and secondary lands less military reserve	64,170	62,800	21,450	17,280	53,390	431,820	650,910

[1]Primary lands consist of all lands below 3,000 foot elevation with less than or equal to five percent slope, having clay, loam, or clay-loam soil types, and excluding urban land use districts.
[2]Secondary lands consist of all lands below 3,000 foot elevation with less than or equal to five percent slope, excluding primary lands and urban land use districts.

Table 3. Acreages Suitable for Aquaculture by Hydrographic Regions, Kauai

Description of Lands	Hydrographic Regions					Total
	I	II	III	IV	V	
0 to 100 feet						
Primary lands[1]	1,090	2,480	470	1,330	5,300	10,670
Secondary lands[2]	1,690	1,010	2,630	820	5,010	11,160
Military reserve	-	-	-	-	2,230	2,230
Total primary and secondary lands	2,780	3,490	3,100	2,150	10,310	21,830
Total military reserve	-	-	-	-	2,230	2,230
Total primary and secondary lands less military reserve	2,780	3,490	3,100	2,150	8,080	19,600
101 to 3000 feet[3]						
Primary lands	3,140	14,280	2,430	990	10	20,850
Secondary lands	5,580	11,150	5,800	1,170	20	23,720
Total primary and secondary lands	8,720	25,430	8,230	2,160	30	44,570
Total (0 to 3000 foot elevation)	11,500	28,920	11,330	4,310	10,340	66,400
Less military reserve	-	-	-	-	2,230	2,230
Total lands for aquaculture	11,500	28,920	11,330	4,310	8,110	64,170

[1]Primary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, having clay, loam, or clay-loam soil types, and excluding urban land use districts.
[2]Secondary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, excluding primary lands and urban land use districts.
[3]No military reserves at this elevation.

Table 4. Acreages Suitable for Aquaculture by Hydrographic Regions, Oahu

Description of Lands	Hydrographic Regions						Total
	I	II	III	IV	V	VI	
0 to 100 feet							
Primary lands[1]	3,390	1,810	240	4,470	2,520	3,240	15,670
Military reserve	-	260	-	480	1,200	120	2,060
Secondary lands[2]	1,980	1,770	-	7,600	2,910	1,990	16,250
Military reserve	-	470	-	1,060	870	520	2,920
Total primary and secondary lands	5,370	3,580	240	12,070	5,430	5,230	31,920
Total military reserve	-	730	-	1,540	2,070	640	4,980
Total primary and secondary lands less military reserve	5,370	2,850	240	10,530	3,360	4,590	26,940
101 to 3000 feet							
Primary lands	170	400	100	15,800	200	14,830	31,500
Military reserve	-	-	-	760	200	2,120	3,080
Secondary lands	270	260	50	2,920	2,610	3,800	9,910
Military reserve	-	-	-	160	2,040	270	2,470
Total primary and secondary lands	440	660	150	18,720	2,810	18,630	41,410
Total military reserve	-	-	-	920	2,240	2,390	5,550
Total primary and secondary lands less military reserve	440	660	150	17,800	570	16,240	35,860
Total (elevation 0 to 3000 feet)	5,810	4,240	390	30,790	8,240	23,860	73,330
Less military reserve	-	730	-	2,460	4,310	3,030	10,530
Total lands for aquaculture	5,810	3,510	390	28,330	3,930	20,830	62,800

[1]Primary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, having clay, loam, or clay-loam soil types, and excluding urban land use districts.

[2]Secondary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, excluding primary lands and urban land use districts.

Table 5. Acreages Suitable for Aquaculture by Hydrographic Regions, Molokai

Description of Lands	Hydrographic Regions				Total
	I	II	III	IV	
0 to 100 feet					
Primary lands[2]	100	950	830	390	2,270
Secondary lands[3]	1,420	1,290	1,790	960	5,460
Total primary and secondary lands	1,520	2,240	2,620	1,350	7,730
101 to 3000 feet					
Primary lands	-	-	5,590	2,200	7,790
Secondary lands	280	150	3,780	1,720	5,930
Total primary and secondary lands	280	150	9,370	3,920	13,720
Total lands for aquaculture (elevation 0 to 3000 feet)	1,800	2,390	11,990	5,270	21,450

[1] There are no major military reserves on those lands identified as suitable for aquaculture on Molokai.

[2] Primary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, having clay, loam, or clay-loam soil types, and excluding urban land use districts.

[3] Secondary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, excluding primary lands and urban land use districts.

Table 6. Acreages Suitable for Aquaculture by Hydrographic Regions, Lanai

Description of Lands	Hydrographic Regions I	Hydrographic Regions II	Total
0 to 100 feet			
Primary lands[2]	260	-	260
Secondary lands[3]	1,340	100	1,440
Total primary and secondary lands	1,600	100	1,700
101 to 3000 feet			
Primary lands	30	5,280	5,310
Secondary lands	700	9,570	10,270
Total primary and secondary lands	730	14,850	15,580
Total lands for aquaculture (elevation 0 to 3000 feet)	2,330	14,950	17,280

[1] There are no major military reserves on those lands identified as suitable for aquaculture on Lanai.

[2] Primary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slopes, having clay, loam, or clay-loam soil types, and excluding urban land use districts.

[3] Secondary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, excluding primary lands and urban land use districts.

Table 7. Acreages Suitable for Aquaculture by Hydrographic Regions, Maui

Description of Lands	Hydrographic Regions					Total
	I	II	III	IV	V	
0 to 100 feet						
Primary lands[2]	790	1,940	5,610	-	-	8,340
Secondary lands[3]	490	1,530	3,250	1,740	900	7,910
Total primary and secondary lands	1,280	3,470	8,860	1,740	900	16,250
101 to 3000 feet						
Primary lands	830	2,560	17,370	-	-	20,760
Secondary lands	250	2,850	11,310	1,160	810	16,380
Total primary and secondary lands	1,080	5,410	28,680	1,160	810	37,140
Total lands for aquaculture (elevation 0 to 3000 feet)	2,360	8,880	37,540	2,900	1,710	53,390

[1] There are no major military reserves on those lands identified as suitable for aquaculture on Maui.

[2] Primary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, having clay, loam, or clay-loam soil types, and excluding urban land use districts.

[3] Secondary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, excluding primary lands and urban land use districts.

Table 8. Acreages Suitable for Aquaculture by Hydrographic Regions, Hawaii

Description of Lands	Hydrographic Regions					Total
	I	II	III	IV	V	
0 to 100 feet						
Primary lands[2]	110	50	-	-	10	170
Secondary lands[3]	980	19,700	19,480	14,750	9,270	64,180
Total primary and secondary lands	1,090	19,750	19,480	14,750	9,280	64,350
101 to 3000 feet						
Primary lands	2,470	12,570	830	-	900	16,770
Secondary lands	11,670	142,190	100,020	33,050	63,770	350,700
Total primary and secondary lands	14,140	154,760	100,850	33,050	64,670	367,470
Total lands for aquaculture (elevation 0 to 3000 feet)	15,230	174,510	120,330	47,800	73,950	431,820

[1]There are no major military reserves on those lands identified as suitable for aquaculture on the island of Hawaii.

[2]Primary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, having clay, loam, or clay-loam soil types, and excluding urban land use districts.

[3]Secondary lands consist of all lands below 3000 foot elevation with less than or equal to five percent slope, excluding primary lands and urban land use districts.

research and consulting activities. A more detailed treatment of these resources is expected to be published at a later date.

Effectiveness of Past Research

There are five principal organizations in Hawaii which conduct basic and applied aquaculture research: the State Department of Land and Natural Resources (DLNR) Anuenue Fisheries Research Center (AFRC); the University of Hawaii's Hawaii Institute of Marine Biology (HIMB), Department of Botany and College of Tropical Agriculture (CTA); and the Oceanic Institute (OI). During the past 16 years (the period generally thought to correspond with the growth of modern aquaculture), nearly $8 million from both State and non-State sources have been invested in research. Nearly one-half of this sum was from the Sea Grant College Program (SGCP) of the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce (USDOC), while approximately one-fourth was State money. The remainder can be primarily attributed to private sources (grants and contracts for international development work), and some County contributions.

In general, the purpose of this research effort was to determine the aquaculture potential of selected marine and freshwater species. Of the more than 20 plant and animals species researched, the Malaysian prawn and a marine seaweed (*Eucheuma*) have emerged as viable commercial enterprises. However, it should be noted that research into commercial seaweed production was carried out primarily in the Philippines. The majority of the potential aquaculture species were tested at HIMB under a Sea Grant funded program. Species eliminated from further consideration possessed major bio-technical problems, and funding agencies could not provide the resources necessary to find solutions, if, indeed, solutions were possible. Other organizations concentrated their research efforts on fewer species, e.g., prawns (DLNR) and mullet (OI). Cooperative research efforts between State and private organizations have been developing slowly, but steadily.

A critical examination of these research activities reveals that some species were selected for evaluation without an adequate examination of the costs involved in raising the species locally. Moreover, the funding provided for the study was often too meager to achieve results. In addition, certain species were apparently researched because of their biological interest to the principal investigator, rather than their aquaculture potential. If the investigator chose to leave the State, research efforts were reduced or terminated.

These observations reveal some of the complexities of aquaculture development. Furthermore, they indicate that a system with specific objectives and mechanisms for coordination and the placement of responsibility for actions was clearly needed. However, Hawaii's early research efforts have provided extensive biological and ecological information on local species and this background research can be used in future aquaculture development decisions.

Development of Freshwater Prawn Farming

Malaysian prawn (*Macrobrachium rosenbergii*) is the most successful aquaculture species cultured in Hawaii (Chapter I). An analysis of the historical development and present status of prawn farming (Corbin, 1976) provides the basis for a system for developing other species under Hawaii conditions. The characteristics highlighted below can be grouped into two categories: (1) the basic economic factors involved in prawn

The Anuenue Fisheries Research Center, Sand Island, Oahu. (Courtesy of AFRC.)

Aquaculture Disease Specialist, Dr. James Brock, shares his time between the AFRC and the Plant Quarantine Branch of the State Department of Agriculture.

Hawaii has a wide range of technical resources for aquaculture. The State should continue to encourage commercial operations through such support services as extension/advisory, disease prevention and marketing assistance, as well as the provision of stocking material.

farming in Hawaii and (2) State activities which have encouraged the development of a commercial aquaculture enterprise.

An important reason for the success of prawn farming in Hawaii is the existence of a substantial market for the product. Since prawns are considered a luxury food, the wholesale market price for prawns has tended to remain high in comparison to other aquatic species. Thus a strong demand for prawns has resulted in profit margins which have made prawn farming an attractive activity.

State activities performed primarily by the AFRC have done much to encourage commercial prawn farming. The State's development of a workable hatchery technology to produce juvenile prawns and provision of free stocking material has spurred prawn farming in Hawaii and around the world (Corbin, 1976; Hanson and Goodwin, 1977). Perhaps equally important was the active part the State played in the demonstration of the scientific and economic feasibility of commercial pond culture. State personnel worked closely with private farmers and provided the technical expertise necessary for success. This type of close working relationship was augmented by the State's provision of a broad array of free extension/advisory services and stocking material at cost after the farmer became established. These services touched on every aspect of the growout system from site selection to harvesting and were supported by a limited State research capability. The State was also active in providing initial assistance in establishing markets for the farmers' production. The final area of State assistance concerns the increased availability of loans to aquafarmers and the training of a competent labor force through workshops and on-site assistance.

Prawn farming is now at a point where private entrepreneurs are organizing to address common needs. Recently, a prawn farmers association was formed with a view towards evolving into a cooperative. Such organizations can assist all farmers by (1) purchasing feed and other inputs in volume, (2) assisting the State in establishing priorities for research and support services, and (3) collectively participating in post-harvest handling and processing activities. In addition, recent increases in prawn production have identified the need for a concerted market development program.

In summary, a State commitment to the development of hatchery technology, the demonstration of growout techniques, the provision of extension/advisory services, the establishment and development of markets, and the increased availability of loan capital have contributed to the establishment of successful freshwater prawn farming. The inescapable conclusion is that similar State efforts directed towards other species could accelerate their rates of commercial development.

Laboratory Research Facilities

Well-staffed and equipped laboratory research facilities for basic and applied research are essential to the growth and development of aquaculture. Hawaii is fortunate to have research capabilities in a wide variety of scientific disciplines. These facilities are located in the State University system, at the DLNR and at private organizations. Currently, the Manoa campus of the University has faculty and staff, with professed or demonstrated aquaculture interest, located in the following branches: the Departments of Botany and General Sciences of the College of Arts and Sciences; the Departments of Agricultural Engineering, Resource Economics, Animal Sciences, HAES, Food Sciences and Technology of the CTA; Department of Genetics of the School of Medicine; the Center for Engineering Research; Hawaii Cooperative Fishery Research Unit; HIMB; Hawaii Natural Energy Institute (HNEI); and the Pacific Biomedical Research

Center. The DLNR has laboratory facilities associated with its freshwater prawn research at the AFRC (Corbin, 1976). A partial list of commercial research laboratories with aquaculture interests are discussed in the "Private Research and Consulting" portion of this section.

All of the above-mentioned entities have the personnel and resources to conduct aquaculture research, if these personnel are encouraged to utilize their skills to address problems relating to aquaculture. Areas of critical concern to the development of economically important species are selective breeding, pathology, engineering, pond ecosystem management, food technology, nutrition and physiology. Joint or interdisciplinary programs, which combine expertise from appropriate disciplines, have been applied to a moderate extent in Hawaii, most notably with freshwater prawns (*Sea Grant Institutional Program, Year 11,* 1978). The success with prawns suggests that the other cooperative programs should be encouraged to address the complex development problems of other species. The key to the establishment of these programs is the encouragement of the lateral movement of specialists in traditional disciplines into aquaculture research; for example, directed research contracts could be used to investigate specific problems. A final consideration of special importance to the development of aquaculture in Hawaii is the need to establish national and international cooperative efforts which would include exchanges of aquaculture specialists among agencies and organizations.

Outdoor Research and Demonstration Facilities

The research and development activities of State organizations have been limited by the need for and lack of outdoor ponds for controlled statistically valid growout experiments. This lack poses particular problems for the Malaysian prawn research group, composed of the AFRC, UH/CTA and UH/SGCP members, because large-scale growout experimentation is necessary to address important pond management questions. Moreover, performance evaluation tests of potential fresh, brackish or salt water aquaculture species cannot be undertaken because appropriate pond complexes are not available. Likewise, the transfer of technology to the private sector is difficult because growout demonstration activities, e.g., pond growout for freshwater prawns, cannot be readily carried out by State or University extension/advisory personnel.[5]

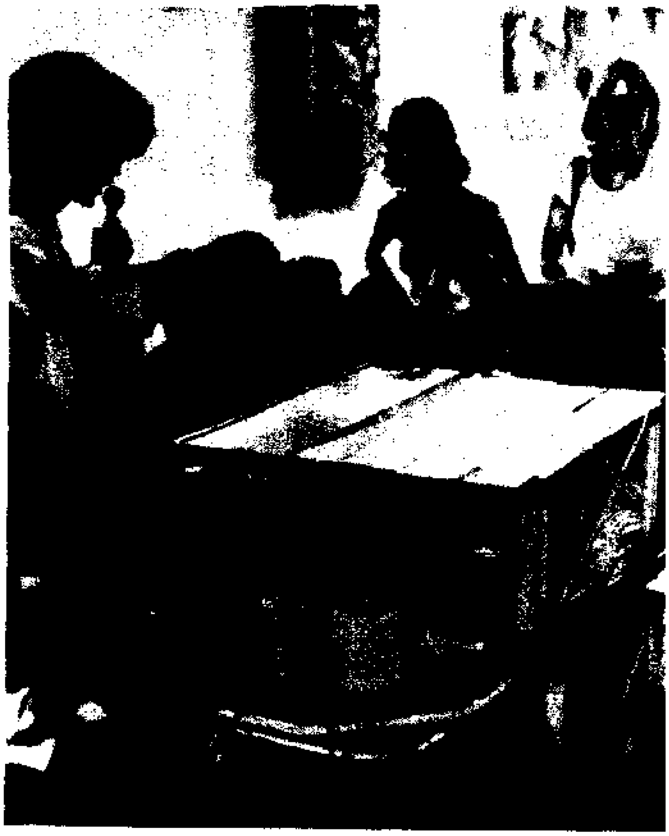
Extension/Advisory Services

Extension/advisory capabilities in Hawaii range from providing advice on fundamentals to "hands-on" assistance at the production facility. Sources of this support can answer basic questions ("What is prawn farming?"), as well as problem-oriented inquiries ("Why do my prawns have black gills?"). There are six principal public sources where these services are provided at no cost to the farmer. Briefly, these are:

Anuenue Fisheries Research Center, Division of Fish & Game, DLNR. The AFRC is the foremost source of advice on commercial prawn aquaculture systems. Personnel provide information concerning all aspects of prawn aquaculture, from siting to marketing. The rapid expansion of commercial prawn production has resulted in the number of requests for assistance to exceed the capabilities of the AFRC to respond.

---

[5]For a more detailed treatment of this subject, see Appendix B, "Tropical Aquaculture Center for Hawaii."



There are many ways the State can encourage the expansion of aquaculture—from increasing the public's awareness of opportunities, to providing "grass roots" assistance to aquafarmers.

Finding out about prawns—an exhibition in downtown Honolulu.

Prawn farmers learn harvesting techniques from Anuenue Fisheries Research Center workers. (Courtesy of AFRC.)

Marine Advisory Program, UH/SG. Marine Advisory Program (MAP) agents, located in each County, are responsible for identifying and meeting the marine information needs of the citizens of their County. Aquaculture services make up a limited, but growing, part of their activities. To date, their focus has been on the practical backyard operation and inquiries concerning commercial operations are referred to the appropriate State agency or the University. A MAP/Aquaculture Development Program (ADP) cooperative effort has produced a general information slide show on aquaculture in Hawaii and a film on raising freshwater prawns is under consideration.

The Hawaii Agriculture Extension Service, UH/CTA. The HAES has a long history of extension/advisory services for the agriculture industry. On the Mainland, advice on the pond aquaculture of various freshwater (primarily catfish) species is routinely provided (*Aquaculture Joint Hearings* before the Subcommittee on Fisheries and Wildlife Conservation and the Environment and the Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries, House of Representatives, 1975). However, this is not the case in Hawaii. HAES agents in this State have specialties in terrestrial plant culture or livestock husbandry. At present, there are no aquaculture specialists; however, the potential exists for increasing the level of aquaculture skills if the existing infrastructure is utilized.

Soil Conservation Service, USDA. SCS's capabilities for advising on freshwater aquaculture are limited to erosion control around pond banks. On the Mainland, SCS agents provide freshwater aquaculture extension/advisory information which includes (1) biotechnical aspects of fish farming, (2) engineering aspects of pond design, and (3) site selection of ponds. This range of services has not carried over to Hawaii, yet the potential for developing these services exists.

The Aquaculture Development Program, Department of Planning and Economic Development. The ADP, an interim program, carries out State aquaculture planning and development activities. ADP staff can provide advice on various types of fresh, brackish, and saltwater aquaculture, and refer inquiries to appropriate extension personnel and other experts.

County services. Several of Hawaii's Counties are considering the establishment of aquaculture specialist positions to perform extension/advisory work. To date, only Maui County has this position.

In summary, Hawaii has limited capabilities in extension/advisory services to aquafarmers. Prawn farming is the major commercial aquaculture activity in the State, however, an expansion of current resources is needed to keep up with the projected growth of operations. There is a need for training agents in the skills necessary to keep pace with the projected diversification of the industry. The possibility of sharing the cost of this development through joint programs should be explored.

Analytical Services

New aquafarmers may not possess the wide array of technical knowledge to manage a commercial aquaculture enterprise. For example, there are many new aquafarmers in Hawaii with a background in terrestrial agriculture, but who have little experience in managing aquatic systems (Corbin, 1976). Furthermore, the cost of obtaining the appropriate expertise from consulting firms may be too great for many new businesses. For these reasons, the provision of analytical support services is a valuable area for State assistance to beginning farmers.

Two State-supported analytical services for the commercial production sector will be available to a limited extent in late 1978. These are water chemistry analysis and disease prevention assistance. A water chemistry laboratory, which will be administered by the AFRC and located at that facility, will support pond management research and extension/advisory services. Services for commercial producers for "trouble shooting" problems may be available initially on a limited basis, but may be expanded at a later date.

In the area of disease prevention, a State-supported aquaculture disease specialist position was recently created on the ADP staff. The specialist works jointly with the DLNR and the Department of Agriculture (DOA). The individual will be responsible to the AFRC for providing disease identification and pathology services to the aquaculture community for species which are currently cultured, or are under investigation for culture in Hawaii. At the DOA, the individual will work out of the Plant Quarantine Branch and catalog diseases which affect species under cultivation in Hawaii, inspect live shipments of aquatic species for cultivation in the State and institute follow-up procedures with importers regarding the health and well-being of imported aquatic species for culture in Hawaii.

Possible future analytical services include soil analyses--important in aquaculture site selection--and shellfish depuration to help establish profitable oyster farming in Hawaii. Key analytical services should be provided by the State until such time as they are adequately available in the private sector.

Education and Training

Opportunities for formal education and training in aquaculture have been limited in Hawaii. At present, there is no degree program for aquaculture in the State University system, although students can receive a degree in a number of related fields and carry out thesis research in aquaculture. Several courses recently offered by the UH at Manoa were directed at a wide range of students from the non-technically oriented undergraduate to the advanced degree candidate. Courses offered outside the University have been introductory in nature.

With the exception of freshwater prawns, "hands-on" training that would give the individual the opportunity to work with a system under supervision has not developed to a great extent. The UH/SG Marine Option Program (MOP) works with the State aquaculture community to place undergraduate students with an interest in aquaculture in appropriate learning situations, while the UH/CTA is providing first-hand experience in pond management through courses at their Pearl City Instructional Facility. The AFRC, in cooperation with the East-West Center and other members of the State's aquaculture community, has conducted comprehensive training workshops for Malaysian prawn farming systems (hatchery to growout). In addition, training opportunities have been available during the summer months when the AFRC's hatchery is operating at full capacity. Notably, AFRC workshops have attracted students from many countries, and have provided the trained personnel necessary for the growth of the prawn industry overseas and in Hawaii.

Future education and training goals may include offering undergraduate as well as graduate degrees in aquaculture, according to the needs of both sectors of the industry. The curriculum should have a high degree of local relevancy, as well as value to students from Asian and Pacific Basin nations. It is clear that the expansion of quality aquaculture education and training opportunities will depend on the State's ability to attract

Opportunities for aquaculture education and training in Hawaii have increased substantially in the last few years. In addition to Federal, State, and private international programs, the University of Hawaii system has added courses that offer local residents the chance to become aquafarmers.

Above: Learning about aquaculture in Hawaii: Indonesian officials taking part in a prawn workshop are shown a project at the Hawaii Institute of Marine Biology. (Courtesy of AFRC.)

Below: Students from Kauai Community College acquire "hands-on" training at Astro Marine, Inc.'s prawn and brine shrimp facility. (Courtesy of Astro Marine.)

experienced individuals to teach in Hawaii. Furthermore, the possibility of establishing cooperative programs with other local, national and international groups should be explored.

Information Transfer

A rapidly increasing awareness of opportunities in aquaculture has resulted in a need for a variety of information. There are several sources of information relating to aquaculture in Hawaii: the National Marine Fisheries Service (NMFS) of the NOAA; the Cooperative Fisheries Unit of the U.S. Fish and Wildlife Services; several State agencies, including the AFRC and the ADP of DPED; and several departments within the UH, e.g., SGCP, CTA, and HIMB. State libraries are generally aware of aquaculture as a business and a science, but have few informational materials to distribute. The organizations listed above answer general inquiries on an individual basis because pamphlets and other informational materials are not presently available. A clear need exists for promotional material identifying the various opportunities for commercial aquaculture in Hawaii.

Complementary Programs

State energy and fisheries programs complement and enhance the development of aquaculture in Hawaii. The DPED's Center for Science Policy and Technology Assessment (CSPTA) is involved in several programs directed at developing alternate energy sources for Hawaii. Among the proposed technologies which can interface with aquaculture are: (1) ocean thermal energy conversion (OTEC), and (2) biomass energy conversion projects. The development of these technologies in Hawaii could broaden the scope of aquaculture activities, particularly those related to mariculture (*State of Hawaii, Energy Resources Coordinator's Report,* 1977).[6]

In addition to alternate energy projects, there has been a rising interest in expanding live bait skipjack tuna fisheries in Hawaii and the Pacific (Pacific Tuna Development Foundation, 1978). Aquaculture can play an important role in the development of the tuna fishery through the culture of baitfish (*Hawaii Tuna Fishery Development Plan,* 1977). Aquaculture technologies can also play a significant role in other State fisheries management activities, such as enhancement of natural stocks and the development of waste water and nutrient recovery systems. Activities in these areas are likely to increase in the near future.

Private Research and Consulting Activities

Hawaii has several private research and consulting firms which are committed to developing aquaculture locally and in the Pacific. The Oceanic Institute, a nonprofit organization, has a long and prestigious history of involvement in aquaculture, particularly in research on the artificial spawning of mullet. The Pan Pacific Institute of Ocean Science, another nonprofit organization, engages in various aquaculture-related biological studies, including algae culture, sewage re-use systems and OTEC development. In recent years, several private, profit-oriented aquaculture consulting firms have become established. Most of these perform feasibility studies and consult on numerous operational

---

[6]See also Chapter II, G.

Cooperative projects, which combine skills available in two or more programs, make efficient use of Hawaii's resources for aquaculture.

Prawn workshop: a joint effort of Anuenue Fisheries and the East-West Center. (Courtesy of East-West Center.)

Slide show, Aquaculture in Hawaii, *produced by Sea Grant's Marine Advisory Program and DPED's Aquaculture Development Program (center).*

components of commercial aquaculture systems. These firms include the Pacific Aquaculture Corporation, Aquatic Farms, Ltd., Systems Culture, Inc. and Environmental Consultants, Inc. In addition, Hawaii has numerous firms which can consult on such specific production problems as soil analysis, water chemistry analysis, etc.[7]

Actions to promote Hawaii as a center for aquaculture technology for Asia and the Pacific can aid the further development of these private activities. Also, the existence of this private infrastructure presents opportunities for cooperative research and development programs between the State and the private sector.[8]

C. Legal and Environmental Constraints

There are few aspects of aquaculture uses of lands and waters that are not regulated by State, County or Federal agencies. Public regulations are many and varied, ranging from environmental assessments and impact statements to special permits. Some regulations govern specific activities (e.g., grading, construction, well digging, effluent, disposal) regardless of location, while others govern activities within specific geographic areas (e.g., conservation districts, shoreline setback and management areas, near-shore waters).

An initial problem faced by prospective aquaculturists is determining the number of permits, project reports, and public hearings that could be required for securing government approvals, and then forecasting the amount of time and expenditure needed to meet agency requirements. Another difficulty centers on the uncertainties of the many laws and regulations that were adopted before aquaculture developed into a well-recognized activity and which are now relevant to it. Statutes relating to land and water use are broadly phrased, leaving room for administrative judgment on their applicability to aquaculture use.

Major Legal Bases

The number of government approvals for aquaculture projects can vary widely depending on the complexity of a project, the location, type of activities, potential impact, as well as the degree of controversy generated. *In general, a choice of inland locations can greatly minimize regulatory problems since shoreline land and water use permits are both numerous and complex.*

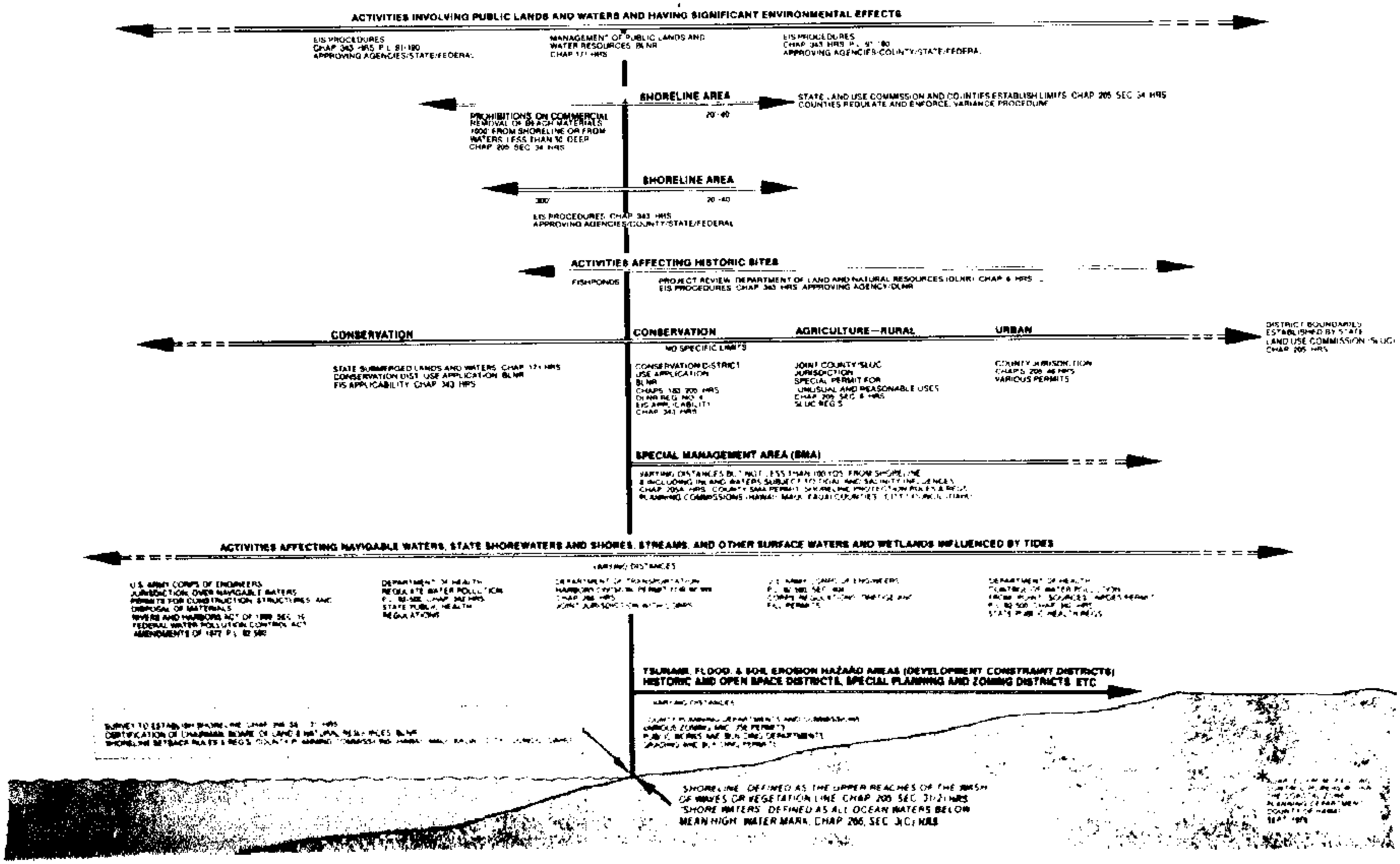
Figure 1 shows a comprehensive view of the major legal bases that govern land and water use in Hawaii with reference to the shoreline. An understanding of these major laws is a prerequisite for understanding the regulatory processes governing aquaculture use. Detailed discussions of these laws, their relationship to each other, and their applicability to aquaculture activities are presented in *Permits and Environmental Requirements for Aquaculture in Hawaii*, a study published under separate cover by the State Department of Planning and Economic Development (1977). This study contains a description of permits that can be required for aquaculture projects, including their purpose, data requirements, filing fees, time from filing to approval, public participation requirements, and problem areas.

---

[7]See Hawaii Scientific Resources Directory, 1977.

[8]A report detailing Hawaii's technical resources for aquaculture is expected to be published by the Aquaculture Development Program.

Figure 1. Major Control Powers Over Aquaculture Uses of Lands and Waters



Jurisdictional Overlaps

Government approvals for aquaculture activities within nearshore locations are compounded by overlapping statutes and a fragmentation of jurisdictional authority that mandate independent agency reviews. The following examples illustrate this point:

1. State law defines "shorewaters" as all ocean shores below the mean high water mark within the jurisdiction of the State. U.S. "navigable waters" are defined in Federal law and Army Corps of Engineers regulations as those which are subject to the ebb and flow of the tide. Aquaculture activities within or affecting coastal waters are thereby subject to concurrent authorization by the Corps and the State Department of Transportation (DOT).

2. According to State Land Use Commission regulations (LUC), lands below the zone of wave action are included in the conservation district, unless otherwise designated on district maps. Therefore, in addition to securing Corps and DOT authorization, an applicant would need to obtain a Conservation District Use Permit (CDUP) from the State Board of Land and Natural Resources (BLNR) for aquaculture activities involving coastal waters and submerged lands.

3. Under State law, the care and control of navigable reaches of streams are placed with the DOT. Similarly, wetlands and streams are within the jurisdiction of the Corps. Moreover, State regulations set forth that "all waters within the State are considered to be within a (land) use district and (are to be) controlled by the applicable district regulations." Therefore, aquaculture activities involving the use of inland water areas are subject to County, State, and Federal controls.

4. The Special Management Area (SMA) overlaps the 20- to 40-foot setback area inland of the shoreline. Aquaculture uses involving lands within the shoreline setback are thereby subject to both SMA and setback rules and regulations. Setback areas and SMA's that are in the conservation district are under concurrent jurisdiction of the respective County authorities and the State BLNR.

5. Finally, under State law, Environmental Impact Statement (EIS) determination is required for proposed actions within the shoreline setback area (including stream mouths by definition), for actions within 300 feet seaward of the shoreline, for actions in conservation district land and waters, and for actions within designated historic sites (some coastal fishponds). Moreover, State and Federal EIS and SMA administrative procedures can require duplication of information on a broad set of environmental attributes and project impacts.

Common Data Requirements

Table 9 depicts common data requirements that could be necessary for securing project approvals from the various agencies that have legal authority over aquaculture-related activities near the shoreline. The DPED aquaculture permit report (1977) provides basic information on permits required for constructing and operating projects, and indicates the appropriate public agencies for prospective aquaculturists seeking detailed information on the scope of agency requirements.

There are other government approvals that deal with importations of animals, and with public health requirements in the propagation and sale of shellfish.

Table 9. Common Data Requirements for Aquaculture Proposals

PERMIT OR PROCEDURE / POSSIBLE DATA REQUIREMENTS	BASIC ENVIRONMENTAL ASSESSMENT INFORMATION	WATER QUALITY DATA	SOILS DATA	ARCHEOLOGICAL FIELD STUDIES	INSTRUMENT SURVEY	TOPOGRAPHIC SURVEY	ENGINEERING DRAWINGS
SMA PERMIT (COUNTY)	*	*	*	*	*	*	optional
VARIANCE FROM SHORELINE SETBACK REGULATIONS (COUNTY)	*			*	*	*	*
CONSERVATION DISTRICT USE PERMIT - DLNR (STATE)	*		*			*	optional
HISTORIC SITE REVIEW - DLNR (STATE)	*			*			
PERMIT FOR WORKS IN STATE SHORE WATERS - DOT (STATE)	*				*		*
NPDES EFFLUENT DISCHARGE PERMIT - DOH (STATE)	*	*					
STATE SYSTEMS EIS (STATE OR COUNTY)	*	*	*	*		*	optional
PERMIT FOR WORKS AFFECTING U.S. NAVIGABLE WATERS (FEDERAL)	*	*	*		*		*
FEDERAL EIS	*	*	*	*		*	optional
WELL PERMIT (STATE OR COUNTY)		*					*
GRADING PERMIT (COUNTY)			*			*	

Importation

State regulations. Before any new species can be introduced into Hawaii, either for release or for culture, permission must be received from the State Board of Agriculture (BOA). The procedure is initiated by filing an application form and supporting documentation with the Plant Quarantine Branch of the Plant Industry Division of the DOA. The application and supporting materials for new aquaculture species are forwarded to the Advisory Subcommittee on Invertebrates and Aquatic Biota for their review and recommendation. The Subcommittee's comments and recommendations are, in turn, transmitted to the Advisory Committee on Plants and Animals for additional review and recommendation. The BOA can approve, deny, or approve with modification, those importation requests that have been reviewed by the respective committees. This procedure can take a minimum of six to eight weeks or longer depending on the amount of supplemental information required by the three levels of review. Once permission is granted for the importation of a species, requests for further importations of that species are handled administratively.

Federal regulations. The Lacey Act (Section 42, Title 18, United States Code) authorizes the Secretary of the Interior to restrict, by regulation, the importation of non-native organisms which could be injurious to aquaculture and wildlife resources of the United States. A *proposed* injurious wildlife list published in the March 7, 1977 *Federal Register* includes all species of the genus *Sarotherodon*, the white amur or grass carp, and the silver carp. The Aquaculture Advisory Council and Liaison Committee (AACLC) has formally requested that these species be struck from the proposed list of injurious species for various reasons including the fact that they have significant economic potential as low-cost, high-quality sources of protein. The matter of final rule making is in abeyance since the issuance of Executive Order 11987 on May 24, 1977 which directs the Secretary of Agriculture to develop legislation to deal with the importation of exotic species.

Shellfish Regulations

Regulations prepared by the State Department of Health (DOH) controlling the production, harvesting, processing, packaging, storage, and distribution of shellfish (oysters, clams, and mussels) grown in either natural or artificial environments have recently been adopted. These regulations were prepared in conformity with the National Shellfish Sanitation Program of the U.S. Food and Drug Administration (FDA). The adoption of the regulations paves the way for the sale of cultured shellfish for both local and export markets.

Findings

Government regulations over land and water use can have an impeding effect on aquaculture ventures. Jurisdictional fragmentation due to overlapping statutes requires repetitive agency reviews. The result is a duplication of data requirements that appears unnecessary for the timely processing of legal requirements for aquaculture ventures. This situation can result in several consequences:

1. Obtaining financing, leasing land, and planning cash flows may be difficult since there can be no advance guarantee that a project will be approved at each permit request stage.

2. Risks are compounded by the repetitiveness and fragmentation of government approvals. This can result in escalating project costs and possibly, the abandonment of the project.

3. The "red tape" inherent in the existing network of controls works against innovation. Red tape has had an inhibiting effect on the emerging aquaculture industry since prospective aquaculturists have had to satisfy the questions of regulatory personnel unfamiliar with aquaculture technology.

4. Because of the costs associated with satisfying permit requirements, financial resources will often be the determining factor for those entering the field. Starting an aquaculture venture can be a relatively impossible task for those lacking investment capital and the ability to absorb the costs of delay, but who might otherwise have the knowledge and practical skills required to engage in aquatic farming.

Conclusions

1. Consideration should be given to the adoption of an omnibus State policy on aquaculture. A key feature of this policy would be the recognition of aquaculture as a highly desirable form of economic activity, well-suited to the culture, economy, and environment of Hawaii.

2. Aquaculture activities should be accorded high priority in resource allocation plans, i.e., leases should be comparable to those held by traditional agricultural activities. By nature, many aquaculture activities must be concentrated in the coastal zone and suitable coastal lands should, therefore, be set aside for this purpose.

3. Aquacultural development can be assisted by a thorough, uniform enforcement of all laws affecting the construction or operation of aquaculture facilities. Fair and equal enforcement practices are critical in a new industry, since the timing of entry is crucial to chances for commercial success.

4. The system of government approvals should be simplified to expedite agency processing of permits. Possibilities include consolidating permits, the development of a master application form, the establishment of joint hearing procedures, and the adoption of abbreviated administrative approvals for those aquaculture activities that clearly have no detrimental environmental effects.

5. Aquaculture should be considered as a form of agriculture. Possible effects could be the raising of the ceiling on State aquaculture loans, the easing of grading requirements for pond construction, and the facilitation of other permit and regulatory procedures.

D. Species Selection and Assessments

A pivotal issue in the development of aquaculture in Hawaii is deciding which animals and plants should receive funding for research and demonstration projects. A State program to develop even a portion of the potentially culturable species in the world is unrealistic due to the resources required and the existing state-of-the-art for culture of many of the candidates. Previous research undertaken in Hawaii on a large number of species has resulted in only one, Malaysian prawns, achieving a significant

Table 10. Federal, State and Privately Supported Aquaculture Research in Hawaii by Species, Year, Funding Source and Organization

	1962-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	
A - DLNR[b]														
Species:														
Malaysian Prawn		■	■	■	■	■	■	■	■	■	■	■	■	
Channel Catfish										■	■	■	■	
Grass Carp										■	■	■	■	
Silver Carp										■	■	■	■	
Oysters	■	■	■	■	■	■	■	■	■	■	■			
Funding ($):														Total
Federal (PL 88-309)	$ --	25,100	23,300	29,800	32,000	32,700	27,700	26,000	30,500	29,100	30,000	30,000	30,000	346,200
NOAA Sea Grant	--	--	--	--	--	--	--	--	--	81,600	85,900	80,000	90,000	337,500
State	22,000	21,000	18,500	23,200	24,000	25,000	25,700	22,200	33,500	80,600	77,500	90,000	90,000	553,200
Private	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal	22,000	46,100	41,800	53,000	56,000	57,700	53,400	48,200	64,000	191,300	193,400	200,000	210,000	1,236,900
B - HIMB/Sea Grant														
Species:														
Omaka				■	■	■	■	■	■					
Yellow *Ulua*				■	■	■	■	■						
Moi						■	■	■	■	■	■	■		
Mahimahi								■						
Kumu							■	■	■	■				
Rabbit Fish									■	■				
Baitfish					■	■	■				■	■	■	
Jap. Yellowtail								■						
Opihi						■	■	■	■					
Octopus[c]				■	■	■	■	■	■					
Penaeid Shrimp						■	■	■	■	■				
Malaysian Prawn							■	■	■	■	■	■	■	
Brine Shrimp						■	■	■	■					
Samoan Crab						■	■	■						
Japanese Clam						■								
American Oyster					■									
Green Sea Turtle							■	■	■	■				
Funding ($):														Total
Federal (Other)	$ --	--	--	--	--	--	--	--	--	--	--	--	--	--
NOAA Sea Grant	--	--	--	42,900	53,600	119,500	124,700	272,900	209,700	210,000	268,100	184,000	177,210	1,662,610
State	--	--	--	22,500	72,400	136,000	117,600	163,900	99,700	126,100	134,400	192,300	214,175	1,279,075
Private	--	--	--	--	--	--	--	--	--	10,000	3,600	--	--	13,600
Subtotal	--	--	--	65,400	126,000	255,500	242,300	436,800	309,400	346,100	406,100	376,300	391,385	2,955,285

Table 10 *(continued)*

	1962-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	
C - University of Hawaii, Department of Botany and Sea Grant Program												
Tropical Marine Agronomy		■	■	■	■	■	■	■	■	■	■	
Marine Plant Production and Introducing Farming Practices for *Eucheuma*												
Seaweed Agronomy												
Tropical Plant Aquaculture												
Tropical Marine Agronomy												
Production of Food Colloids from Tropical Marine Algae												
Exploitation of Hawaii Algal Species for Food, Additives and Drugs			■	■	■	■	■					
Algal Food for Aquatic Organisms				■	■	■	■			■	■	
Location of Prospective Industrial Aquaculture Sites in Hawaii				■						■	■	
Samoan Seaweed Farming								■	■			
Instruction in Tropical Plant Aquaculture				■		■	■			■	■	
Funding ($):												Total
NOAA Sea Grant		6,300	54,600	87,900	114,700	97,300	105,500	134,800	123,200	100,000	40,000	864,300
State and private matching		17,000	40,200	77,900	--	--	--	--	--	--	--	135,100
State matching		--	--	--	20,900	17,400	26,900	24,300	23,300	48,700	39,473	202,973
Private		--	--	--	20,400	67,000	67,200	95,500	35,800	--	50,000	335,900
Subtotal		23,300	94,800	165,800	156,000	181,700	199,600	254,600	184,300	148,700	129,473	1,538,273
Grand Total	109,900	141,700	276,800	479,000	451,700	666,700	573,000	792,000	783,800	725,000	730,858	5,730,458

[a] ■ Indicates work was in progress during a particular year.

[b] Funding figures do not include all types of expenditures, i.e., capital construction, state employees' salaries, and other in-kind contributions.

[c] Includes Day and Mexican species.

Source (until 1975-76): John S. Corbin, *Aquaculture in Hawaii 1976*, January, 1976.

Table 11. Listing of the 20 Species-Groups and the Scientific Names and Common Names of the Principal Members Which Were Considered as Candidates for Aquaculture Development in Hawaii

	Species-group	Scientific Names of Principal Members	Common Names of Principal Members
1.	American Lobster	*Homarus americanus*	Lobster
2	Aquatic Algae	*Eucheuma striatum* *Eucheuma spp.* *Gracilaria coronopifolia* *Chrondrus spp.* *Macrocystis spp.* *Spirulina spp.*	*Tambalang* *Limu* or *Ogo*
3.	Baitfish	*Poecilia vittata*	Topminnow or *Tabai*
4.	Brine Shrimp	*Artemia salina*	Brine Shrimp
5.	Catfish	*Ictalurus punctatus*	Channel Catfish
6.	Chinese Carps and Tilapia	*Ctenopharyngodon idella* *Aristichthys nobilis* *Hypophthalmichthys molitrix* *Cirrhina molitrolla* *Sarotherodon spp.*	Grass Carp Bighead Carp Silver Carp Mud Carp Tilapia
7.	Clams	*Mercenaria mercenaria* *Tapes japonica*	Hard Clam or Quahog Japanese or Manila Clam
8.	Eel	*Anguilla japonica* *Anguilla anguilla*	White Eel or *Unagi*
9.	Freshwater Prawn	*Macrobrachium rosenbergii*	Malaysian Prawn
10.	Limpet (*Opihi*)	*Cellana exarata* *Cellana sandwicensis*	Limpet or Black Foot *Opihi* Limpet or Yellow Foot *Opihi*
11.	Marine Shrimp	*Penaeus japonicus* *Penaeus vannamei* *Penaeus stylirostris* *Penaeus monodon* *Penaeus schmitti*	Japanese Tiger Prawn White Shrimp Blue Shrimp Giant Tiger Prawn Blue Shrimp
12.	Milkfish	*Chanos chanos*	Milkfish or *Awa*
13.	Mullet	*Mugil cephalus*	Grey mullet or *Ama-ama*
14.	Octopus	*Octopus cyanea* *Octopus mya*	Day Octopus Mexican Octopus
15.	Ornamental Fish	*Abudefduf abdominalis* *Dascyllus albisella* *Forcipiger flavissimus* *Centropyge potteri* *Chaetodon miliaris*	Sargent Major or *Maomao* *Alo' ilo'i* Longnose Butterfly Fish Potter's Angel Fish Lemon Butterfly Fish
16.	Oysters	*Crassostrea virginica* *Crassostrea gigas* *Crassostrea spp.*	American Oyster Pacific Oyster
17.	Samoan Crab	*Scylla serrata*	Samoan Crab
18.	Scallops	*Patinopecten yessoensis* *Hinnites multirugosus*	Sea Scallop Purple-hinge Rock Scallop
19.	Threadfin (*Moi*)	*Polydactylus sexfilis*	Threadfin or *Moi*
20.	Trout	*Salmo gairdneri*	Rainbow Trout

Table 12. Species-group Tables, Rescored to Show Favorable Characteristics (+) and Problem Areas (−)

Biological Considerations	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Reproduction in captivity		+	+	+	-		+	-	+	-	-	-	+	+	-	+	+	-	+	
Broodstock maintenance		+	+	+	+	+	+	-	+	-				+		+			+	+
Reproductive cycles		+	+	+	-		+	-	+	-	-	-	-		-	+	-	-	-	
Culturing stocking material	+	+	+	+	+	+	+	-	+	-	+	-	-	+	-	+	-	-	-	+
Survival to time of stocking	+	+		+	+	+	-	-	+	+	+	+		+	-	+	-		+	+
Diseases and parasites	+	+		+		+	+		+	+				+		-	+	+		
Hardiness		+	+	+	+	+		+				+	+			+	+	-		
Growout time	-	+	+	+			+		-		+		-	+	+					
Survival to harvest	+	+	+	+	+	+		+			+	+	+	+	-			-	+	+
High density culture	-	+	+	+	+	+	+	+		+	+	+	+	-	+	+	-	+	+	+
Feed conversion efficiency		+	+	-	+	-	-	+		-		-	-	+	-	-	-	-	+	+

*Blanks indicate no distinct problem or benefit.

Table 12 (*continued*)

Biological Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Trophic level	-	+		+	-	+	+	-	-	+	-	+	+	-	-	+	+	+		-
Maturation	+	+	+	+			+	-	+		+	-	-	+	-	+	+	+	+	+
Cannibalism	-	+		+	+	+	+	+		+	+	+	+	-		+	-	+	+	+
Biotechnical Considerations																				
Broodstock maintenenace		+	+	+	+	+	+	-	+	-		-	+	+	+	+			+	+
Mass rearing of stocking material		+	+	+	+	+	+	-	+	-		-	+	-		+			+	+
Mass growout	-	+	+	+	+	+	+		+	-			+			+	-		-	
Broodstock feeding	-	+	+	+	+	+	+	+	+	-		-	-	-		+	-		+	
Larval feeding		+	+	+	+	+	+	-	+	-		-	-	-		+	-	-	-	
Juvenile feeding		+	+	+	+	+	+		+	-		-	+	-	+	+	-		-	

*Blanks indicate no distinct problem or benefit.

Table 12 (*continued*)

Biotechnical Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Adult feeding	-	+	+	+	+	+	+		+	-			-	-	+	+	-		+	
Harvesting		-	+	+	+	+	+		+	+			+	+	+	+	-		+	
Transporting	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+
Processing/Purging	+	+	+	+	+	+	+	+	-	+	+	+	+		+	+	+	+	+	+
Larval nutritional needs known		+	-	-	-	-				-	+	-	-	-	-		-	-	-	+
Juvenile and adult nutritional needs known		+	-	-	+	-	-	-		-		-	-	-	-	-	-	-	-	+
Larval rations developed	+	+		+	+	+	+	-	-	-		-	-	-	-	+	-		-	+
Juvenile and adult rations developed	+	+		+	+	+	+	-	-	-		-	-	-	-	+	-		-	+
Year-round cultured stocking supply	-	+	+	+	-	+	+	-	+	-	-	-	-	-	-	+	-	-		-
Year-round cultured market supply	-	+	-	+	+	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-

*Blanks indicate no distinct problem or benefit.

Table 12 *(continued)*

Market Considerations	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Identifiable local market	+	-	-	-		-		-	+	-	+	-	-	-	-	+	-	-	-	-
Identifiable mainland market	+	+	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-
Identifiable international market	+	+	-	-	-	-	-	+	-	-	+	-	-	-		-	-	-	-	-
Potential local market	+	-	+	-	+	-	+		+		+	-		-	-	+	-			-
Potential mainland market	+	+	-	+	-	+	-	-	+	-	+	-	-	-		-	-	-	-	-
Potential international market	+	+	-	+	-	+	-	+	+	-	+	-	-	-		-	-	-	-	-
Wholesale price - Hawaii	+	-	-	+	+	-	-	+	+		+	-	+		+			+	-	-
Subcultural preference	+	+	+	+		-	+			-	+	-				+	+	+		
Inter-regional competition	-		-		-	-	-	+		+	-	-	-	-	-	-	-	-	+	-
Recreation potential	-	-		-	+			-	-	-	-	-		-	-		+		+	+
Catch fisheries competition - Hawaii	+	+		+	+	+	+	+	+	-	+			-		+	-	+		+

*Blanks indicate no distinct problem or benefit.

Table 12 (*continued*)

Market Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Economic risk	+	+	+		+	-	+		+	+	+					+		+		+
Resource Considerations																				
Site	+	-	+	+	+	+		+	+				+		+					-
Water	+	+	+	+			+			+	+	+	+	+	+	+	+	+	+	-
Expertise required	+	+	+	+	+	+	+		+	-		-	+	+	+	+	-		+	
Economic Considerations																				
Past performance	-				+				+	-				-	-		-	-	-	
Likelihood of institutional financing	-	-	-	+		-	-	-	+	-	-	-		-	-		-	-	-	-
Potential profitability	+		+	+				+	+	+	+	-	-		+			+	-	

*Blanks indicate no distinct problem or benefit.

Table 12 (*continued*)

Economic Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Confidence in profitability estimate					+				+	-	+	-	+	-	+	+	-		-	+
Time to develop industry			+		+	+	+	-	+	-	-	-	+	-	-	+	-			
Legal/Social Considerations																				
Legal barriers to import	+	+	+	+	+		+	-	+	+	+	+	+	+	+		+		+	+
Legal barriers to culture		-	+		+	+		-	+								+			+
Legal barriers to sale	+	+	+	+	+		+	+	+	+	+	+	+	+	+				+	+
Social barriers to import	+	-	+	+	+	-		-	+	+		+	+		+		+		+	+
Social barriers to culture	+	+		+	+	+	+	-	+	+	+	+	+			+	+	+	+	+
Social barriers to sale	+	+		+			+		+	+	+		+	+	+	+	+	+	+	+

*Blanks indicate no distinct problem or benefit.

level of commercial culture. When the expense involved in this research is taken into consideration—over $5.5 million in State, Federal, and private sector monies—it is clear that the development of aquaculture in the State did not benefit greatly from this investment (Table 10). As the State's financial resources for aquaculture development are limited, it is essential that potential species be closely examined to identify only those that will ultimately provide the greatest benefits to Hawaii for the least amount of investment.

This section is divided into two parts. Part one presents a brief account of the procedure whereby first, second and third priority species-groups[9] were selected for aquaculture development in Hawaii (Appendix C). Part two presents the individual assessments for each group.

Species Selection

Potential aquaculture species for Hawaii were examined by a comprehensive selection process. This process sorted the species into five different categories: (1) those species that are presently commercially cultured, e.g., prawns, catfish and oysters; (2) those species that are presently commercially cultured on the Mainland or in a foreign country, e.g., trout, milkfish; (3) those species that are undergoing experimentation on the Mainland or in a foreign country, e.g., lobster, sea bass; and (5) those species that were investigated in Hawaii, on the Mainland or in a foreign country, but were found infeasible for aquaculture, e.g., octopus, pompano.

A total of 54 species-groups, each fitting one of the above categories, were identified (*Hawaii Aquaculture Planning Program—Interim Report,* 1977). Many of these groups consisted of a single species. The Aquaculture Planning Program (APP) staff reduced this number to the 20 species-groups and their member species listed in Table 11. These 20 species-groups were then numerically evaluated by a Species Subcommittee and the APP staff using the criteria and tables shown in Appendix C. Unfortunately, comparisons among summations of individual numerical scores could not be justified (Appendix C). However, examination of the individual scores for a particular species group proved useful in further deliberations.

Assigning priorities to species-groups. The magnitude of individual scores for a particular species-group, that is, the number of high scores and low scores, gave a good indication of those areas where a favorable level of development had been attained or where development had been constrained. To better highlight these points, the evaluation tables were remarked with pluses (+) for the high scores, i.e., 4's or 5's and minuses (-) for the low scores, i.e., 1's and 2's (Table 12).

Utilizing the numerically scored evaluation tables and their accompanying criteria in concert with the rescored tables discussed above, the planning staff formulated the following list of priority species for development:

First priority: Aquatic Algae
Baitfish
Brine Shrimp

---

[9]For ease of tabulation and discussion, general names, e.g., marine shrimp, are used throughout this report and all species in a group are collectively termed the "species-group."

Catfish
Chinese Carps and Tilapia
Clams
Oysters
Freshwater Prawns
Marine Shrimp

Second priority: Threadfin (*Moi*)
Mullet
Limpet (*Opihi*)

Third priority: American Lobster
Eel
Milkfish
Octopus
Ornamental Fish
Samoan Crab
Scallop
Trout

The species-groups within each priority have several common characteristics. Those considered "first priority" generally have the fewest major biotechnical problems to prevent commercial culture. They have all been cultured either on a pilot or commercial scale in various parts of the world. In addition, they have established potential local and world markets. Second priority species-groups are market favorites in Hawaii. However, they are not as advanced on a biotechnical basis as the first priority species; that is, there are some problems of varying difficulty to be solved before they are considered economically viable. The third priority species-groups are animals which either have major biotechnical problems requiring long-term research and/or major marketing problems which impede their commercialization.

Species-groups and their members may be reevaluated pending results of future research and/or changes in economic characteristics. For example, new markets may be developed, changes may occur in the cost of various elements in the production strategy (e.g., energy or feed), or competition may result from capture fisheries or aquaculture production elsewhere. Furthermore, new aquaculture candidates not considered here may be discovered by the research community. It is essential, therefore, that an active species evaluation process be maintained to insure a responsive and dynamic State aquaculture development program.

Individual Species-group Assessments

The first and second priority species-groups, together with those lower priority species which are either cultured or investigated in Hawaii, were subjected to further individual analysis and assessment. Summaries are based on more detailed reports which may be published at a later date as a technical series. As a matter of convenience, certain species-groups are combined and discussed under one assessment heading [for example, the filter-feeders, oysters and clams, are presented together as are various marine species including brine shrimp, threadfin (*moi*), mullet, milkfish, and limpet (*opihi*), which are grouped under the heading "Marine Finfish and Other Miscellaneous Marine Species"].

Subjects presented under the individual species-group assessments include: (1) the state-of-the-art of culture; (2) the market characteristics and opportunities; (3) the major constraints and recommended actions for development; and (4) the projected production, employment and revenue from their culture and sale. Subheadings under each subject listed above were modified to fit the species-group being discussed.

Aquatic Algae

State-of-the-Art for Culture

Species. Aquatic algae are among the most diverse members of the plant kingdom (Naylor, 1976; Neish, 1976). They occur in a wide range of shapes and sizes, from microscopic single-celled species, such as *Spirulina*, to the giant kelp, *Macrocystis*, which can reach a length of 140 feet (43 meters). Algae are classified into four groups on the basis of pigmentation: greens (*Chlorophyceae*), blue-greens (*Cyanophyceae*), reds (*Rhodophyceae*) and browns (*Phaeophyceae*). Green and blue-green algae, while present in saltwater, are more commonly associated with freshwater. Red and brown algae, which are the most economically important, are found almost exclusively in marine environments. Browns are particularly abundant in cold northern waters, although a few species are found in the tropics. Red are numerous at all latitudes.

Genera being considered for Hawaii include *Spirulina* (blue-green), *Eucheuma* (red), *Chrondrus* (red), *Gracilaria* (red), *Sargassum* (brown) and *Macrocystis* (brown). Research and commercial development activities for algae have been in progress for some time and have resulted in a large body of technical literature in such areas as biology, ecology, engineering, production economics, processing, marketing and transportation.

Management systems: extensive to intensive. The cultivation of aquatic algae mostly marine macroalgae—involves techniques which can be as simple as the close management of natural stocks or as complex as the propagation of selected clones and genetically selected hatchery seed stock in capital-intensive cultivation situations (Neish, 1976).

Management and husbandry of natural stocks are practiced with most intensively-harvested algal populations throughout the world. Efforts to regulate the giant kelp (*Macrocystis*), harvest are particularly notable since harvestable stocks, which virtually disappeared in California coastal waters in the late fifties, are now being actively exploited. Techniques used to harvest natural populations include collecting storm-damaged weed from the beach (castweed), using rakes or grapnels from boats, and using a mechanized barge-like mowing machine (Naylor, 1976). Hawaii has few areas suitable for planting and actively managing extensive wild populations of seaweeds. However, one species, *Gracilaria* (*ogo*), is harvested from a few reef flats and bays (e.g., Kaneohe Bay).

The Japanese are among the world leaders in the cultivation of red and brown seaweeds in shallow coastal waters using various habitat improvement techniques. Techniques vary with the species, but, generally, seed alga collected from the wild or reared in a hatchery are attached to a system of nets, lines, stakes, etc., in areas which are subject to good tidal circulation so that nutrients can be supplied by the natural environment. Yields for certain species of *Laminaria* average 2,150 wet weight pounds per acre annually (1,914 kilograms/hectare/yr). For *Porphyra*, from which *nori* is made, yields are approximately 700 dry weight pounds per acre per year (623 kg/ha/yr) (Bardach et al., 1972). Harvesting is usually carried out hand.

Eucheuma and *Spirulina*, two types of algae that have been commercially grown outside the State, are now being studied for possible large-scale production in Hawaii. *Eucheuma* is an important source of carrageenan, which is widely used in the dairy industry. Utilizing livestock waste as fertilizer, *Spirulina* farmers may be able to produce high protein feed for agricultural and aquacultural animals.

This Eucheuma *was grown in trenches by these Marine Option Program students. (Courtesy of Windward Community College and UH Dept. of Botany.)*

Researcher examines dense culture of Spirulina *in media prepared from treated cattle manure.*

Eucheuma cultivation in the Philippines is similar to Japanese seaweed farming with algae seed branches attached to a rectangular grid system of ropes (Doty, 1975). When the plants reach 2.6 to 3.3 pounds (1.2 to 1.5 kg) in wet weight, they are pruned to 1.1 pound (0.5 kg) and the process continues. Current labor-intensive methods yield approximately 19,600 pounds per acre (17,444 kg/ha) of wet weight algae every 90 days. From this, about 5,000 pounds (2,268 kg) of dry salable product is recovered (Deveau and Castle, 1976). Again, areas in Hawaii where these techniques could be practiced on a commercial scale are few, and natural nutrient concentrations are not generally adequate- except in certain areas where point and non-point source discharges elevate the ambient level to adequately support culture.

The cultivation of seaweeds in deep water, offshore areas is being carried out in California on a pilot scale. The results of this project may someday be applied to large scale marine plantations consisting of algae attached to rope grids (North et al., 1977). Nutrients are provided by both the natural and artificial (ocean thermal energy conversion) up-welling of deep ocean water. Some futuristic design applicable to open-ocean farming have been suggested (Beleau et al., 1975), and reports on the theoretical and economic feasibility of such farms for Hawaiian ocean waters have been recently published (Keller and Murata, 1977), but at present, offshore or open-ocean marine plantations appear to be cost-prohibitive and technologically difficult.

Another futuristic approach to the mass culture of freshwater and saltwater algae involves the mass rearing of micro- and unattached macroalgae in tanks or raceways (Huguenin, 1976; Deveau and Castle, 1976; Goldman and Ryther, 1977). This concept, which is being tested in such places as the United States, Mexico, and Japan, is capital- and technology-intensive. The basic cultivation system employs a square tank, or a raceway with a slanted bottom. The water, agitated by bubbling air into the deepest part of the container, establishes a strong circulation pattern which keeps the densely-packaged algae in suspension and assures all plants sufficient sunlight and nutrients. Nutrients from domestic or animal wastes could be utilized in this system.

Macroalgae which can be grown in intensive culture on a laboratory scale include *Eucheuma isoforme, Gracilaria spp., Chrondrus crispus,* and others. Projected yields from a commercial-scale system raising any one of the above alga on 25 acres (10 ha) would be approximately 2,200 dry tons per acre per year (979 mt/ha/yr) or 90 dry tons per acre per year (40 mt/ha/yr). According to one scientist, "Assumed system performance parameters have been based on what are considered to be optimistic but reasonable projections. This system is intended to represent the state-of-the-art as it might realistically be expected to exist about 5-10 years from now" (Huguenin, 1976).

In Hawaii, one operation is attempting to grow *Gracilaria* and *Eucheuma* in discharge waters from an intensive oyster culture system. The Kahuku Seafood Plantation hopes to cleanse the seawater of oyster metabolites, while providing a salable product. Due to the paucity of available coastal sites, such land-based systems will probably be necessary for seaweed aquaculture to become a commercial reality in Hawaii.

The intensive commercial culture of single-celled freshwater algae, particularly *Chlorella spp.* and *Spirulina spp.*, is practiced in similar fashion in macroalgae cultivation in various places around the world with productivity averaging 360 tons per acre per year (160 mt/ha/yr) (Ryther et al., 1972). Under suitable conditions, these algae may be comprised of as much as 50 to 60 percent protein (Naylor, 1976). Although *Chlorella* has possibilities as a food supplement (e.g., when mixed with flour), there remain the questions of poor digestibility and palatability (Naylor, 1976). *Chlorella* is cultured extensively in Japan and Taiwan.

Spirulina is being cultured in Mexico on a 25-acre (10 ha) pilot plant which reportedly produces one ton (.91 mt) of fresh weight algae per day (Oswald and Brenemann, 1977). The State of Hawaii is supporting a small-scale preliminary feasibility study to investigate the potential for *Spirulina* culture. This study has so far indicated that, by utilizing livestock waste as fertilizer, *Spirulina* production could be between 25 and 35 wet tons per acre per year (11 and 16 mt/ha/yr).

Market Characteristics and Opportunities

The uses of algae can be grouped into three overlapping areas: (1) direct human consumption, (2) industrial additives, and (3) other purposes, including fertilizer, feeds, waste recovery and the manufacture of energy. After a brief discussion of the general supply and demand situation for all forms, each use category will be discussed separately.

General supply and demand. Although precise figures are difficult to obtain, the total value of the world seaweed crop and its related industries is estimated to be between $1 billion (Naylor, 1976) and $20 billion (Saito, 1976) annually. In 1973, the "first-hand value" of the world seaweed crop was approximately $765 million for approximately 1.17 million wet tons (1.06 million mt) (Naylor, 1976). Approximately 95 percent of this value was obtained from the sale of semi-processed (e.g., dried, powdered, etc.), edible products in Japan, Korea and Taiwan. Seaweeds for industrial purposes (e.g., food additives) are generally sold in a simple dried and unprocessed state and account for the greater part of the balance ($25 million). Algae used in animal feeds and fertilizers make up the remainder--a mere fraction of the value of edible seaweed.

Direct human consumption. The major world markets for edible seaweeds are located in Japan, Korea and Taiwan, as tastes and traditions in these countries have contributed to the development of a dietary preference for seaweeds. Seaweeds of greatest economic importance are *Porphyra*, *Undaria*, and *Laminaria*. There have been a few attempts at introducing marine algal products to the western world (e.g., seaweed soups), but these have met with limited success.

Seaweeds can be consumed in a wide variety of product forms. *Porphyra* (commonly known as *nori*) is used in soups, sauces, salads, and sandwiches, and as a condiment. *Nori* cultivation accounts for over 40 percent of the volume, and 56 percent of the value of the total aquaculture production of Japan (Naylor, 1976). *Laminaria* and *Undaria* (*wakame*) are used in soups, sauces, salads, teas, garnishes, vegetable dishes, coated candy, and pills as a source of Vitamin C.

To date, there are no commercial aquaculture enterprises culturing algae for the Hawaii market. However, several species of edible algae are collected and consumed in significant quantities. Fresh *Gracilaria* or *ogo* is harvested from the wild and retails in local supermarkets for $1.30 to $1.80 a pound ($2.87 to $3.97/kg). *Ogo* is used as an appetizer, salad or snack, and vegetable side dish, alone or in combination with rice or raw fish. One preliminary market analysis indicates that there is sufficient local demand to utilize an additional 316,000 pounds (143,338 kg) per year. Processed and packaged *Porphyra* is imported from the Far East.

Industrial additives. Industrial use of seaweed extracts (marine colloids) is the fastest developing area of the algae industry today. Seaweed extracts of economic importance are agars, carrageenans, furcellarans and algins. Extracts are being utilized in an ever-increasing array of processes and food and non-food products including milk, ice cream, dressings, soups, beverages (beer), leather manufacturing, photographic chemicals, pharmaceuticals, cosmetics, textiles, paper products, rubber explosives, and paints (Naylor, 1976). Although each type of gel possesses unique characteristics, they all basically function to stabilize, suspend, emulsify or thicken.

The total world production of marine colloids in 1974 was 32,700 tons (29,685 metric tons) worth approximately $300 million (Naylor, 1976). This was comprised of (1) agar, 7,500 tons (6,808 metric tons) at $86.25 million; (2) carrageenan, 8,000 tons (7,262 mt) at $93.6 million; (3) furcellaran, 1,200 tons (1,089 mt) at $42.96 million and algin, 16,000 tons (14,525 mt) at $80 million. A conservative estimate places the annual growth rate of this industry at 10 to 20 percent with the wholesale value of the U.S. gel market alone totaling between $68 and $100 million per year (Doty, 1978). The principal consumers and processors of algae and its derivatives are the U.S., Canada, Japan and Europe.

Extensive wild populations do not exist in Hawaii but the State has several indigenous and exotic species of algae that may prove valuable for colloids, and aquaculture appears to be a means of exploiting these species. Valuable species include *Gracilaria spp.*, *Chondrus spp.* and *Eucheuma spp.* Both *Chrondrus* and *Eucheuma* produce carrageenans which are marketed in two biochemically distinct forms: IOTA and KAPPA. IOTA carrageenan has a high world demand and may sell for as much as $1,000 per dry ton ($1,100 per day metric ton) wholesale. Researchers at the University of Hawaii are responsible for the rapid development of *Eucheuma* farming in the Philippines (Deveau and Castle, 1976). They suggest that opportunities exist for the commercial culture and processing of *Eucheuma* in Hawaii. The State can function both as a source of farmed algae and a location for processing colloids for the Pacific.

By-product production and other purposes. The production of marine and freshwater algae can be a subsystem of some other form of technology directed at problems other than the cultivation of food for direct human consumption and marine colloid production (Neish, 1976; Naylor, 1976). Several immediate needs in Hawaii (and other parts of the world) to which algae culture can contribute are: (1) low-cost feed production for livestock; (2) the recovery of waste nutrients from human and animal wastes through conversion into a salable product; (3) the recovery of waste water from industrial, agricultural or aquacultural operations while producing a salable product; and (4) the production of a less expensive form of energy through the culture of biomass for fuel. Each of these will be discussed below.

Hawaii is almost completely dependent on the Mainland United States for agricultural and aquacultural animal feed ingredients. The increasing demand for high-protein animal feeds, together with rising shipping charges due to increasing petroleum costs, will no doubt escalate the cost of feeds. The technical feasibility of culturing such single-celled algae as the bluegreen alga, *Spirulina spp.*, using domestic or animal wastes as fertilizer and the subsequent use of the algae as a food supplement for cattle, chickens and catfish, has been demonstrated (Dugan et al., 1972). *Spirulina* is presently being cultivated on a 25-acre (10 ha) pilot facility in Mexico with crops sold to Japan for $11 per pound ($24.25/kg). Opportunities exist for demonstrating the utilization of *Spirulina* as an animal feed under Hawaii conditions. *Chorella spp.*, another single-celled freshwater algae, is also cultured as fish feed in Japan. In 1976, 350 tons (318 mt) of this algae were grown. Taiwan reportedly produces 800 tons (726 mt) per year, mostly for human consumption (Tsukada and Kawahara, 1977).

Cultivation of salable algae from domestic or animal waste recovery systems could aid Hawaii by solving several immediate environmental problems. For example, manure production at the State's major feedlot is approximately 15,000 tons (13,617 mt) per year. State environmental protection laws which prohibit disposal of animal wastes in the marine coastal ecosystem, together with the low local demand for cattle manure as organic fertilizer, have resulted in stockpiling between 150,000 and 200,000 tons (136,170 and 181,560 mt) of cattle manure at Campbell Industrial Park, Oahu (Michael Santerre, personal communication, 1978). The use of this manure as an inexpensive source of nutrients for algae production is one method of relieving the problem, while reducing the social costs of waste treatment.

Hawaii needs to develop means of conserving and reusing its limited water resources (*Hawaii Water Resources Plan*, 1977). Aquatic algae culture systems have been used to reduce the quantity of nutrients and other pollutants from domestic and agricultural waste waters. Opportunities exist for the application of these principles in Hawaii.

Hawaii's dependence on imported oil for energy has caused the State to investigate locally available alternate energy sources (Hawaii Natural Energy Institute and Department of Planning and Economic Development, 1975, 1976; Keller and Murata, 1977). The large scale cultivation of seaweed biomass on marine plantations and the intensive culture of oil rich single-cell marine alga are two technologies which may have the potential to contribute to State energy self-sufficiency by providing a material for use in methane or alcohol generation. Presently, laboratory and pilot-scale demonstrations of key biological and engineering concepts are needed before commercialization can be considered. State and private research groups have the opportunity to participate in Federal- and State-funded programs in the area of alternate energy sources.

Major Constraints and Recommended Actions

Markets for algae, both for human consumption and colloids, are substantial and, for the most part, unfilled. Moreover, Hawaii possesses an abundance of sunlight and warm water–excellent resources for aquatic algae production. However, the commercialization of algal culture is constrained by a lack of inexpensive nutrients and adequate technology. Inasmuch as there are significant differences between the extensive or ranch-type culture versus the intensive, land-based culture, constraints and recommendations will be presented by the type of culture or management system.

There appear to be serious constraints to the near-term, extensive, nearshore or open-ocean culture of marine algae. Although Hawaii's surrounding waters are warm and otherwise near-ideal for the culture of various algal species, they, nonetheless, have low nutrient concentrations. Moreover, the addition of nutrients to an open, uncontrollable environment is considered both economically and technically infeasible. At present, there may be a few nearshore locations which possess sufficient nutrient concentrations from land outfalls and/or land runoffs to permit algae culture. However, with the promulgation and enforcement of water quality regulations, these conditions are not expected to persist. It is, therefore, recommended that extensive, nearshore or open-ocean algal culture not be encouraged at this time.

It would appear, then, that the major opportunities for marine agronomy lie in semi-intensive and intensive, land-based culture systems with the capability of controlling

The Chlorella *cultured in these tanks at the Oceanic Institute will be used for feeding fish.*

Cultured aquatic algae have a wide variety of uses—for human consumption, fertilizers, industrial additives, nutrient recovery, biomass energy, waste water reclamation and animal feeds.

Gracilaria, *or* ogo.
(Courtesy of Windward Community College and UH Dept. of Botany.)

Off-shore seaweed experiments: limu *and* ogo *are attached to a net suspended between two stakes. (Courtesy of Windward Community College and UH Dept. of Botany.)*

nutrient concentrations. This would include a broad range of physical settings, from existing Hawaiian fishponds to intensive, above-ground culture systems, as well as poly-culture with fish and shellfish.

The constraints to commercialization are essentially technological and economic. Efforts should, therefore, concentrate on demonstrating the feasibility of systems for the culture and harvest of economically important indigenous and introduced species. *Gracilaria* appears to be an excellent initial candidate due to its value both as a fresh food product (*ogo*) with a considerable local demand and as a source of commercially valuable colloids. Legal/institutional constraints (discussed in Section C of this Chapter) must also be removed.

Economic Projections

The previous sections concluded that the development of algal culture will probably be limited to shore-based or land-based activities by virtue of the limited number of embayments and protected waters, and lack of nutrients in Hawaii's surrounding waters. The projections reflected in Table 13 below are based on the establishment of the shored-based culture of macroalgae, such as *Gracilaria spp.* (*ogo*). Initially, it is envisioned that *Gracilaria* would be cultured for human consumption, with possible processing for colloids after production increases.

Table 13. Projected Production, Employment and Revenues from the Culture of Aquatic Algae for Colloids and Food in Hawaii: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs.)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	–	–	–	–	–	–
1980[7]	100	5	1	2	3	$ 35
1985[8]	5,500	275	14	24	38	1,925
1990[9]	25,000	1,250	63	189	252	8,750
1995	50,000	2,500	125	375	500	17,500
2000	100,000	5,000	250	750	1,000	35,000

Assumptions:

[1] *Gracilaria spp.* (*ogo*) initially cultured for human consumption. However, major opportunities lie in algae for colloids. Production yields estimated at 20,000 pounds (90% dry weight) per acre per year.
[2] Represents surface acres of impounded water. Farm size will be considerably larger.
[3] Approximately one direct job per 20 acres.
[4] Approximately 1.7 indirect jobs per direct job until processing begins in 1990. Thereafter, 3.0 indirect jobs per direct job.
[5] Wholesale value of $0.35 per pound.
[6] Performance evaluation tests in process. No production.
[7] Development program in process with first commercial demonstration.
[8] Production originating mainly from 270-acre airport reef runway pond. Construction of processing plant begins.
[9] Processing plant in full operation.

State-of-the-art for Culture

Species. Topminnows (*Poecilia spp.*) are a species which possess many of the biological and behavioral characteristics necessary for use as a baitfish for skipjack tuna (*aku*). The topminnow is a member of the family *Poeliliidae* which include fish variously described as mosquito fish, guppies, mollies and live bearers. They are omnivorous (feed on plants and animals), extremely hardy, and reproduce in waters ranging from fresh to salt water. Topminnows exhibit the ideal behavioral characteristics of a tuna baitfish, i.e., marked avoidance of predators (rapid, erratic swimming) and a tendency to school at or near the surface.

Hatchery and growout technology. Research into the biology and biotechnology of culturing topminnows has advanced to the development of pilot-scale facilities. However, until recently, investigations of fishing techniques utilizing topminnows have been limited due to insufficient supplies of fish for sea trials.

Research into culturing topminnows was initiated in 1970 at the University of Hawaii's Hawaii Institute of Marine Biology (HIMB). Studies focused on the identification of the optimum environment for intensive culture, maintenance and harvesting techniques and systems for broodstock and young, methods of rearing juveniles to baitfish size, feed development, disease prophylaxis and treatment and the economics of commercial-scale systems (Corbin, 1976).

Under controlled conditions, brood size averages 50 young every 28 to 30 days at water temperatures between 77 and 86°F (25 and 30°C) (Herrick and Baldwin, 1975). Newborn topminnows—approximately .4 inch (1 cm) in length—require 10 to 12 weeks to attain the desired 1.5 to 2.2 inches (3.8 to 5.7 cm) baitfish size. Optimum temperatures for reproduction and growth are between 32 and 86°F (28 and 30°C), with optimum salinity between 10 and 50 percent. Growout ponds are stocked at five per gallon (1 to 3 fish/1). Fish are fed a mixture of commercial chicken starter mash and tuna meal.

The results of these studies and others undertaken in American Samoa and Palau have provided the basic scientific data and experience for an attempted full-scale demonstration facility near Maalaea, Maui. The project is a cooperative effort between Maui County, Office of the Marine Affairs Coordinator, Aquaculture Development Program, UH/HIMB and the UH/Sea Grant College Program. The facility, which started production on September 1, 1977, will produce 15,000 pounds (6,804 kg) of topminnows to conduct 50 fishing trials using two Maui-based *aku* vessels (see Appendix D). These trials will be analyzed to provide a detailed economic analysis of the species under Hawaii *aku* fishing conditions. Preliminary topminnow culture and sea testing in American Samoa (1974 and 1978) have given favorable results. A more critically controlled test will present numerous opportunities for identifying and testing other areas of investigation; e.g., transporting and holding topminnows, baitwell designs, modifications in fishing methods and gear.

Market Characteristics and Opportunities

Supply and demand. Demand for baitfish is derived from the substantial local demand for skipjack tuna to satisfy the local fresh and dry fish markets, as well as a portion of the requirements of the State's only cannery. Three tuna species comprise

A serious problem restricting the expansion of Hawaii's skipjack tuna fishery is an adequate supply of a hardy, effective baitfish. The mass culture of topminnows can provide a solution to this constraint.

The topminnow: Poecilia vittata.

A dependable supply of baitfish is vital to the success of these pole-and-line skipjack tuna fishermen. (Courtesy of National Marine Fisheries Services.)

This 11.5-acre facility at Maalaea, Maui, is capable of producing 9 tons of baitfish a year. (Courtesy of Wayne Baldwin.)

approximately 80 percent of the commercial fish catch in Hawaii. In 1976, skipjack tuna (*aku*) accounted for approximately 64 percent of the total catch, while yellowfin and bigeye (*ahi*) tallied 12 percent and three percent, respectively.

The Hawaii-based *aku* fleet of 14 boats focuses on the fresh fish market, with annual sales currently approaching 4.5 million pounds (2,041,200 kg) (*Hawaii Tuna Fishery Development Plan*, 1977). Fish in excess of the daily demand in the fresh and dried fish market are sold to the local cannery, Hawaiian Tuna Packers, which is a part of the Bumble Bee Seafoods operation of Castle & Cooke, Inc. Only 20–25 percent of the cannery's needs are supplied by the local fleet. The remainder is imported from foreign countries or is off-loaded from American purse seiners fishing between Central America and Hawaii (*Hawaii Tuna Fishery Development Plan*, 1977).

Landings of the local skipjack fleet have historically ranged between 5 and 16 million pounds (2,268,000 and 7,257,600 kg) (1965 to the present). In 1977, the value was 7.8 million pounds (3.5 million kg), down from 9.8 million pounds (4.4 million kg) in 1976. The amount of bait utilized varies from year to year. For example, in 1955, approximately 600,000 pounds (272,160 kg) of bait was used to catch 9.7 million pounds (4,399,920 kg) of *aku*, while in 1965, approximately 400,000 pounds (181,440 kg) was needed to catch 16 million pounds (7,257,600 kg) (*Hawaii Tuna Fishery Development Plan*, 1977).

The objective of the State's skipjack tuna plan is to encourage the continuation of a tuna cannery industry in Hawaii by increasing the supply of locally-landed tuna by an additional five million pounds (2,268,000 kg) within five years (*Hawaii Tuna Fishery Development Plan*, 1977). The estimated maximum local market potential for top-minnows, assuming a total catch of 20 million pounds (9,072,000 kg) and a catch ratio of 20:1 (pounds of tuna to pounds of bait) would be approximately one million pounds (453,600 kg) a year at the end of five years. Although these figures may be optimistic, they serve to illustrate the fact that the expansion of the tuna industry in Hawaii will require a substantial increase in supplies of a suitable bait. Moreover, the possibility of selling bait to foreign vessels, e.g., Japanese, and exporting the culture technology to other locations around the Pacific, also exists.

Expansion of the tuna fishery. Frozen and canned tuna are international trade commodities and, therefore, their demand is not limited by the "pocket nature" of the local tuna market. The worldwide consumption of tuna is rising rapidly at the rate of eight percent per year, and many of the world's tuna fisheries are fully exploited (Saila and Norton, 1974). However, large underexploited resources of skipjack tuna have been identified in the central Pacific Ocean (*Hawaii Tuna Fishery Development Plan*, 1977).

Fishery biologists estimate that the skipjack fishery in the Central Pacific can be expanded to a minimum annual sustainable yield of 100,000 metric tons, representing an ex-vessel cannery price of $75,000,000 (1976 dollars). This potential yield is approximately 20 times larger than the size of the current Hawaiian skipjack fishery. Hawaii's strategic mid-Pacific location places the State in a highly favorable position to capitalize on this large resource.

However, before development can take place, a number of problems need to be solved. The most serious of these concerns the traditional livebait, the *nehu* (*Stolephorus purpureus*). Existing resources of *nehu* are not adequate to support a large expansion of a Hawaii-based livebait skipjack fishery. Therefore, another suitable livebait, or appropriate alternatives to using the livebait technique, must be found.

Alternative livebait. Livebait tuna fishing, or "pole-and-line" fishing, is used to catch surface schools of tuna, e.g., skipjack. Livebait, primarily the *nehu* is captured in coastal embayments and stored in recirculating baitwells aboard the fishing boats. Bait-fish capture accounts for as much as 40 percent of the total fishing time. Moreover, *nehu* are fragile and shipboard mortality is often as high as 25 percent a day (Herrick and Baldwin, 1975). These factors limit the effective fishing range of the local skipjack fleet to trips of less than two days, or a range of about 90 miles. In addition, *nehu* can now be found in only a few embayments around Oahu, e.g., Kaneohe Bay, Kihei Lagoon and Pearl Harbor.

Topminnows can be cultured in large quantities for an estimated $0.91 per pound ($2.01/kg) (Baldwin, 1977, unpublished data). Increases in fuel and labor costs may cause this estimate to be higher, but it appears that topminnows are a prime candidate to supplement and supplant more traditional livebaits, e.g., anchovies (*nehu,* etc.), in Hawaii and around the Pacific.

Other uses. Topminnows can also be used as a recreational bait and a commercial bottom fishing bait. Recreational fishing is an industry of approximately equal value to the commercial fishing industry (Hoffman and Yamauchi, 1973). Preliminary tests indicate that topminnows can be used to catch such species as ladyfish (*awa*), jacks (*papio*) and various bottom fish (i.e., *opakapaka*). Commercial bottom fishermen could use topminnows to catch certain economically important species. Potential future trends in the exploitation of the Northwestern Hawaiian Islands may provide a substantial bait market. Opportunities in both these areas appear promising, but some market promotion activities may be necessary.

Major Constraints and Recommended Actions

Demonstration. The lack of a conclusive local demonstration of the ability of topminnows to catch skipjack tuna as effectively as traditional baitfish has deterred its acceptance. Local fishermen are hesitant about using a new species of baitfish which may require different types of holding facilities or new methods of fishing. New techniques may interrupt their fishing schedules until they are adequately learned. State-supported, scientifically-conducted sea trials using topminnows should be carried out to test the catchability of this bait as compared to the traditional bait (*nehu*). Informed suggestions on changes in fishing methods or equipment can then be made to skipjack fishermen.

Pending the results of the Maui trial project, a permanent baitfish facility is tentatively planned for the Island of Molokai. This facility, to be funded by the Pacific Tuna Development Foundation and the Economic Development Administration, would be capable of producing 180,000 pounds (81,650 kg) of topminnows a year. Its purpose would be to provide bait for long-range tuna vessels from Hawaii, California and, perhaps, foreign countries, so that they will be able to fish the unexploited schools of skipjack tuna in the Central Pacific, particularly around the Northwestern Hawaiian Islands. Initial phases of the project would test the feasibility of long-range tuna fishing trips using Hawaii-grown topminnows.

Market. The development and expansion of the tuna baitfish market is directly related to the degree of expansion of the skipjack tuna industry in Hawaii and the Pacific. In addition to the lack of supply of a suitable bait—which the aquaculture of topminnows could alleviate—several other major constraints exist. Qualified fishermen must be attracted to work on skipjack tuna boats and sufficient capital must be provided to build new shore facilities and longer range boats. Presently, several State, Federal and Pacific Island agencies are involved in major fisheries development activities, including the formulation of a fisheries development plan.

Such aquaculture activities as baitfish production that contribute to the development of State fisheries should be encouraged. In addition, the transfer of technology to other areas of the Pacific lacking such expertise should be stressed.

Economic Projections

There appears to be considerable baitfish market opportunities in such other areas as sport fishing and long-line baitfish fishing. However, the following projections are based solely on the anticipated expansion of the skipjack tuna fishery to the year 1995. Thereafter, it is assumed that the aforementioned uses will grow in significance. Therefore, nearly all of the assumptions listed are taken directly from the *Hawaii Tuna Fishery Development Plan*, 1977.

Table 14. Projected Production, Employment and Revenue from the Culture of Baitfish (Topminnow) in Hawaii: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs.)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	15	3	1	7	8	$ 14
1980[7]	50	10	2	13	15	46
1985[8]	500	100	20	134	154	455
1990[9]	800	160	32	214	246	728
1995[10]	900	180	36	241	277	819
2000[11]	1,000	200	40	268	308	910

Assumptions:

[1] Production yields estimated at 5,000 pounds/acre/year.

[2] Represents surface acres of impounded water. Farm size is considerably larger.

[3] Approximately one direct job per 5 acres.

[4] Approximately 6.7 indirect jobs per direct job (based on 10-man crew per vessel per year or 50,000 pounds of bait which represents 5.1 indirect fishing jobs plus 1.7 others).

[5] Boat price estimated at $.91 per pound.

[6] Local sea trials using two boats.

[7] First extended sea trials and 1 new tuna boat.

[8] Total of 7 new tuna boats.

[9] Total of 15 new tuna boats.

[10] Includes 100,000 pounds used other than by skipjack tuna boats.

[11] Includes 200,000 pounds used other than by skipjack tuna boats.

State-of-the-art for Culture

Species. The channel catfish, *Ictalurus punctatus*, is the species of catfish of commercial importance in the Mainland United States. Biological information and effective techniques for spawning, hatching, and raising channel catfish are well known. Research and commercial development of channel catfish began in 1961 in the southeastern United States. Since 1966, the number of acres of cultured catfish has increased from 400 to over 56,000 (160 to 22,700 ha), with production centered primarily in the Tennessee Valley States. Federally-sponsored research and extension/advisory services have been essential to this expansion through the compilation and dissemination of aquafarming information.

Another species of catfish, the Asian walking catfish, *Clarius spp.*, has recently been tested for commercial feasibility in Hawaii by one private firm. Inasmuch as the outcome of these feasibility tests is not certain, and the market for this species has not yet been determined (but is suspected of being limited to local residents familiar with the product in Asia), *Clarius spp.* will not be assessed at this time.

Controlled reproduction. Three techniques are practiced in the U.S.: pond spawning, pen spawning and aquarium spawning using hormone injections. Broodstock are generally three or more years old and within a weight range of 2 to 10 pounds (1 to 4.5 kg) (Bardach et al., 1972). Males and females of similar size are paired only when the female is ready to spawn, otherwise fighting occurs. The time of the year for spawning is dependent on temperature and photoperiod (length of the day). Water temperatures of 80°F (27°C) are optimum.

In Hawaii, catfish reportedly do not spawn readily in ponds under ambient light and temperature conditions. However, occasional spawning has been observed in higher elevation ponds such as Nuuanu Reservoir. Environmental manipulation with hormone injections appears to be a viable alternative. The eggs, which females deposit on an available substrate, takes five to 10 days to hatch.

Hatchery technology. A wide variety of artificial hatching systems can be used. Once hatched, fry are usually reared in a separate facility prior to stocking in growout ponds. On the Mainland, the fingerling size most preferred for pond stocking is five to six inches (13 to 15 cm) in total length.

Growout technology. Essentially, three techniques for growout to market size are used on the Mainland: culture in ponds, cages or raceways. Pond and cage culture have been demonstrated to be economically feasible. Few commercially viable raceway operations exist today. The high technology of such systems has not yet been proven economical when compared to low technology systems.

Commercial pond production of catfish in Hawaii began on Maui in 1974. In 1977, this operation had 16 acres (6.5 ha) of ponds ranging in size from one-half to four acres (.2 to 1.6 ha). Yields of 7,000 pounds per acre per year (6,200 kg/ha/yr) have been achieved in this system. This figure, which is more than four times the 1,600 pounds per acre per year (1,400 kg/ha/yr) average observed on the Mainland (Brown, 1977), can be attributed to Hawaii's higher temperatures and year-round growing season.

Catfish farming is one of this country's most successful aquaculture industries. A relatively small number of catfish have been raised in Hawaii, but this supply is expected to greatly increase in the next few years.

These Hawaii catfish, grown from fingerlings imported from the Mainland, are headed for local restaurants. (Courtesy of AFRC.)

Yields of 7,000 pounds per acre per year have been achieved from this 15-acre operation at Kihei, Maui.

Fingerlings, purchased from California at a cost of $0.05 to $0.15 each, are stocked at a density of between 8,000 and 10,000 fish per acre (19,768 and 24,710/ha). Because the cost and availability of fingerlings fluctuates considerably, there has been a great deal of local interest in devising methods for controlled reproduction of catfish in the State (Corbin, 1976).

Market Characteristics and Opportunities

Supply and demand. The United States market for catfish in 1976 was estimated to be 135.1 million pounds (61,281,000 kg) from 56,000 acres (22,700 ha) with a value of $48.3 million. In Hawaii, the present cost of raising catfish is high. Consequently, Island catfish cannot compete in price with Mainland catfish.

Catfish have been cultured in Kihei, Maui, since 1974. First year production was approximately 100,000 pounds (45,360 kg), but in 1975 and 1976, this figure dropped to 40,000 and 30,000 pounds (18,140 and 13,610 kg), respectively, because of unforeseen production problems. However, production is being reestablished. This inconsistency of supply has severely restricted market development activities, yet the market appears to be rapidly expanding. Total catfish consumption in Hawaii in 1976, including local production and foreign and domestic imports, was 52,000 pounds (23,590 kg), but the present demand may be around 600,000 pounds (272,160 kg) per year (*Fish Farms Hawaii*, 1976).

Product forms. Foreign and domestic catfish imports are usually sold in the form of frozen fillets or steaks. Local catfish are marketed mainly in filleted and whole forms. Most catfish marketed whole are locally grown and sold live at the pond bank to final customers. However, some whole, dressed (eviscerated) fish are imported from the Philippines. About 95 percent of the production of the Maui operation is filleted into portions between two to six ounces (57 to 170 g) and distributed to restaurants through a wholesaler. These restaurants list the fish as a "Hawaiian" product on their menus, and serve it as a breaded entrée or as a Spanish dish with tomatoes and onions.

The quality of Hawaii catfish may be superior to its Mainland counterparts. Brokers have stated that they are hesitant to buy Mainland and foreign catfish because they are considerably inferior in taste and texture to the Maui product.

Price. Mainland processed farm-raised catfish are sold wholesale, fresh (ice packed) or frozen for $1.11 to $1.25 a pound ($2.45 to $2.76/kg), and retail for $1.59 to $1.79 a pound ($3.51 to $3.95/kg). Imported wild-caught catfish, which come principally from Brazil, retail in dressed form for $0.99 to $1.29 per pound ($2.18 to $2.84/kg) (Brown, 1977). Hawaii-grown catfish would have to be produced for approximately $.50 per pound ($1.10/kg) before Mainland marketing would be feasible and this appears to be a difficult task.

Hawaii prices for live catfish are currently $1.25 per pound ($2.76/kg) at the pond while fillets are $3.50 per pound ($7.72/kg). The appeal of a fresh "Hawaiian" specialty seafood item has produced a demand that exceeds supply, and in the opinion of some brokers, locally raised catfish could probably be sold in most of the State's seafood restaurants if the supply were available (Ken Horimoto, 1977; personal communication).

Major Constraints and Recommended Actions

Culture. Although channel catfish fingerlings can be purchased from the Mainland, such supplies are either inconvenient or too expensive for Hawaii's aquafarmers. The further development of catfish farming will be greatly enhanced by a local source of stocking material. A research program aimed at artificially spawning channel catfish in Hawaii at all times of the year to provide fingerling production will aid the expansion of farming activities. Such a research effort is presently being carried out by the Anuenue Fisheries Research Center and the University of Hawaii. The successful conclusion of the research will not only further commercial aquaculture development, but also provide a steady source of catfish juveniles to use for stocking recreational fishing areas.

Market. A broad spectrum of Hawaii consumers is unfamiliar with catfish. Because of inconsistencies in the local production of catfish, State and private entities have hesitated to launch major market promotion programs.

Once the local production of channel catfish is sufficient, market development activities can commence. These activities would be directed at optimizing the institutional, restaurant and home markets. The saturation of the restaurant sector may generate a home consumer demand. Cooking demonstrations could be undertaken to stimulate public interest. Non-traditional product forms (smoked catfish, breaded catfish or catfish sticks, for example) may appeal to a broader group of consumers.

If opportunities for export should develop, the State should also support these activities. However, the development of export markets on the U.S. Mainland or Japan appears unlikely in the near future due to increasing competition from Mainland and South American producers and the current costs of production and shipping.

Perhaps the major constraint to the successful marketing of catfish will be the high retail price. Research is, therefore, needed to reduce the costs of pond production of freshwater finfish, through mechanization or other means.

Economic Projections

The following growth projections are limited -for the most part—by market opportunities. It is assumed that current production will gradually increase over the next five to seven years, during which time the demand for the product will exceed available supplies of locally-produced catfish. Thereafter, it is assumed that production will grow at a moderate pace, in keeping with increasing demands brought about by promotional activities. It should be noted that if production costs can be brought down to approximately $.50 per pound ($1.10/kg) (1978 dollars), export opportunities would occur and these projections would, therefore, be far too conservative. Moreover, these projections do not account for the emergence of a fingerling production industry, a strong possibility because of Hawaii's current disease-free status and relative isolation.

Table 15. Projected Production, Employment and Revenues from the Culture of Channel Catfish in Hawaii: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	100	16	2	6	8	$ 125
1980	350	4	5	15	20	438
1985[6]	600	75	8	24	32	750
1990	750	94	10	30	40	938
1995	1,000	125	13	39	52	1,250
2000	1,250	156	16	48	64	1,563

Assumptions:

[1] Production limited by local market. Yields estimated at 8,000 pounds/acre/year.

[2] Represents acres of impounded water. Farm size acreage is considerably larger.

[3] One direct job per 10 acres of ponds.

[4] Wholesale price of $1.25/pound is equivalent to $3.50/pound for fillets (35 percent recovery factor).

[6] Market promotion begins.

Freshwater Finfish

State-of-the-art for Culture

Species. Chinese carps and tilapia[10] are groups of fishes which possess certain favorable biological and ecological characteristics that allow mass culture at a low cost.

Chinese carps consist of four major species: the grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalmichthys molitrix*), big head (*Aristichthys nobilis*) and mud carp (*Cerrhina molitrolla*). Tilapia are a genus of warm water fishes originating in the intertropical waters of Africa. Species of commercial aquaculture interest include: *Sarotherodon mossambicus*, *S. nilotica*, *S. aureus*, *S. galileus*, *S. melanopleura*, and *S. macrochirus*.[11] Members of both groups have been introduced into many tropical and temperate countries around the world to be cultured as a source of inexpensive food protein (Bardach et al., 1972), and both groups are extremely hardy with high tolerances for such environmental stresses as high temperatures, low levels of oxygen and high metabolite concentrations.

Several species of Chinese carps are often cultured together or with other economically valuable species of aquatic plants and animals because the feeding characteristics of each species are such that each consumes a different portion of the natural food

[10] Although *Tilapia spp.* are euryhaline, or can tolerate a wide range of salinities, they will be discussed in this section with other freshwater finfish.

[11] The genus *Tilapia* was recently changed to *Sarotherodon*, however, *Tilapia* is still used as the common name.

chain. This concept known as "polyculture" allows large quantities of fish and other animals to be cultured in a pond with little or no supplemental feeding. However, some fertilization (with either commercial agricultural fertilizers or animal manures) of the pond to increase natural productivity is required.

Optimum rearing temperatures for tilapia range between 68° and 86°F (20° and 30°C) (Huet, 1970). Like Chinese carps, tilapia can utilize the natural pond productivity as feed. However, since the feeding niches (that is, the components of the natural productivity each species eats) for the various species are not well known, and since the history of culture is short compared to other polyculture systems, species combinations and stocking practices are not firmly established (Bardach et al., 1972).

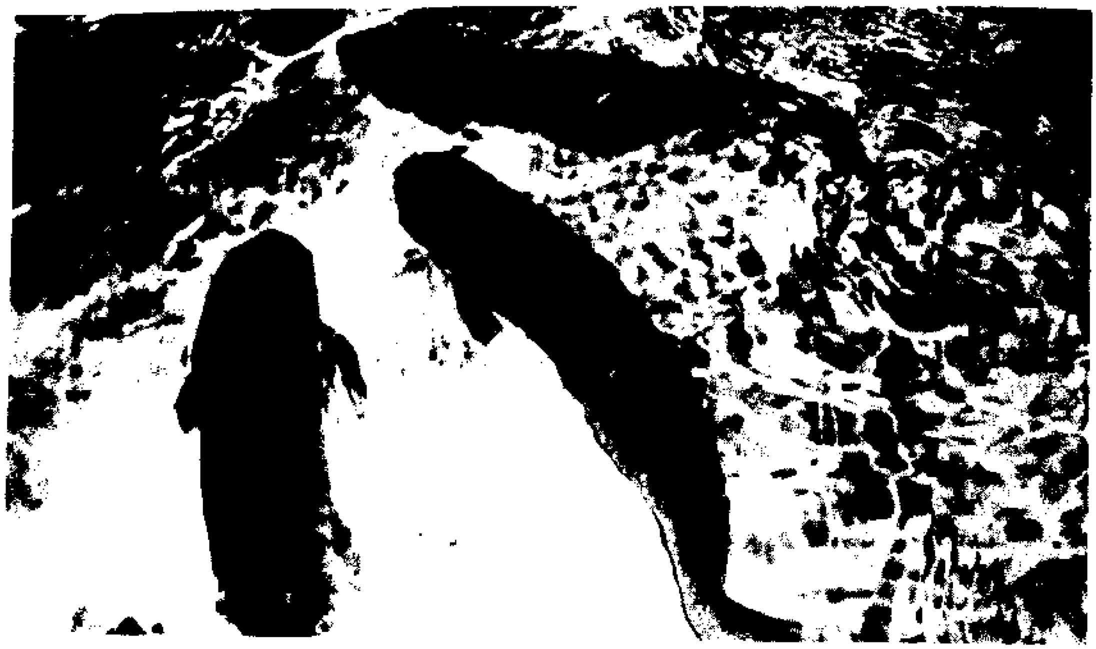
Reproduction and hatchery technology. Controlled reproduction of carps and tilapia is carried out routinely. Chinese carp fry can be obtained by artificially spawning broodstock using hormone injections. This technique is practiced in many countries around the world, including China, the Soviet Union, the United States, Israel, Malaysia, Japan, Brazil, and Taiwan. The details of the procedure differ for each carp species, however, there are three principal phases: preconditioning, injection and spawning (Bardach et al., 1972). Chorionic gonadotropin hormones from common carp or humans are used with spawning generally carried out in an earthen pond stocked with males and injected females. Spawning takes place in one to two hours, after which the pond is drained and the eggs collected. Hatching is usually carried out in special baskets in the laboratory. Chinese carps hatch in 24 hours at 82°F (28°C) and the yolk sac is absorbed within three to six days. As soon as the yolk sac is absorbed, the fry are transferred to the first of a series of nursing and rearing enclosures or ponds.

Tilapia spawning occurs naturally in ponds and other rearing enclosures. Indeed this has caused problems for tilapia farmers as spawning is difficult to prevent and overstocking in ponds may result. Tilapia make "nests" or hollowed out depressions in the pond bottom or bank for egg laying and fertilization and, then, in most species, fertilized eggs are carried or brooded in the mouth of the female for about 10 to 15 days after hatching. Some species of tilapia may mature in two to three months, at which time they reach 2.4 to 4 inches (6 to 10 cm) long (Bardach et al., 1972). One technique used to avoid unwanted spawning in growout ponds is monosex culture, usually the culture of all males.

Growout technology. Chinese carp growout ponds are prepared for stocking through the addition of fertilizer. The type and amount of fertilizer (usually animal manures) depend on the characteristics of the soil and water supply, and the species of Chinese carps, i.e., which portions of the natural productivity are going to be used (Bardach et al., 1972). Stocking densities vary considerably depending on the species stocked and whether polyculture or monoculture is practiced. Chinese carps grow well in high densities, and intensive growout systems can be successful when supplemental feeding is provided.

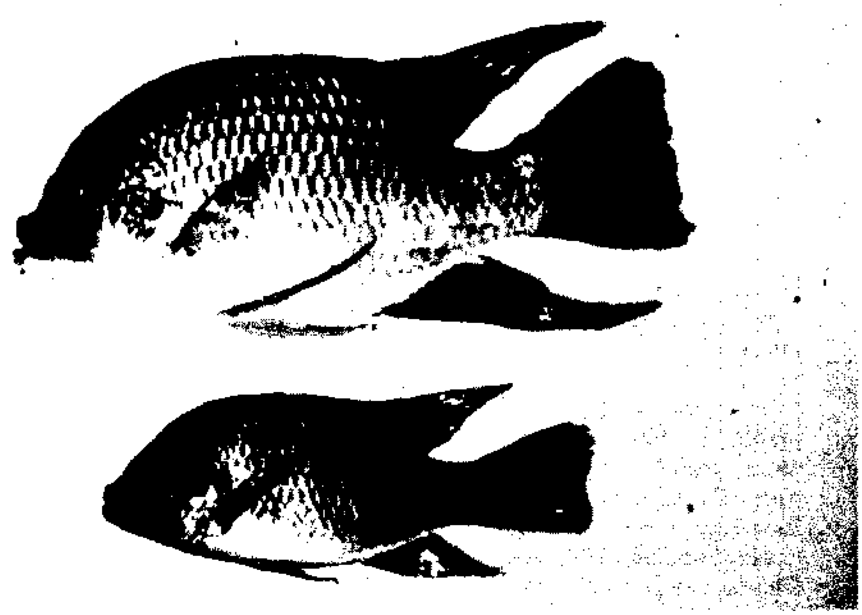
Yields from carp growout ponds vary with the amount of fertilizer and supplemental feeding, the stocking density, the species reared and the management techniques employed. The most productive combinations of species of Chinese carps and their proportionate stocking densities (polyculture) are not clearly defined at this time. Under favorable conditions, yields from the polyculture of several Chinese carp species may range between 340 to 9,000 lbs/acre (300 to 8,000 kg/ha). The effects of culturing Chinese carps with other aquatic animals (prawns and oysters) have not yet been determined. However, Chinese carps can reportedly be cultured with prawns, food fishes and molluscs with little or no increase in supplemental feeding.

The polyculture of Chinese carps and tilapia represents an opportunity for Hawaii to meet the food processing industry's increasing demand for high quality, low cost fish flesh.



Above: Chinese carp can be spawned in captivity by using hormone injections. (Courtesy of DLNR.)

Below: Tilapia spawn naturally in ponds and other rearing enclosures. (Courtesy of DLNR.)



The greatest potential for tilapia culture appears to be in polyculture with other species. According to Bardach et al., 1972, the critical question is not "How many kilograms of tilapia can be produced in this pond?", but rather "Will tilapia add significantly to this pond's fish production?" Even so, annual yields from the monoculture of tilapia have ranged between 1,120 and 20,200 lbs/acre (1,000 and 18,000 kg/ha). As with Chinese carps, there is little precise data available on methods of using tilapia in polyculture situations.

Market Characteristics and Opportunities

Supply and demand. Both carps and tilapia have been cultured and consumed in various European, African and Asian countries for hundreds, if not thousands, of years (Bardach et al., 1972). Today, both groups play critical roles in the diets of people in the developing countries (Bell and Canteberry, 1976). The popularity of Chinese carps and tilapia as food in the United States has not been established, though some small experimental market development activities have been carried out in Alabama (Crawford et al., 1978) and Florida. On the Mainland United States, two species from these two groups of fishes have been widely used for aquatic vegetation control (the grass carp, *Ctenopharyngodon idella*) and as a recreational sport fish in bodies of freshwater (*Sarotherodon spp.*). Commercial culture has, therefore, been limited to support of these two developing uses.

A major unresolved issue affecting the continued use of both Chinese carps and tilapia in aquatic vegetation management and recreational fishing, as well as food production, is the question of the impact of non-native species on native fishes and the natural balance of freshwater ecosystems. Considerable resistance to the further stocking and distribution of both species groups have been observed in some states, e.g., Florida and Missouri (Guillory and Gasanay, 1978).

An example of a country where these groups of freshwater finfishes are important food items in a non-subsistance economy is Israel, where Chinese carps are produced in polyculture systems. The per capita aquatic protein consumed per annum in Israel is 20 pounds (9 kg). Roughly 20 percent of this figure is composed of Chinese carps (Moav, personal communication, 1977). Likewise, the use of tilapia in the diet has been increasing (Brown, 1977).

In Hawaii, combined sales of Chinese carps by the two local producers amounted to approximately 25,000 pounds (11,300 kg) for the period 1972 through 1976 or an average production of 6,250 pounds (2,800 kg) per year. Preliminary calculations indicated a market potential of approximately 46,000 pounds (20,870 kg) of whole fish in 1977.

In 1977, approximately 3,180 pounds (1,440 kg) of tilapia were produced in local ponds. Reportedly, an unknown amount of this production is being exported to Canada to a small pocket market.

Product forms. In Europe, Israel and the Far East, live and fresh-frozen carps and tilapia can be found in traditional fish markets, and some dried and processed products can be found in food and specialty stores.

In Hawaii, Chinese carps (principally the grass carp) are sold wholesale either live at the pond or fresh-chilled. They are particularly popular with people of Chinese descent. Chinese restaurants often prepare the fish by steaming.

Although some tilapia are undoubtedly consumed in Hawaii, they are not generally favored as a food fish and do not often appear in fish markets or food stores. It is safe to assume that all tilapia presently consumed in Hawaii are from the recreational fishery.

Prices. Prices for live and fresh-chilled carp in Hawaii range from $2.00 to $2.50 per pound ($4.41 to $5.51/kg) wholesale, depending on the producer. Retail prices vary between $3.50 and $4.50 per pound ($7.72 and $9.92/kg). By comparison, in Israel the government-controlled price for live carp was between $.90 and $1.10 per pound ($1.98 and $2.43/kg) in 1977.

In 1977, approximately 3,180 pounds (1,442 kg) of tilapia were sold in Hawaii for a value of $4,060, or about $1.24 a pound ($2.73/kg).

Wholesalers in Alabama have indicated a willingness to purchase several types of Chinese carps for about $.45 to $.50 a pound ($.99 to $1.10/kg) (Crawford et al., 1978). Even without the cost of the air transportation required to market a fresh product, prices of Hawaii-raised fish would be prohibitive.

Potential markets. A large export market potential for both these groups of fishes in developed countries clearly lies in their possible use as low cost, high quality processed fish protein for such items as fillets, fish cakes, burgers, sticks, etc. The United States consumed in excess of 300 million pounds (136,080,000 kg) of fish sticks and portions in 1976. These items are cut from blocks of fish flesh, more than 90 percent of which are imported (USDOC, 1977).

A smaller, near-term potential exists in Hawaii for the development of polyculture systems that utilize combinations of these species along with other economically important local species, such as freshwater prawns. Once optimal management techniques are worked out, increased pond production can be expected for the same amount of feed and/or fertilizer input.

The increasing demand for Chinese carps in Hawaii and the Mainland in other than the "unrecognizable" processed product forms will require consumer education programs. Educational activities could include in-store promotions, giving the product a brand name and/or test marketing product forms which appeal to a broad segment of the community.

Major Constraints and Recommended Actions

Culture. Although certain species of both Chinese carps and tilapia are present in Hawaii, neither group has been scientifically evaluated in a commercial demonstration of pond aquaculture. Likewise, the role that these species could play in increasing the productivity and profitability of existing pond-reared aquaculture species, such as freshwater prawns, has not been tested. Moreover, local commercial aquaculturists are generally unaware of the benefits of polyculture. The State should encourage the commercial demonstration of the polyculture of carps and tilapia, and support research and technology transfer activities from other countries of the world to develop such systems to their optimum.

The importation of certain species of Chinese carps and tilapia not presently in Hawaii may be prohibited if proposed Federal regulations are adopted. Moreover, the lack of scientific information on the impact of these species on local ecology may make it difficult to import brood or seed stock for commercial purposes. State agencies should provide input into Federal injurious species legislation, so that, when appropriate, Hawaii can be exempted from regulations. Initial overtures in this regard have already been made. In addition, State agencies should analyze existing literature on these groups to determine if importation into Hawaii would be detrimental and what precautions should be taken, e.g., closed systems culture, etc.

Both Chinese carps and tilapia are traditionally cultured in Asia and Europe using domestic and animal wastes to enhance the natural productivity of culture ponds and to provide a supplemental feed. The use of such methods to produce food consumed directly by humans is prohibited by Federal regulations. This situation eliminates an inexpensive source of fertilizer and/or feed for aquaculture at this time. State agencies should work with appropriate Federal agencies to define the legal problems in biological terms and formulate solutions and appropriate regulations. The State should also support research into the use of domestic and animal wastes in monoculture or polyculture systems utilizing Chinese carps and tilapia. This research can bring about efficient and cost-effective utilization of State land and water resources.

Market. Chinese carps and, particularly, tilapia have a poor "public image" by virtue, perhaps, of their histories and feeding habits. This situation can account for the general lack of market incentive for culturing these species. One means of overcoming this situation would be to diversify the product and, for example, utilize these fish in processed foods.

When the production of Chinese carps and tilapia warrants, the State should engage in market development activities. Possibly the most potentially valuable activity would be to encourage the construction of processing plants capable of producing bulk fish flesh. The existence of such plants would permit the development of export markets.

Economic Projections

The following estimates of production, employment and revenues for the culture of freshwater finfish are based on the gradual introduction of Chinese carp and tilapia culture over the next 10 years. It is assumed that these species-groups will be introduced first as polyculture with freshwater prawns. Expansion is assumed to proceed rather slowly at first, with most of the product being consumed locally by various ethnic groups. Thereafter, it is assumed that a more rapid expansion would take place upon the establishment of a fish flesh processing plant.

Table 16. Projected Production, Employment and Revenues from the Culture of Freshwater Finfish in Hawaii for Local Consumption: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	6	1.5	1	2	3	$ 6
1980[7]	10	2.0	1	2	3	10
1985[8]	50	10.0	1	2	3	50
1990[9]	250	50.0	5	9	14	250
1995[10]	1,000	200.0	20	50	70	1,000
2000	5,000	1,000.0	100	250	350	5,000

Assumptions:

[1] Includes Chinese carps and tilapia for fillets and other processed forms. Production yields estimated at 5,000 pounds/acre/year.

[2] Represents surface acreage of impounded water. Farm size will be considerably larger.

[3] Approximately one direct job per 10 acres of ponds.

[4] Approximately 1.7 indirect jobs per direct job until processing begins in 1995. Thereafter, 2.5 indirect jobs per direct job.

[5] Wholesale value of $1.00 per pound, live weight.

[6] Single producer, development program begins in 1979.

[7] Feasibility demonstration proceeds.

[8] Commercial feasibility proven.

[9] Track record established and expansion proceeds.

[10] Processing begins.

Freshwater Prawns

State-of-the-art for Culture

Species. Although there are over a hundred species of freshwater prawns of the genus *Macrobrachium* around the world, *Macrobrachium* aquaculture is presently synonymous with the culture of *M. rosenbergii*. This species, like others of the genus, grows best in tropical climates with temperatures above 77°F (25°C). The lower temperature limit for all species of *Macrobrachium* is probably about 59°F (15°C).

Research into the reproduction of the Malaysian prawn was initiated in Penang, Malaysia, in 1959. After several years of experimentation, prawn larvae were successfully reared to adults in the laboratory by Dr. Shao Wen Ling. Commercial prawn aquaculture became possible in 1966 when biologists at the Anuenue Fisheries Research Center (AFRC) of the Hawaii State Department of Land and Natural Resources developed a practical mass larval-rearing technique.

With the availability of a reliable supply of stocking material and advisory services, a few local full-scale pond production tests were begun in 1969. When the economic

A State AFRC worker takes a monthly pond sample and checks for size and sex. (Courtesy of AFRC.)

The freshwater prawn, *Macrobrachium rosenbergii*, introduced to Hawaii in 1965 and developed by the Anuenue Fisheries Research Center, is now exported to countries around the world. Hawaii has emerged as the world's leading center for prawn farming expertise.

Takuji Fujimura, Chief Biologist of the Anuenue Fisheries Research Center, is responsible for the establishment of modern freshwater prawn farming.

feasibility of prawn farming was demonstrated a few years later, more farmers began to take advantage of the State's program.

The AFRC, through its research hatchery and extension advisory activities, supports prawn aquaculture development (Chapter II, B). These activities particularly hatchery and extension/advisory -need to expand to meet the needs of new farmers.

The recent selective breeding and ecotype testing of different varieties of *Macrobrachium spp.* has resulted in the development of a species with a distinctly superior hatchery performance (Spencer Malecha, 1978: personal communication). Evaluations of pond growout performance of this promising new species are now under way.

Controlled reproduction and hatchery technology. Personnel at Anuenue have developed and perfected a workable hatchery technology for Malaysian prawns. *Macrobrachium* will mature, mate and spawn under both laboratory and pond conditions about eight months after hatching. Females carry eggs externally. Although female prawns will mature and mate in fresh water, brackish water is required for the larvae to survive and develop.

Newly-hatched larvae are placed in large 5,020 gallons (19,000. l) tanks. The optimum salinity of the water is between 12 and 14 parts per thousand, with the optimum temperature between 82° and 86°F (28° and 30°C). Prawn larvae are generally stocked between 150 and 230 individuals per gallon (40 and 60 individuals/l). The system uses single-celled algae, "greenwater," in concentrations ranging from 500,000 to 2,000,000 cells per milliliter, in static culture where water is periodically exchanged. *Artemia* nauplii are provided at concentrations of between 5 and 15 nauplii per milliliter. Minced fish flesh is also used to supplement the diet during the latter half or two-thirds of larval development. Survival is usually between 50 and 60 percent. The hatchery phase takes approximately 40 days (Sandifer et al., 1977).

Prawn hatchery technology is undergoing extensive cost reduction research by many public and private organizations around the world. The cost of producing post-larval stocking material at the AFRC is about $8 per thousand, but this only represents operating costs. The AFRC has an extensive research program in this area which functions in conjunction with its commitment to furnishing stocking material to Hawaii's prawn farmers. The focus is on achievening a shorter larval cycle to reduce operating costs and increase annual production. Areas of research include controlling and optimizing environmental factors, nutrition, tank design and flow characteristics, hatchery management techniques and selective breeding (Hanson and Goodwin, 1977).

Growout technology. An effective pond growout system for prawns has been developed by the AFRC (Fujimoto, Fujimura and Kato, 1977). Briefly, the system utilizes unlined earthen ponds with a sluice gate outflow system. Water quality is controlled by flushing rate, fertilizers and oxygen releasing agents. Flow rates, ranging from 10 to 20 gallons per minute per surface acre (90 to 190 l/min/ha), are increased as much as threefold to flush ponds of excess phytoplankton (blooms) and decreased when phytoplankton densities fall. A water depth of three to four feet (.9 to 1.2 m) allows moderate phytoplankton densities, thus preventing benthic algae or aquatic weed growth, which interferes with harvesting. Stocking rates are between 1.5 and 2 post-larvae per square foot annually.

Farmers feed approximately 30 pounds of poultry broiler starter per acre per day (27 kg/ha/day) which represents a feed conversion ratio of a little over three pounds of feed to one pound of prawns.

Weighing prawns after the harvest. (Courtesy of AFRC.)

Prawn juveniles from the State hatchery—ready for stocking. (Courtesy of AFRC.)

Freshwater prawn farming is the largest and most rapidly growing segment of Hawaii's commercial aquaculture sector. *Macrobrachium* has a high market value and a significant export potential—two characteristics that other species recommended for development should possess.

Aquatic Farms, Ltd., of Hakipuu, Oahu, was designed to be a showcase for prawn and other aquaculture technologies. (Courtesy of Aquatic Farms, Ltd.)

Feeding rates are increased if all the food disappears within 24 hours and decreased if there is leftover feed. The role of natural pond productivity in the nutrition of prawns is not well understood at this time.

The stocking of growout ponds takes place once a year with harvesting every two to three weeks throughout the year (after an initial seven-month growth period). The single annual stocking is due to the State hatchery limitations. The hatchery is presently undergoing temperature control modifications to permit it to operate year-round. When these are completed, multiple stockings are expected. Under these conditions, the fastest growing prawns reach a harvest size of five to seven live animals per pound (11 to 15 animals/kg) in about seven months. This commercial production system has proven reliable as sustainable production levels of 2,500 to 3,500 pounds of market-size prawns per acre per year (2,225 to 3,115 kgs/ha/yr) have been demonstrated in some established Hawaiian ponds (Gibson and Wang, 1977).

A detailed analysis of the production process reveals that major costs are distributed into the categories of amortizing debt, labor, and feed. Little can be done at present to reduce the initial capitalization. Labor and feed account for 40 percent of total production costs. Research directed towards the automation of the harvesting and feeding processes could benefit many local farmers. Moreover, the cost of compounded rations is likely to continue to rise due to the increasing price of ingredients. Research aimed at increasing the natural pond productivity utilized by prawns could offer further cost reduction benefits to aquafarmers. Key parameters to be investigated are pond temperature, water quality and flow rate, the amount of natural and artificial shelter, pond size and shape, harvesting frequency and type of feeds. Another area of investigation is the introduction of the polyculture of Chinese carps with prawns.

Commercial sector needs. Active water quality management can be a key factor in maintaining ponds in an optimal production condition. However, few of Hawaii's prawn farmers have the "in house" expertise to carry out a water chemistry monitoring program. Moreover, acquiring these services from the private consulting sector can be too expensive for the small operator. Likewise, the health and quality of the prawns although not major problems to date--have been overlooked. Aquatic disease services have recently been instituted to fill this void. Responsibilities will include responding to on-site production disease problems, research and cataloging of local aquatic diseases, and inspection of export and import shipments of aquatic products.

Market Characteristics and Opportunities

Supply and demand. Malaysian prawns are a popular food item in Asia and Europe. In Japan, prawn consumption has reportedly increased from five million pounds (2,268,000 kg) in 1968 to 12 million pounds (5,443,200 kg) in 1972. The majority of this figure is imported from Southeast Asia. Western Europe and Scandinavian countries are importing significant, yet unknown, amounts of prawns. Although precise quantities cannot be quoted, it can safely be said that the demand far exceeds the supply.

Macrobrachium rosenbergii is largely unknown on the Mainland United States. With the exception of a small *Macrobrachium ohione* fishery in Louisiana, which produces approximately 100,000 pounds (45,360 kg) a year for food and bait, there is essentially no natural fishery. Mexico has a *Macrobrachium spp.* fishery based on wild stocks. The seasonal catch amounted to 700 metric tons in 1974 valued at $8,360,000, however, this catch is consumed within the country (Hanson and Goodwin, 1977). An estimated

10 million pounds (4,536,000 kg) per year of freshwater prawns are presently being imported into the United States from Southeast Asia and India, but this supply has been inadequate and quality has been inconsistent, ranging from fair to poor.

The present Hawaii market for prawns remains undersaturated. From 1972 through 1977, prawn production increased from 4,000 pounds (1,814 kg) annually to 51,000 pounds (23,134 kg). From interviews conducted with wholesalers, retailers and restaurateurs, it is estimated that a small quantity of freshwater prawns is being imported from Bangladesh, Ecuador, Taiwan, and the Philippines. This supply from foreign nations is approximately 5,000 pounds (2,268 kg) a year.

Prawn production is expected to reach 175,000 pounds (79,550 kg) in 1978. Various estimates of demand place the existing hotel and restaurant market alone at approximately 400,000 to 650,000 pounds (181,440 to 294,840 kg) annually (Faison, 1976 MS; APP interviews with restaurateurs, wholesalers and retailers). The potential for substituting prawns for jumbo marine shrimp and other shrimp-like products would increase these demand figures to 1.5 to 1.8 million pounds (682,000 to 818,000 kg) annually.

Product forms. Mainland distributors occasionally handle frozen prawns, heads off, shells on, in five- to ten-pound (2.3 to 4.5 kg) blocks from Vietnam, India, Bangladesh and Indonesia. Supplies have been limited and the quality and taste of the product has generally been variable. Reportedly, samples of these animals often fail to meet U.S. health standards.

Potential U.S. Mainland and local distributors for freshwater prawns have two points of view on the subject of marketing. One group feels that prawns should be sold as a distinct, moderate- to high-priced, specialty product, while the other group feels that prawns should be sold as a substitute for marine shrimp and lobsters.

It was determined from interviews with local and Mainland producers, retailers, and wholesalers, that in order to be a lobster substitute, *Macrobrachium* should have the following characteristics: (1) the product size should be a 10 count, or 10 prawns to the pound (22 prawns to the kg), or 1.6 ounces (45 g) or less, through a five or eight count (11 or 18 count/kg), with heads off, deveined, and shells on; (2) the product flavor and texture should be appealing, i.e., there should be a firm texture with a crisp bite with no trace of a muddy after-taste; (3) the product should be individually covered with a cellophane wrap, quick frozen, and packaged in five-pound (2.3 kg) boxes with 10 boxes to a case.

In Hawaii, producers are selling their entire production as whole, live or fresh on ice. Tamashiro Market, the largest retailer of prawns in terms of volume, markets live prawns in display aquaria. Restaurants vary in methods of preparing prawns. As a shrimp dish, prawns can be prepared and served in a fashion similar to marine shrimp, i.e., deep-fried or sautéed, and in scampi, salads, curries, and tempuras. One restaurant sautées prawn tails in garlic butter and grape brandy, whereas another serves prawns broiled, Japanese tempura-style and grilled. Red Lobster Inns serve prawns as a specialty item, with the body cavity of the prawn stuffed with crab meat and its own meat, and the tail butterfried. Customers are reportedly unable to distinguish between freshwater prawns and marine shrimp when the prawn is served in a breaded and fried form.

Prices. Mainland wholesale prices for frozen imported prawns range from $2.30 to $3.30 per pound ($5.07 to $7.28/kg). The lower price is for 10 count animals (22 count/kg) and the higher price is for five count animals (11 count/kg). These prices are somewhat lower than imported marine shrimp in the same size range. Prawns are sold in moderate- to high-priced restaurants with meal prices usually ranging from $6 to $10 and up.

In Hawaii, during the period 1972 to 1976, the cost of prawns to wholesalers remained at $3.50 per pound ($7.72/kg). Recently, farm prices have reached as high as $4 per pound ($8.82/kg). Live, six to ten count animals (13 to 22 count/kg) at retail markets can be bought for $5.00 to $5.50 per pound ($11.02 to $12.13/kg). The retail price for the iced, whole product has averaged about $5.70 per pound ($12.57/kg). Prawn tails have been priced in local supermarkets at between $7.00 and $8.50 per pound ($15.43 and $18.74/kg). By comparison, frozen lobster tails retail for about $9.00 per pound ($19.84/kg), while fresh, whole marine shrimp is about $8.00 per pound ($17.64/kg). In restaurants, *Macrobrachium* can be found in various seafood combination platters for around $10.50 per meal.[12]

Processing and packaging. Many Mainland and Hawaii wholesalers are reluctant to handle prawns because of erratic supplies and variations in the quality of the product. Prawns which have been offered as fresh, iced or blanched[13] have, on occasion, been found to have a mushy texture and are unacceptable. Using the present blanching and icing techniques, the shelf-life of freshwater prawns is approximately six days. Since wholesalers, retailers and restaurateurs purchase food items that are held in inventory, processing techniques to lengthen shelf-life and ensure a high quality product in terms of texture and taste must be investigated.

A method which appears promising is flash-freezing (or quick freezing) the animals immediately after harvesting. After being frozen, the animals are then packaged in air-tight containers or glazed with ice and stored at low temperatures about -30°F (-34°C). This process, which has not been demonstrated in Hawaii, reportedly lengthens shelf-life to six to eight months (Hanson and Goodwin, 1977).

The increasing popularity of convenience foods for both fast food restaurants and home consumers necessitates the refinement of existing processing techniques and the diversification of product forms if prawns are to capture a large portion of the seafood market. It appears, for example, that restaurants would prefer individual prawns rather than prawns packed in 10-pound (4.5 kg) blocks. Processing of prawns into de-headed, deveined, and breaded forms offers opportunities for an expanded market at some future time.

In summary, grading, processing, packaging and labeling standards which are strictly adhered to by all producers would build consumer confidence and speed development of the market.

Market development. A major obstacle to Mainland market development is the current lack of a distinct market segment for freshwater prawns. Because of similarities between prawn tails and jumbo marine shrimp tails, wholesalers, retailers and their

---

[12] Prices are as of June, 1977.

[13] Process which chill-kills the animals then immerses them in 150°F (66°C) water for 15 seconds before they are packed in ice.

customers have tended to confuse these products. Also, many West and East Coast wholesalers have a negative opinion of prawns due, for the most part, to variations in the quality of the imported product. Specifically, they have mentioned a "blandness" of taste and "inadequate" packaging techniques which shorten shelf-life. Another constraint appears to be the cultural preference of most Americans for "tails only" products.

In addition to the Mainland, Japan and Europe represent other export market opportunities for prawns. Both the cultural food preferences and the existing shellfish distribution systems of these areas favor rapid market expansion, once regular supplies become available.

In Hawaii, four possible markets have been identified: (1) hotels and restaurants, (2) schools, (3) military commissaries, and (4) such retail outlets as seafood markets and supermarkets. Of these, the hotel and restaurant market has the highest initial potential (Faison, 1977 MS). This market, which caters to tourists and residents alike, is a quality market commanding premium prices. There is the further advantage of exposing Mainland visitors to the taste advantages of the "Hawaiian prawn." A conservative estimate for the yearly tourist market is 656,000 pounds, or 297,562 kilograms (Faison, 1977 MS).

An important issue to be decided is whether the product should be marketed as a new entity or as a substitute for existing products of similar form, such as lobster and jumbo marine shrimp tails, whose principal buyers are hotels and exclusive restaurants.

Major Constraints and Recommended Actions

Culture. Commercially viable hatchery and growout technologies have been developed in Hawaii. However, current production costs, combined with a scarcity of supply, have resulted in high market prices which, in turn, have caused people to think of prawns as a luxury item.

Techniques are being researched and refined to reduce the costs of production. Key areas which need to be addressed include: (1) formulating a low cost, high quality supplemental feed; (2) developing techniques to manage the natural productivity of the pond, thereby increasing available food, and (3) reducing labor through development of labor saving equipment and procedures. In addition, emphasis should be placed on developing a domesticated strain of prawns that can be raised less expensively, in a shorter period of time, and which is overall, a higher quality animal. For example, prawns which spend less time in the hatchery phase, or have a greater proportion of edible meat would decrease overall unit cost of production.

In the future, continued encouragement and support should be given to research which contributes to reducing production costs for both the hatchery and growout phases of prawn farming. These experiments should include laboratory and outdoor pond investigations in the following five areas: (1) increasing the total aquatic protein production of a pond through the polyculture of freshwater prawns with finfish (e.g., tilapia and Chinese carps), (2) increasing production and reducing costs through the development of new management techniques, (3) developing a domesticated stock through maximizing the economically important characteristics of various genetic stocks (ecotypes), (4) optimizing prawn productivity and reducing total feed costs through maximizing natural pond productivity and developing least-cost supplemental feeds, and

(5) reducing production costs through the development of labor saving devices for feeding, harvesting, pond maintenance, and water quality maintenance.

Market. The Hawaii market for prawns presently is undersaturated due to insufficient supplies. However, within the next two years, supplies of prawns are likely to increase tremendously due to rapid increases in the number of acres in production (see Economic Projections, Table 17). Indeed, the supply of farmed prawns is expected to exceed the needs of the live and fresh on ice markets by late 1979. Market development activities should begin in anticipation of the large increases in production. Key areas of pursuit should include: (1) the establishment and industry-wide adoption of quality standards for all product forms, (2) the determination and implementation of storage methods and such freezing techniques as flash-freezing, to allow for the expansion of the local market, as well as the development of export markets, (3) the adoption of packaging and labeling procedures, and (4) the undertaking of educational and promotional activities. Initial emphasis should be placed on the expansion of the local market in concert with planning for entrance to the Mainland export market by early 1980. Research undertaken should be a cooperative, interdisciplinary effort between the AFRC and the University and involve both the Hawaii Prawn Farmers Association and private processors. The Hawaii Prawn Farmers Association can and should serve as a major focal point for all of the aforementioned activities.

Economic Projections

Over the past four years, prawn farming has seen a doubling in production nearly every year. This explosive growth rate is not expected to continue. The projected production, employment and revenue from the culture of freshwater prawns through 1980 are indicated in Table 17. These projections are based on present production, current expansion activities, and announced plans. They are, therefore, considered to be highly accurate. Projections for 1985 and beyond are based on a growth rate which reflects a doubling of production every five years as opposed to the current doubling each year.

Table 17. Projected Production, Employment and Revenues from the Culture of Freshwater Prawns in Hawaii: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	175	117	22	20	42	$ 616
1980[7]	1,442	517	52	88	140	5,047
1985[8]	7,500	1,875	190	320	510	26,250
1990[9]	15,000	3,750	375	640	1,015	52,500
1995	30,000	7,500	750	1,280	2,030	105,000
2000	60,000	15,000	1,500	2,560	4,060	210,000

Assumptions:

[1] Production estimated to be 3,000 lb/acre/yr for firms in production for more than one year as of beginning of each calendar year.

[2] Actual surface acreage of impounded water. Total farm acreages are much greater.

[3] Approximately one direct job per 10 acres of ponds.

[4] Approximately 1.7 indirect jobs per direct job.

[5] Wholesale price of $3.50/pound, whole weight

[6] Estimates are reliable since they are based on juveniles stocked in 1977.

[7] Production based on announced plans. Freezing and export begins.

[8] Production per acre increases to 4,000/acre/yr. Production costs decrease, allowing for substitution for shrimp tails.

[9] Full-scale export of both frozen tails and whole animals.

Marine Finfish and Miscellaneous Marine Species

Due to the diverse nature of the species being considered in this section, each species or group of species will be discussed separately.

Mullet

Species. The grey mullet (*Mugil cephalus* Linnaeus), the species most commonly cultured, is distributed in coastal waters and estuaries throughout the tropics and subtropics. Extensive (low yield per unit area) pond culture of this species occurs throughout Asia, but farmers are dependent on natural supplies of juveniles for stocking material (Bardach et al., 1972; Brown, 1977).

Controlled reproduction and hatchery technology. Successful research into the artificial propagation and juvenile rearing of mullets have been carried out in Israel, Taiwan and Hawaii. Results from these locations have clearly demonstrated workable techniques for artificially spawning adult mullet using injections of salmon pituitary hormone (Chen, 1976; Oceanic Institute, 1972, 1974, 1975, 1977). The dosage depends on wet body weight and the internal condition of the female's eggs. Courtship, spawning and fertilization occur naturally with uninjected males (Oceanic Institute, 1972). Despite these successes, the large-scale mass-rearing and, ultimately, the genetic selection of mullet are still not commercial realities. The routine mass-rearing of mullet larvae is receiving major research attention around the world (Chen, 1976; Oceanic Institute, 1977). Private and Federally-funded research at the Oceanic Institute has addressed such key areas as the relation of egg quality to larval mortality, larval foods and nutrition, the effects of temperature, salinity and water quality, as well as container size on growth and mortality rates. In 1976 and 1977, over 10,000 mullet juveniles were produced by the Institute in their research laboratory-hatchery. Most of these fish were given or sold at a nominal fee to four fishpond owners on the Islands of Oahu and Hawaii. Survival rates in excess of 30 percent were observed in some of the experiments (Oceanic Institute, 1977), but the average rate was from five to 10 percent. The pilot-scale rearing of juvenile mullet could be carried out utilizing existing technical information.

Growout technology. Pond culture of mullet, usually in combination with other species, has been practiced in Asia for hundreds of years. Mullet are able to thrive in a wide range of salinities from fresh water to full strength sea water. The most suitable temperature for optimum growth range from 68 to 82°F (20 to 28°C). Mullet can reach a weight of three-fourths of a pound (.34 kg) in 18 months.

Late juveniles and adult mullet feed by sucking up surface layers of muddy bottoms, or by grazing on sea grasses, rocks or other surfaces. The organic material consumed includes single-celled algae (blue-green algae), plant detritus and inorganic sediments which means that mullet can utilize the natural productivity of ponds. Farmers in Asia usually add fertilizer (animal manures) to the pond and, at times, provide a supplemental feed. Current U.S. FDA regulations prohibit using manure for pond feed in the U.S.

Mullet are most often cultured with such other species as grass carp and tilapia. Stocking densities depend on the proportions of other species stocked. For example, in Taiwan, mullet are generally stocked at 400 to 800 per acre (1,000 to 2,000 ha) in polyculture and 1,600 to 4,000 per acre (4,000 to 10,000 ha) in monoculture situations (Chen, 1976). Yields of mullet from such polyculture operations vary for the same reasons. Monoculture of mullet can reportedly produce as much as 2,500 pounds per acre per year (2,220 kg/ha/yr) by relying on natural productivity. By comparison, unmanaged ancient Hawaiian fishponds in 1901 produced 176 pounds per acre per year (157 kg/ha/yr) (Cobb, 1901). In 1977, two commercial ponds which monoculture mullet on a regular basis yielded between 600 and 1,500 pounds per acre (534 and 1,335 kg/ha) (Madden and Paulsen, 1977).

In summary, extensive culture techniques for the earthen pond production of mullet have been used for centuries in Asia and Hawaii, and semi-intensive culture has been practiced in Asia for several years. However, the economic feasibility of pond growout systems remains to be demonstrated under present conditions in Hawaii.

Market: supply and demand. Worldwide, mullet plays an important role in the rural subsistence economies of many developing countries, particularly in Asia and the Pacific Basin. Generally, fish that are farmed in a particular country are distributed to markets within that country, usually within a limited radius of the rearing ponds.

During the 1950's and early 1960's, the annual U.S. production of mullet from catch fisheries was consistently near, or in excess of, 40 million pounds (18,144,000 kg). Production is concentrated in seven southeastern states from North Carolina to Louisiana, with Florida usually accounting for slightly over 80 percent of U.S. landings. Annual production from 1967 to 1971 averaged 32.4 million pounds (14,696,600 kg), valued at $2.6 million a year.

Since the 1950's, the dockside price of mullet has consistently been less than 10 cents per pound ($0.22/kg), a low figure when continuing inflation and an increase in the prices of other seafood products are taken into consideration. Mullet and mullet products are distributed throughout the Southeast and in many Northeastern metropolitan centers with smaller amounts sold in Western markets, mainly in California and Arizona. Approximately 65 percent of the total U.S. production is consumed in the Southeast (Cato et al., 1976).

In Hawaii, mullet have been raised in Hawaiian fishponds for hundreds of years (Cobb, 1901). Today, locally raised mullet make up only a small percentage of the State's total annual mullet consumption. From 1972 to 1976, total consumption increased from 232,000 pounds (105,200 kg) to 248,000 pounds (112,500 kg), while over the same period, the pond-reared contribution decreased from 2,300 pounds (1,040 kg) to 800 pounds (360 kg) and the sea-caught contribution decreased from 18,000 to 10,000 pounds (8,170 to 4,540 kg) (DLNR, 1972 to 1976). These decreases in local supply were compensated by increases in foreign and domestic imports.

Mullet juveniles may also at some future time be sold as a livebait for skipjack tuna (see also baitfish). However, juveniles must be consistently available for this purpose. The export of spawning and hatchery technology for fry production to developing countries would be possible once these techniques are perfected.

Market: product forms and prices. On the Mainland, mullet are sold fresh, frozen, whole (the largest category), and smoked (limited to the State of Florida). Other product forms include canned, fillets, headed and gutted and minced. Mullet roe has become an important export product. During the four months of the year that roe fish are available, it is estimated that about 2 million pounds (904,200 kg) of mullet are frozen and sold. The principal market is Japan, but opportunities for export exist in France and Italy.

Fresh mullet are sold at fresh fish markets or seafood counters in supermarkets. Preliminary calculations suggest that boneless fillets could wholesale for $1.13 per pound ($2.49/kg) and headed and gutted mullet could wholesale for $0.72 per pound ($1.50/kg) on the Mainland. The major problem to marketing mullet is the limited shelf-life due to its tendency to become rancid.

In Hawaii, 95 percent of the mullet consumed are supplied by imports. Mullet from Australia and New Zealand, the major source of foreign imports, are usually chilled and retailed whole for $2.29 per pound ($5.05/kg). Domestic imports, primarily from Florida retail for $0.79 to $0.99 per pound ($1.74 to $2.18/kg) in a frozen, whole form. Mullet cultured in Hawaiian fishponds sell in a fresh, whole form for $1.30 to $3.10 per pound ($2.87 to $6.83/kg), depending on the supply.

Milkfish

Species. The milkfish, *Chanos chanos*, is cultured in brackish and saltwater ponds throughout tropical Asia and the Pacific. Milkfish are able to utilize natural or artificially enhanced (through the use of fertilizers and/or manures) pond productivity, since their primary diet is microscopic plants and crustacea. Since commercial pond culture operations rely on the seasonal availability of natural supplies of fry, there are often shortages of stocking material in various countries (Bardach et al., 1972; Chen, 1976). The routine, artificial spawning of milkfish via hormone injections has not yet been achieved,

Mullet (*ama ama*) and milkfish (*awa*) were the principal species raised by the ancient Hawaiians. Although the local market for these fish is somewhat limited, many Asian countries could benefit from culture technology developed in Hawaii. The culture of *moi* could produce fish for the State's restaurant trade or help stock existing fisheries.

The female mullet spawns only hours after hormonal injection. The male (bottom) will quickly fertilize the eggs. (Courtesy of Oceanic Institute.)

The fast-growing milkfish can reach a market weight of ¾ pound in only 8 months. (Courtesy of Oceanic Institute.)

Moi *have been spawned in suspended net enclosures, but routine success in growout has not yet been achieved.*

though progress towards that goal was recently (1977) made in the Philippines when a few larvae were produced.

Growout technology. Milkfish are commonly reared in ponds. Bottom type and pond depth are two important factors affecting the growth of pond algae -the principal food of juvenile and adult fish. If the pond bottom has a high clay content and considerable nitrogen and organic matter, it will supply nutrients for algal growth. Appropriate algal growth develops most abundantly at a water depth of only four to six inches (10 to 15 cm), which is the depth used for fingerling nursery ponds. Larger fish require pond depths of approximately 12 to 20 inches (30 to 51 cm).

Milkfish ponds are filled gradually to allow for algal growth. Water at a depth of one to two inches (three to five cm) will develop a good mat of blue-green algae in about 15 days. Pond preparation takes some 30 to 50 days, which means that a pond can only be used 10 months a year for growing fish. The growth rate is quite rapid, as fish reach a length of two to three inches (five to seven cm) in one month, five to six inches (12 to 15 cm) in two months, and about 16 inches (400 cm), with a weight of 0.6 to 1.1 pounds (250 to 500 g), when they are eight to 10 months old.

Like mullet, milkfish are often grown in polyculture, hence stocking densities and yields vary considerably from system to system and country to country. Representative stocking densities for the monoculture of milkfish in Indonesia average about 670 pounds per acre (600 kg/ha), or 800 to 4,000 fingerlings per acre (2,000 to 10,000 fingerlings per ha). Fish are usually harvested at a weight of between 0.7 and 1.8 pounds (300 and 800 g). In ponds enriched with dilute sewage, annual yields of 5,618 lbs/acre (5,000 kg/ha) are not uncommon (Bardach et al., 1972). However, average yields vary between 56 and 562 lbs/acre (50 and 500 kg/ha).

In Hawaii, milkfish are polycultured with mullet and other species. The few farmers raising milkfish are dependent on the natural supply of fingerlings for stocking. Production is limited because of the inconsistency in the availability of fingerlings.

Market: supply, demand and prices. Like mullet, milkfish play an important role in the rural subsistence economies of many developing countries. Generally, milkfish are not exported from their country of origin. Three of the world's largest producers of milkfish through extensive, pond aquaculture are the Philippines, Indonesia and Taiwan. In 1973, the Philippines produced nearly 90,000 metric tons from 391,814 acres (158,565 ha) of brackish water ponds. This crop sold for about $0.27 a pound ($0.60/kg) (Brown, 1977).

Milkfish are not found in the Mainland United States. In Hawaii, milkfish have traditionally been cultured along with mullet in ancient Hawaiian fishponds. In 1901, approximately 193,000 pounds (87,500 kg) of milkfish were raised (in polyculture with mullet) in 3,000 acres (1,214 ha) of ponds. Over the period 1960 to 1970, pond-reared milkfish production varied from 7,700 pounds (3,500 kg), valued at $4,200 to 10,470 pounds (4,750 kg) valued at $5,240 (DLNR, 1960 to 1970). A drastic decline in pond production has occurred since 1970, with the lowest figure to date occurring in 1976 494 pounds (224 kg) valued at $265. Over the same period, 1960 to 1970, the marketing of sea-caught milkfish varied from 7,270 pounds (3,300 kg) valued at $1,870 to 16,300 pounds (7,400 kg), valued at $4,900. This decline in pond yields is at least partially blamed on the degradation of the existing pond system by urban and agricultural development (Madden and Paulsen, 1977). Frozen milkfish (*"bangus"*) imported from the Philippines to Hawaii is purchased mainly by the local Filipino population. This fish is usually steamed or fried in a fashion similar to threadfin.

Though no exact figure can be given, it is estimated that the existing market for milkfish in Hawaii is probably less than 50,000 pounds (22,680 kg). Market development activities could probably increase this value slightly if a greater supply were available. There appear to be no opportunities for exporting milkfish at this time, but the transfer of spawning and hatchery technology to developing countries for the production of stocking material is likely once these techniques are perfected. The demand for milkfish in Indonesia alone is 20 million fingerlings annually.

Threadfin (*Moi*)

Species. The threadfin, or *moi* (*Polydactylus sexfilis*), has been a Hawaii favorite as both a food and sport fish. The aquaculture potential of this indigenous species has been investigated in Hawaii since 1973 (May, 1976). Techniques for obtaining *moi* eggs and for the growout of juveniles to market size have been demonstrated on a laboratory scale. However, a considerable research effort will be necessary to develop an adequate mass-rearing hatchery technology.

Controlled reproduction and hatchery technology. Researchers at the Hawaii Institute of Marine Biology demonstrated that mature fish maintained in a suspended net enclosure will spawn spontaneously. Eggs were collected from the net using an airlift pump. Scientists discovered that *moi* spawned with a well-defined lunar rhythm, always in proximity to the last quarter phase of the moon, and that spawning occurred over a six- to seven-month period from April or May to October. Furthermore, the fish spawned at approximately the same time each night. Therefore, an abundance of *moi* eggs for larval rearing could be obtained without hormone injections by maintaining broodstock in a net enclosure.

Initial experiments in rearing *moi* larvae did not prove successful. Among the most serious constraints to routine hatchery rearing was the lack of an adequate knowledge of larval and juvenile nutrition (May, 1976). This problem exists for many economically important marine species around the world.

Growout technology. *Moi* juveniles, obtained from coastal waters around Hawaii, were used to test the growout characteristics of the fish. Growout experiments were conducted in suspended cages. Stocking density was 15 fish per cubic foot (50 fish per cubic meter) of water. Water temperature was about 79°F (26°C).

P. sexfilis requires animal protein (shrimps and other crustacea) in its diet. Fortunately, the fish readily consumes artificially prepared dried feeds, with an excellent conversion of dietary protein into fish flesh. One group of experimental fish grown for 157 days (fed chopped squid and commercial trout pellets) increased from 0.2 pound (8.8 g) to an average of 0.31 pound (142 g). This and other experiments suggest that a marketable fish can be produced in cages from fry in approximately 300 days (May, 1976).

A preliminary analysis of the production economics of culturing *moi* in cages shows that the market price and the cost of labor are the two most significant economic parameters. The stocking rate and growth rate are the most significant biological parameters affecting the profitability of the system (May, 1978 MS).

Potential stock enhancement. A study which examined the feasibility of a commercially-viable natural *moi* stock enhancement program in Hawaii concluded that such a program would be possible if rearing costs of $0.05 or less per juvenile could be achieved (Rao, 1977). However, substantial progress must be made in developing an adequate hatchery technology for *moi*. Techniques for spawning and hatching of *moi* larvae are available, but routine success in rearing larvae to stocking-sized juvenile fish has not been achieved.

Market: supply and demand. Threadfin are found in the waters off Madagascar, Pakistan, India, the Malay archipelago and Johnston Island. Those fish marketed in each region are from capture fisheries, since the aquaculture of threadfin is not practiced in these areas.

Moi has long been a prized eating fish in Hawaii. In 1967, a total of 14,000 pounds (6,350 kg) of fish were sold. Over the period 1972 to 1976, sales declined from 7,000 pounds (3,175 kg) valued at $9,000 to 2,700 pounds (1,225 kg), valued at $4,000. Over the same period wholesale prices increased from $1.29 per pound ($2.84/kg) to $1.93 per pound ($4.25/kg). Unfortunately, no data are available on the numbers of *moi* landed by recreational fisherman although it is thought by some to be greater than the commercial catch. Preliminary estimates indicate a market potential of 120,000 pounds (54,500 kg) annually.

In summary, few places outside of Hawaii are familiar with the threadfin and although the local market is not well-developed, it has reasonable potential.

Market: product form and prices. *Moi* appeals to a broad spectrum of the Hawaii community (Shang, 1977). The fish is usually sold in the fresh, whole form at retail prices that range from $2.00 to $2.50 per pound ($4.41 to $5.51/kg). *Moi* is highly regarded for its fine, white flesh, good texture with few bones, and is found primarily in specialty fresh fish markets, though they occasionally appear in supermarkets. The fish is not carried in restaurants because of the irregular supply. *Moi* is generally considered a substitute for mullet.

Another use for *moi* aquaculture could be the rearing and releasing of juveniles to the natural environment for improvement of the natural fishery (Rao, 1977). A general economic evaluation of a "model" *moi* release program indicates that a commercially viable stock enhancement program is possible if rearing costs could be reduced to $0.05 or less per juvenile, and if one million or more fish could be released annually (Rao, 1977).

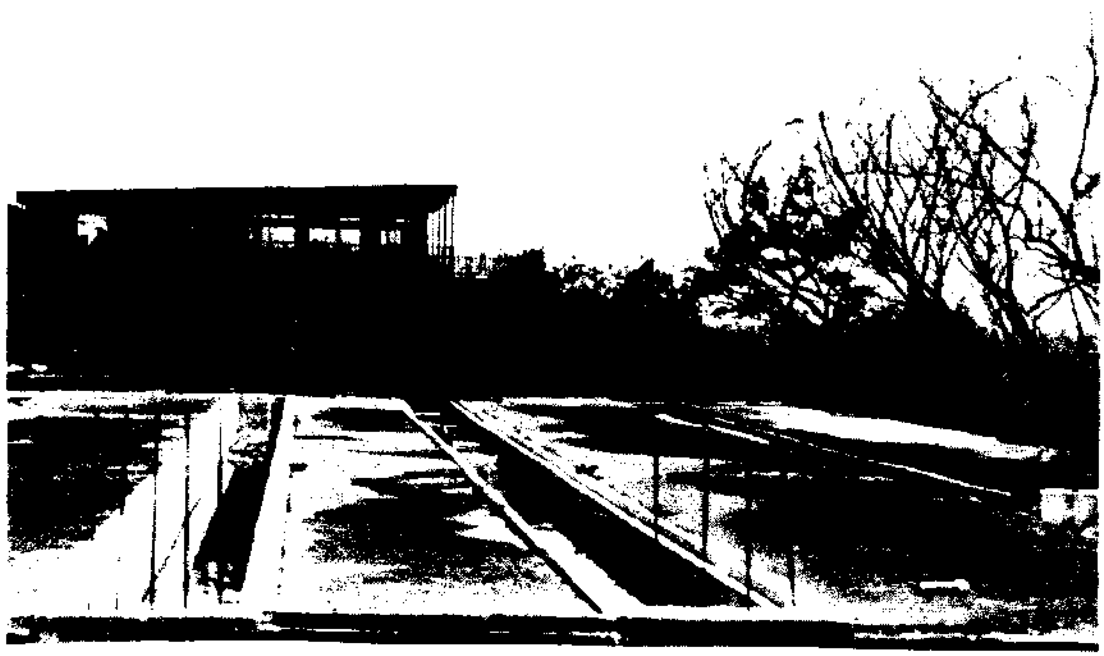
Brine shrimp

Species. Brine shrimp (*Artemia salina*), a species whose life history has been thoroughly studied, are found primarily in the highly saline waters of natural salt lakes and seas around the world (Helfrich, 1973). They are resistant to extremes of temperature (48 to 95°F, or 9 to 35°C) and salinity (5 to 150 ppt) and have a rapid generation time. They can achieve sexual maturity two weeks after hatching, and are able to produce 40 larvae a day throughout their six months to one year life span. *Artemia* are herbivores, feeding on single-celled algae. However, such alternative foods as brewer's yeast or dried algae have been utilized successfully in culture operations. Food conversion efficiencies are high in comparison to other animals, and range between 20 to 80 percent. Values found in the scientific literature for growth rate and conversion efficiency vary due to nutritional differences in the foods used.

Brine shrimp provide a feed for the larvae of numerous organisms, and are in great demand by researchers, commercial aquaculturists and fish hobbyists. Hawaii's brine shrimp farmers are enlarging their facilities for large-scale production.

Island Brine Shrimp Company, Campbell Industrial Park, Oahu. Clearing, sorting and laboratory facilities are on the left.

Astro Marine, Inc., Eleele, Kauai. Brine shrimp are raised under the house in the background. Prawns and tilapia are grown in the trenches. (Courtesy of Astro Marine.)



Larval and adult production. Techniques for the intensive culture of live adult brine shrimp are well-known. Larvae and adults can be reared at extremely high densities, e.g., 2,830 larvae per quart (3,000 per liter) with only a moderate amount of special treatment (Sorgeloos, 1976). Because of their hardiness and relative ease of culture, brine shrimp are reared throughout the world as a food for various species raised by tropical fish hobbyists and experimental and commercial aquaculturists. Hawaii presently has two live brine shrimp producers–one uses ponds, the other uses an intensive tank culture.

Egg production. *Artemia* are one of the few aquatic animals that can produce encysted or resting eggs (eggs with a touch outer covering). These eggs, which allow brine shrimp to withstand environmental extremes of temperature, drought, and salinity, are produced only when the animals are environmentally stressed. Without environmental stress, a more fragile type of egg is produced. *Artemia* encysted eggs can be stored for long periods of time in dry, air-tight containers until they are needed. Methods for hatching eggs in 24 to 48 hours are simple and consist of adding the eggs to seawater and bubbling air into the container.

The precise mechanisms controlling the cyst production of *Artemia* adults are not yet known. Most of the world's commercial supply of encysted eggs presently comes from a few places where they are harvested from wild populations (e.g., Great Salt Lake, Utah; San Francisco Bay; and Saskatchewan, Canada). The quality of *Artemia* in these areas has been seriously affected by urban-industrial pollution. However, supplies of *Artemia* eggs from Australia and South America have recently entered the market. Companies in these areas have seeded naturally-occurring bodies of hypersaline water. More importantly, intensive controlled cyst production has been achieved in several places in the world (e.g., Japan) on a laboratory or pilot-scale. A Hawaii-based consulting firm is attempting to achieve routine *Artemia* cyst production in the natural hypersaline pond systems at Christmas Island.

Market: product forms. World, United States and local brine shrimp markets utilize three product forms: live and freeze dried adults, live nauplii and eggs. All forms are in great demand in both the tropical aquarium fish industry (the majority) and the commercial aquaculture industry (Sorgeloos, 1976). Producers sell live adult brine shrimp at about two weeks old by the cup or quart to pet shops. Retailers, in turn, sell the shrimp to fish hobbyists by the tablespoon. *Artemia* have a red or green pigmentation, and although there are no nutritional differences between the two, commercial outlets have indicated a preference for the red variety (Cohlan, 1977: personal communication). Freeze-dried flakes have been used by aquarium hobbyists, but this product form has not been effective for commercial aquaculture species. It has been suggested that brine shrimp meal could be used as substitute for fish meal in livestock diets (Ralston-Purina Company, 1977: personal communication).

Eggs and live nauplii are utilized extensively in such commercial aquaculture operations as freshwater prawn hatcheries and aquarium fish raising. The eggs are simple to store for several years and require a minimum of time and equipment to hatch into nauplii. Typically, eggs are sold in vacuum-packed gallon tins, though a variety of smaller-sized containers are available. The gallon containers are generally sold wholesale to large users, often through a manufacturer's agent of franchise. Retail outlets prefer smaller sizes of up to one-tenth of an ounce (2.8 g).

Market: supply, demand and prices. It is estimated that the annual U.S. volume of live adults is 0.25 to 1.0 million quarts. At Mainland prices of $6 per cup, the wholesale value of this market is estimated to be $1.5 to $6.0 million (Cohlan, personal communication, 1977). Helfrich (1973) placed the annual world demand for eggs at 40,000 to 50,000 gallons. Furthermore, he has calculated the consumption of brine shrimp eggs–largely by aquarium hobbyists in the U.S., Japan and Europe–at about 14,000 gallons annually. Shortages, together with the reduced quality of eggs (i.e., poor hatchability), have created a large demand for good quality eggs. The price for Grade A eggs has risen from $40 - $50 to $70 or more a gallon in the past year. Recent discoveries of new sources of wild, harvestable brine shrimp eggs and an increase in the number of live adult brine shrimp producers around the world may result in a future reduction in prices.

In Hawaii, only a limited amount of information is available on the brine shrimp market. Egg utilization in 1976 was estimated from personal interviews to be 425 gallons. At $20 to $40 per gallon, the dollar value of the eggs ranges between $8,500 and $17,000. Live, adult brine shrimp retailers estimate sales (largely to hobbyists) at 4,300 cups with a retail value (at $.50 per tablespoon) of $34,500. Approximately 500 pounds (227 kg) of brine shrimp meal, valued at $13,000 ($26 per pound or $57.32/kg), was also sold in Hawaii in 1976. Estimated total sales for all product forms for 1976 was $64,500. It appears that the largest user in Hawaii (about half of the total) is the Prawn Aquaculture Program of the Anuenue Fisheries Research Center.

Indications are that the world, U.S. and Hawaii demand for *Artemia* in the tropical fish industry and the burgeoning aquaculture industry will continue to increase. This demand is particularly strong for eggs and live adults. In Hawaii, it appears that the most important market segment may be aquaculture. Presently, Hawaii has two live adult producers supplying several pet stores. Although there are no egg producers in the Islands, a potential new source is being developed at Christmas Island in the Gilbert-Ellis Islands (Corbin, 1976; Allan Cattell, personal communication, 1978).

Limpet (*Opihi*)

Species. There do not appear to be any operations that are culturing limpets for good or natural stock enhancement. In Hawaii, two of the four species of limpets (Archaeogastropod molluscs) in the State are being considered for commercial aquaculture development. These two species, the blackfoot (*Cellana exarata*) and the yellowfoot (*Cellana sandwicensis*), are not found anywhere else in the world.

Natural ecology. Comprehensive research on the biology and ecology of several endemic limpets (*opihi*) has determined the resource status of wild populations in Hawaii. Further studies suggest that the aquaculture of *opihi* may be biologically and economically feasible (Kay and Magruder, 1977). Both the blackfoot and yellowfoot species are herbivores, that is, they feed on macroalgae which grows on the rocky surfaces of the coastal zone. Furthermore, both species show rapid shell growth in the field, increasing in length from .16 to .20 inch (four to five mm) a month up to a length of about .8 inch (20 mm) when they begin to mature. Growth rates then decrease to about .08 to .12 inch (two to three mm) per month until the shells are at least two inches (50 mm).

Both species appear to be capable of spawning throughout the year, but settlement of spat (young *opihi*) on rocky surfaces is most pronounced during January to June and in November and December. Fertilization occurs externally in the surround seawater, and the larvae settle in two to four days as spat. Animals appear to live no more than one year.

An 8-day old opihi larva grazes on microscopic algae (mag. 200x). The adult shell is beginning to grow from the lip of the protoconch (shell). (Courtesy of Gladys Casambra.)

Although its marketability would most likely be restricted to Hawaii, *opihi* is an excellent source of protein and could replenish severely depleted natural stocks.

A researcher sections juvenile and adult opihi gonads in order to determine the breeding potential at different seasons. This study will enhance the success of artificial breeding techniques.

Aquaculture potential. Many biological characteristics of *opihi* suggest it may have good aquaculture potential. If reared to a marketable size of 1.25 inch (30 mm) shell length, the growing period would be approximately eight to nine months. The animal feeds low on the food chain (on macroalgae), which is the most energy-efficient feeding mode. The larval development period is short and requires little food. Preliminary research at the University of Hawaii is attempting to determine a means of artificially stimulating spawning of the limpets and raising the larvae through metamorphosis from the free swimming stage to settlement (see Appendix D).

Market: supply and demand. The limpets of the family *Patellidae* are distributed in coastal waters around the world, but it appears there is no extensive exploitation of this food resource (Bardach et al., 1972). However, local representatives of the family have been a staple in the diet of the Hawaiian people for hundreds of years. At the turn of the century, annual consumption was estimated at 150,000 pounds (68,040 kg). In recent years, the market for *opihi* (mainly two species *Cellana exarata*, the black-foot, and *Cellana sandwicensis*, the yellowfoot) has averaged 18,000 pounds (8,165 kg). The recent decline in the consumption of *opihi* is attributed to overharvesting of natural stocks, the sole supply (Kay and Magruder, 1977).

The 1976 market value for the 12,830 pounds (5,820 kg) of whole animal sold was approximately $25,000.[14] Preliminary market calculations based on a modest acceptance of *opihi* as an alternative seafood indicate a potential market of 60,000 pounds (27,200 kg) with a wholesale value of $150,000. Because of its rather distinctive taste, a further expansion of the market in Hawaii and elsewhere would require extensive market promotion and product diversification. In short, extensive consumption of limpets (*opihi*) is a local taste phenomenon and development of out-of-State markets appears to have limited potential.

The characteristics of the *opihi* recreational fishery are not well known, although this fishery may equal or be greater than the commercial fishery. Opportunities may exist in Hawaii for natural stock enhancement programs once routine culture methods become available.

Market: product forms and prices. *Opihi* are most frequently eaten, usually raw, by long-time residents of Hawaii. The meat is described as having a strong fishy taste and odor. Asian and Pacific Basin immigrants have been quick to acquire a taste for this product, perhaps because of their familiarity with eating raw seafood. Reactions from Mainland tourists to *opihi* have generally been unfavorable.

The traditional product form for *opihi* is fresh, in-shell, and raw. It is most often served in homes as an appetizer or side dish. Other forms are frozen, slated or shucked in quart- or gallon-sized containers–the most popular form for luaus and wedding receptions. The frozen form is popular with caterers because the product can be stored for up to a year without affecting quality. Caterers usually provide servings of approximately one-fourth ounce (7 g), or three to eight *opihi* meats, depending on the size of the animal. *Opihi* meat can also be served broiled, in soups or pickled, often in combination with seaweed.

---

[14] This total does not include the volume supplied by the recreational fishery.

Opihi are sold in supermarkets in packages of about a pound (0.4536 kg). Caterers purchase shucked *opihi* by the gallon (3.8. l) and use them only when they are specifically requested because of their cost.

Over the period 1972 to 1976, the wholesale value for in-shell *opihi* rose from $1.03 to $1.95 per pound ($2.27 to $4.30/kg) (DLNR, 1972 to 1976), largely due to a decrease in supply. In recent years, *opihi* has sold at a retail price of $2.50 to $3.00 per pound ($5.51 to $6.61/kg) in-shell.

Major Constraints and Recommended Actions

Culture. All marine species in this section have major constraints to commercial development. The expansion of mullet and milkfish farming in Hawaii has been limited, in part, by a lack of adequate supplies of juveniles for stocking commercial ponds. Generally, farmers are dependent on the natural supply of juveniles. In recent years, mullet fingerlings have been available only periodically from the research work at the Oceanic Institute, but the Institute has now developed a laboratory-scale hatchery technology for mullet juvenile production. Research into the controlled production of milkfish juveniles is under way at O.I. under Federal funding, and numerous technical problems need to be solved.

Research conducted at the UH Hawaii Institute of Marine Biology has demonstrated that the threadfin or *moi* can be easily spawned in suspended net enclosures. However, several technical problems need to be solved in order to achieve routine larval rearing with high survival. Although much information has been collected concerning the biology and ecology of Hawaii's economically important limpets (*opihi*), there is little information that describes the spawning and growth performance of *opihi* under controlled culture conditions. Controlled reproduction and the nutrition of juveniles appear to be the major obstacles to culture. The major constraint to fulfilling local and world demand for brine shrimp is the development of controlled egg production. Around the world, research teams are addressing this problem, and new wild sources of harvestable eggs are being developed in various countries, e.g., Argentina and Australia.

State matching funds for the construction of a pilot-scale finfish hatchery at the Oceanic Institute were recently released. Initially, this facility will perfect mullet hatchery technology and, in the process, provide mullet juveniles for commercial farmers and for testing as a tuna baitfish. Future applications for the portion of the facility under State jurisdiction include investigations of the biotechnical problems (reproduction and larval rearing) which are precluding culture of the milkfish, *moi* and *opihi*. The development of hatchery technologies for these species could lead to commercial aquaculture and/or natural stock enhancement programs. Interdisciplinary approaches and cooperative programs are essential for these efforts. The possibility of future support will depend on the resources available. Decisions to commit funds to the solution of these problems should be based on a cost/benefit analysis. The cost is about the same for developing a species with a $50,000 annual market as for a species with a $50 million market. However, the benefits from natural stock enhancement should not be overlooked.

In the case of *Artemia*, the State should monitor research developments for egg production and when a viable technology is perfected, encourage private interests to transfer the technology to Hawaii. In addition, encouragement should be given to those entrepreneurs who are raising live adults and nauplii.

Market. Mullet, milkfish, *moi* and *opihi* appear to have little potential for developing export markets. However, these species have local markets, which are presently supplied either by frozen imports or local capture fisheries. Brine shrimp have little potential for export, except in the form of eggs, which when vacuum-packaged, have a continually growing worldwide demand.

It is important to demonstrate the economic feasibility of the semi-intensive pond or cage culture of mullet, milkfish, and *moi* in Hawaii. Culture systems for *opihi*—yet to be designed must prove to be economically sound.

Economic Projections

The economic projections found in Table 18 represent the combined production, employment and revenues from the culture of mullet, threadfin (*moi*), limpet (*opihi*), milkfish and brine shrimp. Each of these species is affected by significant market and/or technological constraints. For example, *moi*, mullet, *opihi* and milkfish are all local favorites which appear to have no export potential at this time. Live adult brine shrimp also appear to be limited to a local market. There also appear to be major technological constraints to the culture and reproduction of brine shrimp eggs and *moi*, *opihi* and mullet juveniles. For these reasons, a conservative assumption would be that production of these species will be limited to the amount which can be locally consumed. The relatively low commercial growth rates reflected in the table assume the solution of technological problems prior to commercialization, followed by gradual expansion of the local market.

Table 18. Projected Production, Employment and Revenues from the Culture of Marine Finfish and Miscellaneous Marine Species in Hawaii 1978 to 2000

Year	Production		Employment			Wholesale
	Yield (1000 lbs)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	Revenues (1000s of 1978 $)[5]
1978[6]	20	7	1	2	3	$ 40
1980	40	14	2	4	6	80
1985	100	34	4	7	11	200
1990	400	134	14	24	38	800
1995	700	234	24	41	65	1,400
2000	1,000	334	34	58	92	2,000

Assumptions:

[1] Includes mullet, *moi*, *opihi*, milkfish and brine shrimp. Production levels limited by local market and technology. Average yields estimated at 3,000 pounds/acre/year.

[2] Represents surface acreage of impounded water. Farm size will be considerably larger.

[3] Approximately 1 direct job per 10 acres.

[4] Approximately 1.7 indirect jobs per direct job.

[5] Wholesale values range from $1.00 to more than $10.00 per pound. Average price of $2.00/pound used.

[6] Mullet, milkfish and brine shrimp produced. *Opihi* being studied for culture.

State-of-the-art for Culture

Species. There are 318 recognized species of penaeid shrimp throughout the world, of which approximately 80 species are either being exploited by the capture fishing industry or by aquaculture (Motoh, 1977). At least five economically important species give preliminary indications of being suitable for aquaculture in Hawaii. These species are the Japanese tiger prawn (*Penaeus japonicus*), the white shrimp (*P. vannamei*), the blue shrimp (*P. stylirostris*), the giant tiger prawn (*P. monodon*), and another blue shrimp (*P. schmitti*). None of the species listed above occurs naturally in Hawaiian waters. The single indigenous Hawaiian species, *P. marginatus*, does not appear amenable to culture. This conclusion is based on intensive culture studies from 1970 to 1975 at the Hawaii Institute of Marine Biology (Corbin, 1976).

Controlled reproduction. Closing the life cycles of economically important shrimp species has been achieved on a laboratory scale in many instances, but not on a practical commercial scale (Hanson and Goodwin, 1977). Predictable supplies of stocking material are essential to commercial aquaculture ventures, particularly in Hawaii where natural stocks of the five species listed above do not exist. Presently, gravid female shrimp (shrimp with eggs) are obtained from the wild using fishing boats. This arrangement is extremely costly, although it can be the basis for a commercially viable aquaculture operation if culture operations are located near supplies of wild shrimp.

World research efforts to mature, mate and spawn shrimp in captivity take two basic approaches: (1) biochemical manipulation of the female shrimp in the laboratory, and (2) nutritional and environmental manipulation of females in large tanks or ponds (Neal, 1976). A third method, eye ablation, or pinching off of one or both eye stalks to induce maturation, is generally considered a less viable technique although refinement of ablation procedures continues and some feel it may have certain application in a commercial operation (Hanson and Goodwin, 1977). Male shrimp mature in captivity with greater frequency than female shrimp, and there has usually been no problem in achieving mating.

Environmental and nutritional requirements necessary to induce spawning vary from species to species. The species under consideration generally perform best in brackish to full strength seawater at temperatures of 77° to 82°F (25° to 28°C). All penaeid shrimp are highly fecund animals, that is, they spawn a large quantity of eggs. Depending on the species, age and size of the female, anywhere from 30,000 to one million eggs may be produced at one time. Hatching success of 80 to 90 percent has been obtained regularly with some species.

Hatchery technology. Penaeid shrimp grow through several life stages before they become post-larvae or juveniles, capable of being stocked in ponds. The time for various species to develop into post-larvae generally varies between nine and 30 days. Each stage of early development may require a specific size and type of food.

Two basic hatchery systems (variously modified) are utilized extensively in marine shrimp research and culture today: (1) the "Japanese" or "Fujinaga" system, which was developed for culturing the *kuruma* prawn, *Penaeus japonicus*, and (2) the "Galveston" system, which was originally developed for culturing native Gulf of Mexico species. Biotechnically, both systems have proven reliable with survival rates of 50 to 70 percent being routinely achieved. The feeding regimes employed include pure culture of diatoms, live and frozen rotifers and *Artemia*. Densities at the end of the rearing period may be as high as 125 larvae per gallon (33 larvae/liter). Adequate aeration and food concentration are extremely important at these densities.

Growout technology. Marine shrimp have been commercially cultured extensively with limited management in Southeast Asian fish ponds for thousands of years (Bardach et al., 1972). Stocking material has been obtained from the natural environment, and yields of 340 to 900 pounds per acre (300 to 800 kg/ha) have been reported.

Modern day semi-intensive shrimp culture utilizes a combination of nursery and growout ponds. Nursery ponds are generally less than an acre (0.4 ha) and stocking densities vary widely from operation to operation. Post-larvae feed on the natural productivity of the pond, as well as supplemental rations. Formulated pelleted feeds are favored by operations in Central America, while Japanese companies favor minced clams and trash fish. Generally, post-larvae are reared for one month to about 1 to 3 gram juveniles before they are transferred to larger growout ponds.

Semi-intensive growout ponds range in size from one to 20 acres (0.4 to 8.1 hectares) and from one to three feet (0.3 to 0.9 meter) in depth. Ambient temperatures of between 79° and 86°F (26° and 30°C) are favorable for growth for most penaeids. Some operations attempt to optimize natural pond productivity through fertilization of the pond with commercial plant fertilizers. Supplemental feeding of pelleted rations (20 to 50 percent crude protein) is usually carried out. In Japan, *P. japonicus* is fed minced clams and trash fish–an economically feasible procedure because of the high market prices for the product. Survival is commonly between 50 and 75 percent in effective pond culture operations (Hanson and Goodwin, 1977). Annual yields of between 2,000 to 4,000 pounds per acre (1,780 to 3,560 kg/ha) have been obtained in some Central American operations, such as those in Costa Rica and Panama (Hanson and Goodwin, 1977). Certain Japanese companies have reportedly achieved annual yields of between 5,000 to 7,000 pounds per acre (4,450 to 6,230 kg/ha) with *P. japonicus*.

Intensive shrimp culture techniques using raceways and tanks are being developed at various research locations in Japan, the U.S., and Tahiti. The purpose of these techniques is to achieve economy of production by rearing a greater quantity of better quality animals in less time and space (Hanson and Goodwin, 1977). Optimum production of 40,000 to 60,000 pounds of whole animals per surface acre per year (35,600 to 53,400 kg/ha/yr) are envisioned for the experimental raceways being developed by the University of Arizona.

Market Characteristics and Opportunities

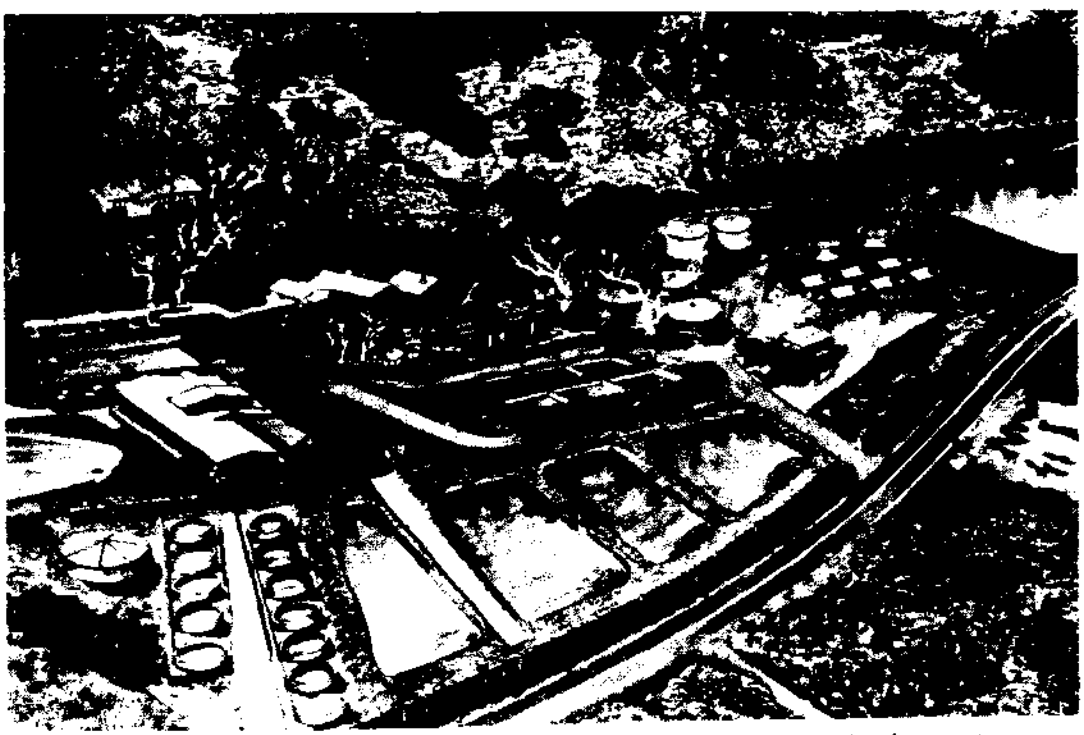
Supply and demand. Worldwide, over 2.7 billion pounds (1,224,720 mt) of shrimp (live weight) were caught and consumed in 1975 (*Living Marine Resources*, 1977). Together, the United States and Japan accounted for 70 percent of the total consumption with India, Thailand, Pakistan and Mexico representing the other major consumers. The world's largest shrimp producing country is India, followed by the United States, Thailand, Mexico, Japan and Indonesia.

The total U.S. shrimp supply, including imports, increased to 514.6 million pounds (233,423 mt) (heads off) in 1976, with steadily rising wholesale prices indicating a continued high demand (U.S. Department of Commerce, 1977). Approximately 60 to 70 percent of U.S. consumption is imported. In 1976, the U.S. imported 80.4 million pounds (36,470 mt) (fresh weight) from Mexico, 41.6 million pounds (18,870 mt)

Now being tested: Panaeus japonicus.

New shrimp hatchery at the Oceanic Institute.

Marine shrimp culture represents a major economic opportunity for Hawaii because of an abundance of seawater, the availability of sites, and a tremendous worldwide market. Before marine shrimp can be commercially cultured, the most suitable species for Hawaii must be selected, and reproduction in captivity must be achieved.



Marine shrimp facilities in this drawing of the Oceanic Institute include four growout ponds and two rows of tanks in the foreground. (Courtesy of Oceanic Institute.)

from India and 11.6 million pounds (5.262 mt) from Panama. The U.S. exports fresh and frozen shrimp to Canada. Mexico, Japan and Sweden. Much of the shrimp sent to Mexico is processed and returned.

Hawaii's consumption of shrimp in 1976 was estimated at 2.4 million pounds (1,089 mt), nearly all of which was imported from either foreign or domestic sources. Foreign sources, in addition to Mexico, who have captured the largest share of the market include Australia, New Zealand, Taiwan and the Philippines. Foreign imports have recently declined to approximately one-third of the total Hawaii consumption. This shift has been attributed to competition from more profitable markets.

Product forms. Fresh and frozen shrimp account for approximately 91 percent of the total amount of shrimp processed in the United States. These are sold in whole, headless, peeled, raw, cooked, breaded, and specialty forms. Peeled-raw and peeled-deveined, which require a minimum of processing, are most widely sold and would probably be the forms produced by aquaculture operations. Canned shrimp account for the remaining nine percent of processed production (U.S. Department of Commerce, 1976).

Much of the popularity of shrimp can be attributed to the wide variety of forms and sizes which offer consumers a certain amount of flexibility in planning meals. Larger shrimp tails (numbering 15 and under to the pound or 33 to the kilogram) are generally used as an entrée item. Medium-sized tails (numbering 15 to 30 to the pound or 33 to 66 to the kilogram) are used in main dishes, and the small shrimp (numbering 30 to 50 or more to the pound or 66 to 110 or more to the kilogram) are widely used in cocktails, soups, creoles and in canning.

Prices. Prices for marine shrimp are related to the size of the animal and the degree of processing. The larger the shrimp, the higher the price, and the more processing required, the greater the value. Prices for shrimp of all forms have increased in recent years. For example, Chicago prices for 26 to 30 count per pound (57 to 66/kg) shrimp, heads on, increased from \$1.89 to \$3.69 per pound (\$4.17 to \$8.13/kg) over the period 1972 to 1976. In June, 1977, representative Mainland prices for under 15 count (33/kg), shell on, headless were between \$5.70 and \$5.80 per pound (\$12.57 and \$12.79/kg), and for 26 to 30 count (57 to 66/kg), \$4.50 to \$4.75 per pound (\$9.92 to \$10.47/kg). Cocktail shrimp, 70 to 80 count (154 to 176 kg) were between \$2.00 and \$2.50 per pound (\$4.41 and \$5.51/kg).

In Hawaii, shrimp prices are generally \$0.18 to \$0.20 per pound (\$0.40 to \$0.44/kg) higher than on the Mainland due to handling, holding and transportation costs. Under 15 count (33/kg) shell on, headless shrimp were approximately \$5.33 per pound (\$11.75/kg) in 1977, and 26 to 30 count (57 to 66/kg) shrimp of the same type were approximately \$4.28 per pound (\$9.44/kg).

Processing and distribution. A sophisticated marine shrimp distribution and marketing system has developed from the continuous supply produced by capture fisheries, and the inception of freezing techniques which give wholesalers and retailers the ability to maintain large inventories. Frozen shrimp can be purchased in a variety of package sizes, ranging from one to 10 pounds (0.5 to 4.5/kg), depending on the type of processing. Both fresh and frozen shrimp are graded on the basis of flavor, odor, deterioration, uniformity in size, texture and freedom from defects. U.S. grades "A" to "C" and "substandard" are used.

Fresh and frozen shrimp are sold to both institutions and commercial retail outlets. Inasmuch as fresh shrimp have a short shelf-life, essentially all shrimp are frozen, or previously frozen and thawed. Institutions, consisting mainly of restaurants, drive-ins, hotels, and military commissaries, purchase approximately 80 percent of the supply. Retail stores and supermarkets account for the remaining 20 percent.

Shrimp appeals to a broad spectrum of consumers, suggesting further expansion of the market could occur with sufficient promotion.

Market factors. The following market factors play an important role in encouraging the culture of marine shrimp: (1) the large size of the existing market, (2) the large Mainland and Hawaii dependence on imports, (3) the current high prices commanded by marine shrimp products, (4) the expanding markets for marine shrimp in Japan and Europe, and (5) potential decreases in the supply from capture fisheries due to overfishing, pollution of nearshore spawning grounds and/or the enactment of the 200-mile economic zones which would limit fishing by highly efficient foreign vessels.

Major Constraints and Recommended Actions

Culture. Because Hawaii does not have indigenous stocks of species suitable for culture, candidate species will have to be imported. Due to the biological and technical problems and the time and distances involved in transporting gravid females or stocking material to Hawaii, it is most likely that the local commercialization of marine shrimp will be based on the routine maturation, mating and spawning of shrimp in Hawaii.

Routine reproduction has not been achieved on a commercial scale anywhere in the world to date, but the achievement of controlled reproduction of penaeid shrimp is one of the highest priority research areas in aquaculture today and a major breakthrough appears imminent. Hawaii's research and commercial sectors must keep informed of publicly-sponsored research efforts to insure the early transfer of results.

It is important to select the species which grow best under Hawaii conditions. There are five prime candidate species of penaeid shrimp (mentioned earlier) that should be evaluated in pond growout tests. Once the best animal(s) is selected, research to mature, mate and spawn the shrimp should be undertaken. Currently, two approaches to controlling reproduction appear most promising: biochemical control and environmental manipulation. A full-scale demonstration of the economic feasibility of shrimp farming in Hawaii can be conducted after the appropriate species are selected and stocking material becomes available through controlled reproduction.

Work on penaeid shrimp culture is currently under way at the Oceanic Institute. Initial efforts are focused on preliminary, bioeconomic growout performance evaluations of *P. japonicus*, *P. vannamei*, *P. stylirostris* and *P. monodon* to determine which species perform best under Hawaii conditions. This will be followed by attempts to achieve routine reproduction using both the previously described biochemical and environmental approaches. This developmental research is jointly sponsored by the State of Hawaii, Oceanic Institute, Office of Sea Grant and private sources (see Appendix D).

Market. Once marine shrimp farming becomes a reality in Hawaii, the substitution of locally grown animals for imports can be anticipated. Key factors affecting this development will be the competitive prices of foreign and domestic wild-caught and aquacultured shrimp, and the production costs of the local product. It is generally assumed that the adoption of 200-mile fishing zones by many nations of the world will cause a reduction of supply and an increase in prices for capture fisheries products. This would place aquacultured shrimp in a more competitive sales position. It is further anticipated that increases in the world production of aquacultured shrimp will come from developing countries or countries with non-restrictive environmental regulations and inexpensive labor because such a situation contributes to low-cost shrimp production. Locally grown shrimp can substitute for foreign and domestic imports, if State research and development activities reduce production costs to appropriate levels.

Furthermore, if Hawaii-grown shrimp enter the foreign and domestic export markets, special institutional considerations, such as tax breaks, as well as innovative business strategies may be needed. These may take the form of the vertical integration of production, or special back-haul rates for ships and planes returning to another State or country only partially full. The State should support and encourage the development of such strategies.

Economic Projections

As previously mentioned, marine shrimp face several biotechnical constraints which must be solved before commercial culture can become a reality in Hawaii. As such, the projections indicated in Table 19 below assume no production over the next five to seven years beyond currently envisioned pilot demonstration tests. It is assumed that the reproduction problem will be solved within the next three years and the practical, large-scale rearing of larvae from animals reared in captivity will be achieved within five years. Since various culture systems are widely practiced throughout the world, it is further assumed that any technology adaptation for Hawaii conditions would proceed rapidly during this initial five-year period. Thereafter, rapid commercial expansion is anticipated.

Table 19. Projected Production, Employment and Revenues from the Culture Marine Shrimp in Hawaii: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	–	–	–	–	–	–
1980[7]	8	2.5	1	2	3	$ 26
1985[8]	35	10.0	1	2	3	114
1990[9]	875	250.0	25	63	88	2,844
1995[10]	4,375	1,250.0	125	313	438	14,219
2000[11]	21,875	6,250.0	625	1,563	2,188	71,094

Assumptions:

[1] Production yields estimated at 3,500 pound/acre/year.
[2] Represents surface acres of impounded water. Farm size is considerably larger.
[3] Approximately one direct job per 10 acres.
[4] Approximately 1.7 indirect jobs per direct jobs until processing begins in 1990. Thereafter, 2.5 indirect jobs per direct job.
[5] Wholesale price $3.25 per pound, whole weight.
[6] Performance evaluation program begins.
[7] Development program begins with first commercial demonstration.
[8] Track record established. Expansion proceeds.
[9] Processing and export begins.

State-of-the-art for Culture

Species. A number of bivalve mollusc species (oysters and clams) are presently grown throughout the world using both extensive and intensive systems. Among the most frequently cultured oysters are the flat oyster (*Ostrea edulis*), the Pacific oyster (*Crassostrea gigas*) and the American oyster (*C. virginica*). At the present time, most of the economically important clam species are harvested from natural stocks. However, several types have been cultured, principally the *asari* (*Tapes japonica*) and the quahog or hard clam (*Mercenaria mercenaria*).

Those cultured bivalve species generally inhabit coastal or brackish water environments. After spending a few days to a few weeks in a free swimming larval stage, young oysters attach themselves to hard substrates, while clams bury themselves in sand or mud bottoms. Both oysters and clams are filter feeders; that is, they remove particulate organic matter and microscopic algae from the surround water by an internal filtering apparatus. This mode of feeding can cause shellfish to concentrate pathogens and toxic substances if they are present in the water or food material. Spawning times for both groups show a high degree of dependence on water temperatures, with spawning initiated when water temperatures warm to a certain level. Oysters, under natural environmental conditions, may take several years to attain market size. However, this time may be reduced to one year if temperatures and feeding conditions are optimal (Bardach et al., 1972).

Hatchery technology. Controlled spawning and hatchery methods for the production of seed oysters and clams are well established. Government and commercial oyster and clam hatcheries utilize similar techniques (Bardach et al., 1972). In the case of oysters, broodstock (e.g., *C. virginica*) are maintained in the hatchery at 50°F (10°C) until they are needed for spawning. In order to condition the broodstock for spawning, the temperature of the adults, paired in glass trays, is slowly raised to 64°F (18°C) or more for a period of two to four weeks. The temperature is then raised to 77°F (25°C) to initiate spawning. These techniques allow controlled year-round production of oyster and clam seed.

Newly hatched larvae are transferred to rearing tanks. Oyster larvae are fed microscopic algae (phytoplankton). Some hatcheries prefer feeding pure algal cultures (one species), while others prefer separating out the naturally-occurring algae in seawater by centrifugation. Both oyster and clam larvae become bottom-living juveniles after about 10 to 15 days, depending on species and water temperature. Some hatcheries provide culch–material consisting of adult oyster shells, rocks, etc.- on which the oyster larvae can settle. Recently, however, "culchless" or "free" spat (settled oysters) have been produced by providing screens or sheets of metal for more economic transporting and handling (Bardach et al., 1972). Several commercial hatcheries on the Mainland can now provide seed stock on demand to various locations around the world.

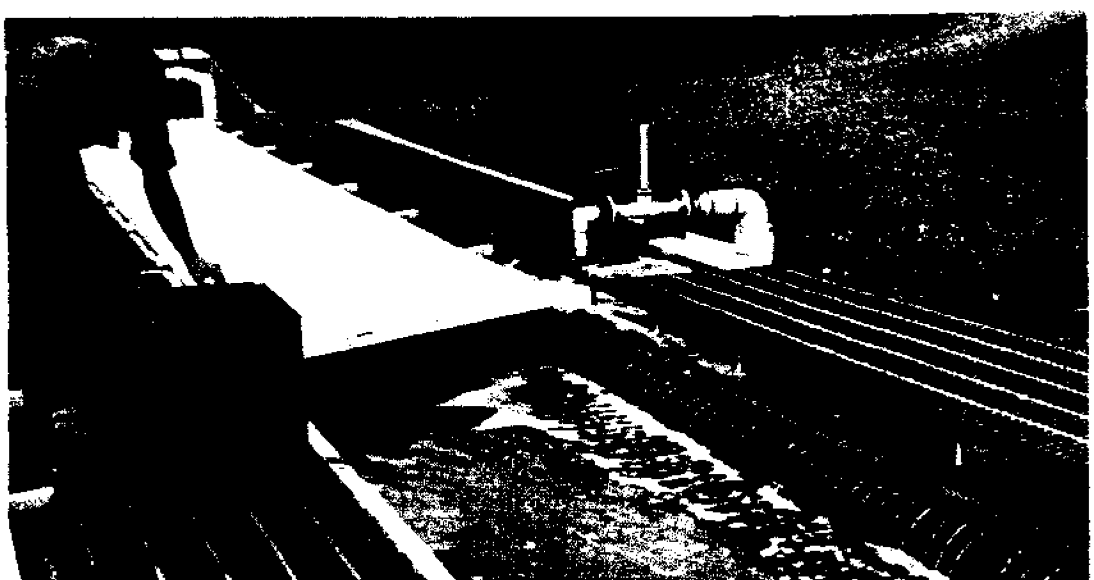
Growout technology. Growout techniques for oysters and clams range from seeding natural beds in coastal waters to intensive land-based systems. Seeding natural oyster beds in coastal waters is practiced extensively in Japan. The seed comes either from hatcheries (as described above) or is collected from coastal habitats where natural reproduction occurs, thereby thinning the natural population and increasing survival. Seed oysters are cultured to market size in Japan using "off-bottom" culture techniques which suspend many animals from rafts and/or lines (Bardach et al., 1972). Yields from

The first commercial demonstration of intensive land-based oyster farming is taking place in Hawaii, and experiments are under way to determine the most suitable clam species for culture in the State. There are significant export opportunities for both oysters and clams if production costs are not prohibitive.

Hawaii's oysters: only nine months from seed to market.

Oysters at Kahuku Seafood Plantation, Kahuku, Oahu, are grown in stacked trays in long raceways. (Courtesy of Kahuku Seafood Plantation.)

Inspecting oysters at Aquatic Farms, Ltd., Hakipuu, Oahu. Phytoplankton feedstock enters the flume from the distribution pipe (left). (Courtesy of Aquatic Farms, Ltd.)



this raft and long-line culture can be as high as 29,200 lbs/acre/yr (26,000 kg/ha/yr) of shelled meat.

In the Mainland United States, oyster seed (attached to a substrate) is distributed onto beds in coastal waters. Typical yields from this "on-bottom" culture technique are between 10 to 110 lbs/acre/yr (10 to 100 kg/ha/yr) of shelled meat with no active management and 5,620 lbs/acre/yr (5,000 kg/ha/yr) of shelled meat with management, i.e., thinning, predator control, etc.

Private interests in Hawaii are attempting to demonstrate the economic feasibility of the technology-intensive, land-based culture of oysters and clams. This system, practiced by the Kahuku Seafood Plantation and Aquatic Farms, Ltd., is based on the sluice or raceway culture of oysters in trays supported by the production of food algae in ponds. Under Hawaii conditions, market size can be attained in seven to nine months. Preliminary calculations for an intensive system similar to the ones undergoing demonstration in Hawaii indicate that 21,650 pounds (9,820 kg) of oyster meat could be harvested per algal production acre per year.

Clam seed is collected from densely concentrated natural sand or mud bottom beds, or produced by hatcheries. The culture of clams in trays is being carried out in various places around the U.S. (including Hawaii) but the principal method of clam culture is still "on-bottom."

Market Characteristics and Opportunities

Supply and demand. There is an established market for oyster products on a world, national and local basis. In 1975, worldwide oyster consumption was 770,000 metric tons round weight. The United States consumed about 60 percent of this figure or about 454,000 metric tons (Glude, 1976).[15] Annual local consumption in Hawaii for the years 1972–1975 ranged between 500,000 and 550,000 pounds (226,800 and 249,480 kg). In 1976, consumption dropped by 21 percent to 435,000 pounds (197,300 kg), all of which was imported [foreign imports were 294,600 pounds (133,630 kg), and domestic imports were 140,000 pounds (63,500 kg)].

The demand for oysters in the United States has stabilized despite increases in the population. Expanding the market for oysters will require improvements in product forms, year-round availability, quality control, and market development activities primarily by the industry itself (Glude, 1976).

World and Mainland supplies of clams are generally dependent on harvesting natural stocks. World production is dominated by Japan and the United States, which combined to account for 80 percent of the total world clam landings in 1972. Japanese production fluctuated between 673 million and 582 million pounds (305,273 and 263,995 mt), round weight, between the years 1965 and 1972. U.S. clam production, however, ranged between 80 million and 125 million pounds (36,290 and 56,700 mt) from 1969 to 1974 (USDOC, 1975).

Japan and the U.S. are also the major world consumers of clams. In 1972, Japanese consumption reached 568 million pounds (257,645 mt) while the U.S. total was 503

[15] 317,800 tons resulted from domestic production, and 136,200 tons was imported.

million pounds (228,160 mt). U.S. per capita clam consumption ranks third in the world at 2.41 pounds per person per year (1.09 kg/person/yr), behind Japan [5.36 pounds (2.43 kg)] and Malaysia [6.01 pounds (2.73 kg)].

The outlook for Mainland domestic landings of clams suggests substantial export markets may exist. Landings of several economically important species have declined recently due to natural and man-made stresses on nearshore clam habitats. Furthermore, if a large Hawaii supply of clams could be available on a year-round basis, a local processing plant may be needed. Such activities would not only provide employment, but reduce the possibility of saturating the local market.

Product forms and distribution. Oysters are sold in fresh, frozen and processed forms. Fresh and frozen oyster products, which make up the largest portion of sales, can be found raw in the shell, shucked and placed on the half-shell, and frozen. Processing is generally for the steamed, canned or shucked, breaded and frozen forms. Substantial numbers of oysters are used in soups, chowders and stews.

The largest segment (about 70 percent) of the Hawaii oyster market is the restaurant trade (Faison, 1977 MS). The most popular form sold is fresh oysters on the half-shell for appetizers. Frozen breaded forms are usually deep-fried and served as an entrée item. Home consumers, who account for about 30 percent of local sales, prefer the fresh in-shell and shucked forms. Approximately 40 percent of Oahu's population consumes oysters annually (Faison, 1977 MS).

Clams are available to the consumer in a wide variety of forms. Fresh or frozen forms may be sold in-shell or shucked. Frozen forms may also be sold as specialty items--breaded, raw or cooked, strips, stuffed, deviled or in cakes, patties, burgers, croquettes or sticks. Clams may also be processed into cocktails, chowders, and juices, and are also available as animal food, and used as bait. The most popular type for processing are surf clams. Hard and soft shell clams are most often sold in-shell.

U.S. frozen clam meat production in 1974 was over 8,500,000 pounds (3,855,600 kg). Institutions are the largest consumers of frozen products, consuming 82 percent of the total frozen poundage, and handling 81.4 percent of the total retail dollar value, or $21 million in 1975 (*Quick Frozen Foods*, 1976).

Price. The majority of domestic imports are shipped into Hawaii from the East Coast, although the amount coming from the Pacific Northwest is steadily increasing. Wholesale prices in Hawaii for fresh, imported, in-shell oysters range between $0.12 to $0.30 a piece including transportation costs. Retail prices range from $0.17 to $0.39 a piece. The commercial oyster producers in Hawaii recently began marketing their product. Their fresh, in-shell oysters were sold wholesale for between $0.10 and $0.20 each, and retailed in supermarkets for $0.25 to $0.50 each. Preliminary calculations suggest that export markets, e.g., the Mainland U.S., could be opened if production costs could be reduced to approximately $0.05 per oyster.

Total canned clam production has declined from 3.58 million standard cases in 1973 to 2.8 million cases in 1976. This may be attributed to a decline in clam landings for 1976–particularly landings of surf clams. In 1976, canned clams represented a $46.4 million industry of which whole and minced clams comprised 57.1 percent, and the specialties category comprised 12.1 percent.

All clams consumed in Hawaii are presently imported (40 percent from the Mainland U.S. and 60 percent from foreign sources). Domestic imports are mainly in the fresh, in-shell or fresh/frozen in-shell forms, while the foreign trade is primarily in the processed form. The average price of all forms of clams has dropped from $0.50 per pound ($1.10/kg) in 1974 to $0.36 per pound ($0.79/kg) in 1976. This may reflect a shifting in consumer demand from fresh, in-shell clams to processed clams, rather than an overall decrease in prices.

Fresh clams in Hawaii are priced at $1.50 to $2.00 per pound ($3.31 to $4.41/kg). Restaurants and supermarkets presently prefer processed forms which can be kept in inventory longer. An evaluation of price data indicates Mainland marketing of fresh or frozen in-shell clams could be carried out by Hawaii entrepreneurs if wholesale prices were approximately $0.75 a pound ($1.65/kg).

Major Constraints and Recommended Actions

Culture. Coastal areas where more conventional forms of oyster and clam culture could be practiced are not abundant in Hawaii, and those areas that do exist are subject to urban/industrial and agricultural pollution. Opportunities for oyster and clam culture are, therefore, limited to a land-based technology-intensive system. However, the high technology involved in this system, as practiced in Hawaii, makes each grow-out operation a high risk venture. The financing of such operations will be difficult, until the reliability of the technology and the economic feasibility of the techniques are demonstrated. The State can assist producers by supporting research designed to help reduce production costs.

Market. Once the economic feasibility of intensive oyster and clam culture has been proven, cost reduction research, e.g., reducing handling costs through mechanization should proceed. State assisted market promotion activities should coincide with increasing supplies of these shellfish to the local market. As cost reduction research reduces production costs, export markets could be developed with State assistance.

Economic Projections

The following projections of production, employment and revenues for the culture of oysters (Table 20) and clams (Table 21) are based, to a great extent, on announced plans of two private Hawaii firms. Achievement of these production estimates is predicated on the successful economic demonstration of culture in Hawaii as well as success in reducing production costs to a point which permits successful entry into the Mainland market by 1990.

E. Marketing

A high and steadily increasing demand for seafood in Hawaii and the Mainland United States, coupled with the local fisheries' limited tonnage, indicates a strong market potential for the State's cultured aquatic products. A substantial volume of seafood is currently imported into the State and the nation. Market development programs are needed to encourage the substitution of locally grown products for imports, and help create markets for new species cultured in Hawaii.

This section summarizes various considerations relating to marketing Hawaii's aquaculture production in order to determine market potential. These considerations are: seafood consumption in Hawaii, the potential for exporting local products, the

Table 20. Projected Production, Employment and Revenues from the Culture of Oysters in Hawaii: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	100	4	6	10	16	$ 120
1980[7]	500	10	15	26	41	600
1985[8]	2,000	40	60	102	162	2,400
1990[9]	3,000	60	90	270	360	3,600
1995	4,000	80	120	360	480	4,800
2000	5,000	100	150	450	600	6,000

Assumptions:

[1] Production yields estimated at 100,000 pounds/algal acre/year.
[2] Represents two acres of land per algal acre to accommodate production trenches, seed pools, nursery and other appurtenances.
[3] Approximately 1.5 direct jobs per acre of land.
[4] Approximately 1.7 indirect jobs per direct job until processing begins in 1990. Thereafter 3.0 indirect jobs per direct job.
[5] Wholesale price $0.15 a piece or $1.20 per pound in-shell.
[6] Production estimates of two firms. Market promotion begins in 1979.
[7] Based on announced expansion plans. Local market beginning to be satisfied and export begins.
[8] Based on announced expansion plans. Full-scale export.
[9] Processing begins.

Table 21. Project Production, Employment and Revenues from the Culture of Clams in Hawaii: 1978 to 2000

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)[5]
	Yield (1000 lbs)[1]	Acres[2]	Direct Jobs[3]	Indirect Jobs[4]	Total Jobs	
1978[6]	10	.5	1	2	3	$ 10
1980[7]	100	2.0	3	5	8	100
1985[8]	500	10.0	15	26	41	500
1990[9]	1,000	20.0	30	51	81	1,000
1995[10]	2,000	40.0	60	180	240	2,000
2000	3,000	60.0	90	270	360	3,000

Assumptions:

[1] Production yields estimated at 100,000 pounds/algal acre/year.
[2] Represents two acres of land per algal acre to accommodate production trenches, seed pools, nursery and other appurtenances.
[3] Approximately 1.5 direct jobs per acre of land.
[4] Approximately 1.7 indirect jobs per direct job until processing begins in 1995. Thereafter, 3.0 indirect jobs per direct job.
[5] Wholesale price of $1.00 per pounds, in-shell.
[6] Prototype testing in process.
[7] Announced expansion plans.
[8] Local market beginning to be satisfied and export begins.
[9] Full-scale export begins.
[10] Processing begins.

market for items not intended for direct human consumption, consumption trends, quality control, local seafood marketing channels, and marketing constraints. Little was known of Hawaii's seafood market at the onset of this investigation. It was, therefore, necessary to examine such previously unexplored areas as total and per capital consumption, distribution networks, etc. Consequently, much of the information summarized here appears for the first time.[16] The marketing potential for specific species are presented in the individual species assessments in Section D of this chapter.

Seafood Consumption in Hawaii

Total and per capita consumption. Approximately 30 million pounds of seafood is consumed annually in Hawaii. Per capital consumption[17] of seafood in the State is nearly 2.5 times higher than the national average. Between 1972 and 1976, local per capital consumption averaged 26 to 29 pounds, whereas per capita consumption nationally averaged only 12.5 to 12.9 pounds.[18] Much of this can be attributed to the Asian or Pacific Basin heritage of many of Hawaii's residents. However, visitors–particularly those from the Mainland–consume a higher proportion of seafood while visiting Hawaii than they normally would at home.

Profile of consumption. Such factors as age, cultural heritage and income affect local seafood consumption. Although young people in Hawaii consume more seafood than young people in most other areas of the country, there are indications that their consumption is lower than that of the older generations. This may be the result of a greater exposure to meats, poultry and convenience foods than their parents. In addition, the fast food outlets have generally not emphasized seafoods on their menus. Thus, young people who patronize these establishments have less exposure to seafoods. Inasmuch as the fast food sector of the restaurant industry is growing rapidly, a concerted effort to develop and promote a variety of processed products is required to capture a larger portion of this market.

The age group 35-50 years of age consumes the most seafood, particularly fresh seafood.[19] This would seem to indicate that this age group is the most familiar with the preparation and utilization of the fresh forms.

Seafood utilization in Hawaii varies among ethnic groups. Persons of Hawaiian and Pacific Basin heritage consume the widest varieties of seafood. Seafood consumed among ethnic groups generally depends on the prepared form of the product. However, for some species, such as shrimp, there appears to be universal appeal (Garrod and Chong, 1977).

The large number of visitors to Hawaii has significantly added to the volume of seafood consumed in the State. In 1977, an estimated 3,433,667 people visited Hawaii

---

[16] More detailed studies are on file at the Aquaculture Development Program.

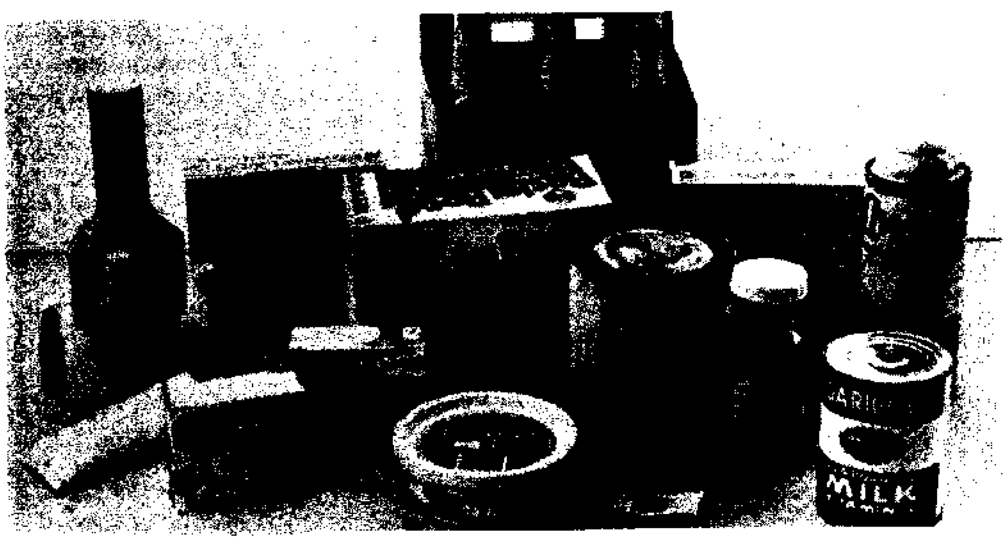
[17] Per capital consumption figures are based on the *de facto* population, i.e., the average number of persons in the State at any given time, including Armed Forces personnel and their dependents, and visitors, but excluding residents temporarily absent.

[18] Per capita seafood consumption in both Hawaii and the nation has increased steadily in the last few years.

[19] Aquaculture Planning Program Survey, 1977.

Of the many considerations for selecting a species for culture, the identification of a substantial market is one of the most important. Although Hawaii's per capita consumption of seafood is more than twice the national average, more than half the seafood consumed in the State is imported. There are excellent opportunities for the substitution of locally grown products.

Developing the market for prawns: a prawn recipe brochure is prepared by Sea Grant's publications staff, with partial funding from the Aquaculture Development Program.



A wide range of products contain seaweed derivatives, and a continued strong demand for cultured aquatic algae is expected.

for business or pleasure (Hawaii Visitors Bureau, 1978). Each visitor stayed an average 11 days, and spent approximately $13 per day for food and beverage (*State of Hawaii Data Book*, 1977). Studies have shown that these visitors expect to eat fresh seafood sometime during their stay; however, fresh seafood is almost always in short supply, and not always available.

Demand. In terms of product promotion, the high volume of seafood consumed in Hawaii suggests that less effort will be required to sell the product in this State than in other locations. The demand for seafood is generally inelastic; that is, consumers will not readily substitute seafood for other protein sources (beef, pork, and poultry, for example). On the other hand, the demand for particular seafood products is rather elastic–consumers will readily substitute one seafood product for another. This seems to indicate that the consumer will be more discriminating in selecting seafood items. Quality, therefore, cannot be compromised. Quality standards should be established for Hawaii's cultured products in order to assure consumer confidence. These standards may be based on such characteristics as color, texture, and age. Where possible, monitoring should be carried out by industry.

Distribution of Seafood Products Imported into Hawaii

Mainland and domestic imports comprised 55 percent of the total seafood marketed in Hawaii in 1976. Imports originated on the west coast of the Mainland, Japan, Australia, New Zealand and elsewhere. Imported products flow from the original source through brokers and wholesalers to the retailers. With few exceptions, imported seafoods are either frozen or canned, and thus do not go through the local auction. Prices for these products are already set upon entering into the State.

Cultured seafood is expected to compete with some products entering this line of distribution. By providing distributors with a product similar or equal to the one from present sources, a significant share of the market may be captured.

Brokers. Many producers/processors of seafoods are represented by selling agents or "brokers" in Hawaii. These brokers have exclusive rights to certain seafood product lines and many carry the entire line of a particular brand of seafood marketed here.

Brokers sell primarily to wholesalers because brokers normally handle large volumes, and, with the exception of large supermarket chains, most retailers do not have the capability to place large orders. They, therefore, order from wholesalers who deal with brokers.

In addition to their selling function, brokers can provide information on new products, services, selling techniques, and promotional material to their customers. In return, they are able to relay their customers' preferences to their suppliers. Normally, brokers receive a 1 – 1½ percent commission on sales.

Brokers traditionally do not take physical possession of a shipment. However, Hawaii's susceptibility to shipping strikes and relative isolation may require that some additional stocks be kept. In this way, the effects of shortages and delays in shipping can be minimized. In addition, special orders may create a sudden excessive demand which cannot be met, and the volume and weight of frozen seafood often preclude air shipment. Excess capacity allows for such contingencies.

Wholesalers. Wholesalers supply retail institutions such as supermarkets, hotels, restaurants, and airlines. They purchase products from local brokers or directly from the producers/processors. The difference between wholesalers and brokers is that wholesalers will take actual possession of seafood products while brokers may simply act as billing houses for the companies they represent. This is especially important in seafood marketing in Hawaii, as orders from producers and brokers must often be large and require prepayment. This means that a large capital base is necessary. Also, wholesalers must be able to store and distribute seafood products efficiently. Storage of seafood requires costly equipment. Transportation must be efficient and rapid to prevent spoilage of the products. Due to the high costs involved in imported seafood products, many wholesalers will only purchase items which have already been ordered and will carry only a minimal inventory.

Retailers. Retail institutions offering imported seafoods in Hawaii can be divided into two groups. The first group, which sells primarily to the home consumers, includes traditional "mom and pop" markets, specialty seafood dealers, and supermarkets. These retailers generally prefer to purchase seafood that (1) sells quickly, and (2) is not affected significantly by refrigeration. Some seafoods, like mullet and *mahimahi*, supplement local supplies. Other types of imported seafood are varieties that are non-indigenous to Hawaii, such as American lobsters and salmon.

The second group of retailers is composed of hotels, restaurants, and caterers. This group lacks storage capacity and tends to rely on wholesalers to meet daily or biweekly needs. In order to carry a product as a standard menu item, they need a consistent supply of a high quality product that is packaged and prepared for convenience.

Distribution of Local Seafood Products in Hawaii

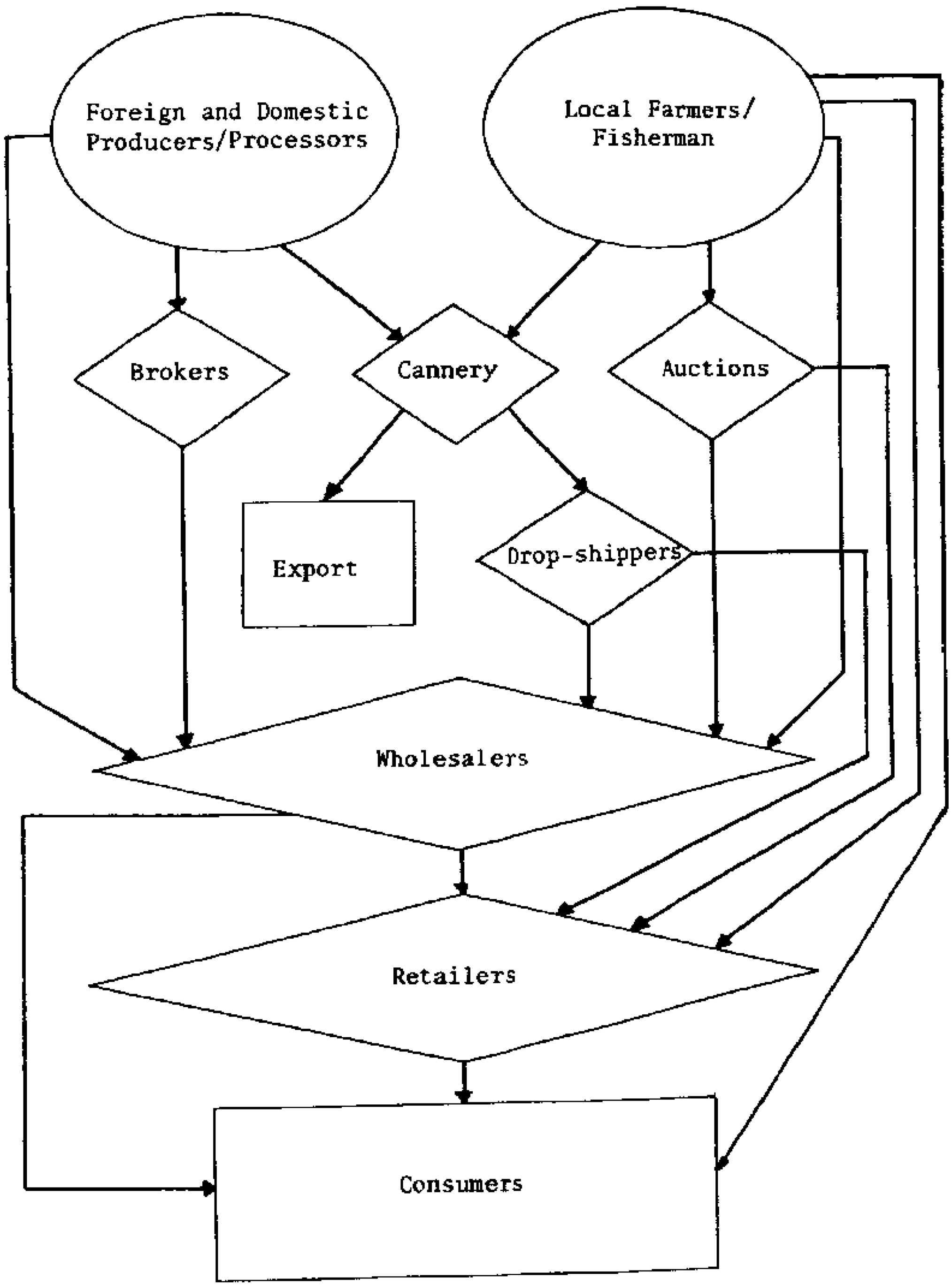
Local seafood is sold directly to wholesalers, retailers, the cannery, or the consumer, or indirectly by means of an auction (Figure 2). The flow of goods may be different from species to species. Most fish caught commercially in Hawaii are sold at the local auction directly to wholesalers. Some commercial fishermen will sell to an individual wholesaler exclusively, thereby omitting the commission earned by the auctioneer. Some cultured fish is sold directly to final consumers from ponds. An example of this is the Chinese carp, which has a minimal production and a very select number of consumers. The large commercial culturists are presently selling to wholesalers/distributors on fairly exclusive bases.

The amount of seafood that flows through these market channels depends on (1) expected prices in each of the various channels, (2) the types of seafood, (3) prearranged agreements with wholesalers and/or retailers, (4) the time of year, and (5) the ownership of the fishing vessel (Garrod and Chong, 1978).

Auctions. Auctions are the usual entry points for fresh seafood in Hawaii. Wholesale and retail prices are greatly influenced by the bidding, which is based on quality, species, size, quantity, etc. (Garrod and Chong, 1978). Because the supply of fish is uncertain, the price bids are likely to vary from day to day. Participants are primarily established firms with years of trading experience.

Wholesalers. Wholesalers of local seafood will often purchase goods at the auction or directly from fishermen, and clean, process, and package the product for resale to retailers or final consumers. Many of these "small wholesalers" have started as retail establishments and have expanded their business to include wholesaling activities.

Figure 2. Flow of Products in Hawaii's Seafood Market



Retailers. Retail markets and local peddlers obtain seafood from the auction, from wholesalers, and directly from fishermen and aquaculturists. Freshness and quality are the most important considerations for the small retailer. Most restaurants and hotels in Hawaii seldom carry fresh fish. The primary reason for this is the inconsistency of supply. Only those restaurants with long-established connections are able to obtain a supply that is consistent enough to justify carrying fresh seafood items on their menus. On the island of Maui, however, fresh fish is available in local restaurants mainly because a fishing cooperative guarantees a steady supply. In fact, "there appears to be more fresh fish restaurants on that island than in Honolulu." (*Honolulu Advertiser*, May 5, 1978)

Skipjack tuna and the cannery. The flow of skipjack tuna, or aku, through market channels differs from other seafoods. For the period 1972–76, Hawaii's total skipjack catch ranged between five million and 10 million pounds per year. Roughly 3.5 million pounds of this have been absorbed by the local fresh fish market. About one-fourth of this amount is distributed through the auction. The other three-fourths are directed to wholesalers, retailers, and consumers. The remaining catch and nearly all imported tuna are processed by Hawaiian Tuna Packers (dba "Bumble Bee"), a cannery at Kewalo Basin.

Of the total amount of skipjack processed, about six million pounds a year is consumed locally. Distribution of canned tuna is done via "drop-shippers" for local distribution to wholesale and retail outlets. Drop-shippers take orders from retailers and wholesalers, then pick up and deliver the product. The remaining canned tuna is shipped to the various Bumble Bee warehouses on the Mainland.

Flow of cultured products. The flow of cultured aquatic products is presently from the farmer to the wholesaler to the retailer, from the farmer to the retailer, or—in a few cases—from the farmer directly to the consumer by means of roadside stands. The price is established through negotiations between the producer and the buyer, thus eliminating the need for an auction.

At some time in the future, the increased production of cultured aquatic products is expected to result in greater competition for markets among farmers. As this occurs, a shift in the flow of product to market channels not currently used can be anticipated. For example, auctions, which influence price in accordance with supply and demand, may be utilized. In addition, canning and processing can increase both product demand and value by effectively using forms of by-products and surplus production.

Market Potential

U.S. seafood consumption. The United States' consumption of seafoods has slowly, but steadily, increased in the 1970's. From 11.2 pounds in 1969, the per capital consumption of seafood grew to 12.9 pounds in 1976, a 15 percent increase. On an aggregate level, the figures are even more dramatic. In 1969, total consumption equaled approximately 2.2 billion pounds while in 1976, total consumption was estimated at 2.7 billion pounds, an increase of 22 percent.

Total domestic landings have been relatively stable. Therefore, in the face of rising consumption and a growing population, the U.S. has had to increase its reliance on imports. Over 60 percent of the total supply of edible fish and shellfish came from foreign sources in 1976 (U.S. Department of Commerce, 1977).

Consumption trends. Consumption trends indicate opportunities for developing and expanding markets. Aquaculture marketing programs are expected to capitalize on: (1) an increase in per capital consumption, (2) a rapid expansion in the fast food trade, (3) a growing awareness of the importance of nutrition, and (4) a greater diversity of seafood products sold in supermarkets.

The fast food industry has experienced considerable growth in the last two decades. Fast food outlets typically market processed and convenience foods, including seafoods. Opportunities exist for marketing low-priced, high-quality fish (Chinese carp, tilapia, etc.), which can be processed into fillets, patties, and sticks. Processing, however, is relatively capital- and labor-intensive. The costs of production and processing, and the availability of capital will, therefore, determine if aquaculture can play a more important role in this area.

Consumers have become more nutrition conscious. Many now feel that a heavy diet of red meats may be harmful to their health. Seafoods, on the other hand, are gaining in favor because, on the average, they contain more total nutritional value with less cholesterol and less calories per serving than beef or pork.

Supermarkets today provide their customers with a wide array of seafood products in many different forms. This allows the consumer to substitute among products, and compare the prices and qualities of various items at one location.

Marketing Opportunities for Hawaii's Aquaculture Industries

Export potential. Hawaii's strategic location, between the U.S. Mainland and the Far East, provides the State with ample opportunities for developing export markets in these locations. For example, the United States' present dependence on imports suggests that Hawaii can contribute to the U.S. balance of trade through substituting cultured aquatic products for imports. As another example, in the Far East, the Japanese seafood market presents special opportunities for freshwater prawns, marine shrimp, brine shrimp, and other species. Europe, with its prosperous economies and demand for luxury seafood items, represents another important area for marketing Hawaii's aquatic products.

Although the costs of land, feed, and other inputs to aquaculture production are relatively high in Hawaii, the warm, year-round growing conditions and positive effects of higher temperatures on the growth rates of most species suitable for culture enables aquafarmers in this State to compete with Mainland producers—even if the cost of transportation is taken into consideration (Aquaculture Planning Program, 1977).

Hawaii's export commodities have been well received on the Mainland and have commanded premium prices. Part of this success is due to the cooperation of the local visitor industry which has supplied statistics indicating the cities of origin of visitors to the State. Agricultural marketing programs in these cities have advertised such products as pineapples, papayas, macadamia nuts, anthuriums and orchids as "Hawaii grown." This experience suggests that locally cultured aquatic products can, likewise, be effectively marketed by concentrating on specific locations, and attaching a "grown in Hawaii" label.

Production of non-food items. Most aquaculture products are intended for direct human consumption. However, a number of opportunities exist in other areas. These include: (1) the production of baitfish for the skipjack tuna industry, (2) industrial and environmental uses of aquatic algae, (3) feeds for aquatic species and livestock, and (4) recreational fishing. Each of these will be briefly discussed below.

Baitfish. The Hawaiian skipjack tuna, or *aku*, fishery has traditionally been the mainstay of Hawaii's commercial fishing industry. In recent years, however, skipjack landings have gradually decreased. In 1976, approximately 9.8 million pounds were caught, and in 1977, this figure declined to 7.8 million pounds (Bank of Hawaii, 1978). Recent analyses have indicated that the single most important limiting factor in the expansion and development of the commercial fishery is the availability of a hardy, effective baitfish. The traditional baitfish, the *nehu*, is a fragile anchovy which occurs sporadically and in limited supply. Because it takes time to obtain this fish from the wild, and the survivability is low, the use of *nehu* restricts the range of skipjack vessels to within 90 miles of shore and greatly curtails fishing activities. The two major sources of *nehu* in Hawaii are Pearl Harbor and Kaneohe Bay. The recent halt in sewage discharge into Kaneohe Bay may have resulted in decreasing occurrences and supplies of *nehu*.

The intensive culture of selected species, such as topminnows, offers a promising solution to this problem. With a suitable baitfish, the Hawaiian skipjack fishery is capable of realizing a 20-fold increase in its landings. equivalent to approximately $100 million per year at the current retail price (*Hawaii Tuna Fishery Development Plan*, 1977).

The culture of baitfish need not be limited to the skipjack fishery. It is equally applicable to other commercial and recreational fisheries (i.e., bottom, shoal, reef, bank, and long-line fishing). In fact, recent anti-purse seining publicity has increased the importance of non-destructive fishing techniques (such as pole-and-line fishing) and the use of live baitfish. Furthermore, to date, purse seining has been shown to be infeasible in parts of the central, tropical Pacific Ocean (Baldwin, 1977).

The State's long-standing research efforts in the biology and technology of culturing baitfish is an added advantage that will, in the long term, enable Hawaii to continue to respond to emerging local needs and remain the center of aquaculture baitfish expertise.

A local market for a hardy and suitable baitfish that will aid the local fishing industry in realizing its full potential appears to exist. The actual market for baitfish, however, will depend greatly on the acceptance of the product by fishermen.

Aquatic algae. Aquatic algae can be cultured for a considerable variety of purposes, including food production, use as a food or industrial additive, to produce energy, and to recover nutrients from organic wastes. Each of these areas has a significant market potential.

Marine algae, or seaweed, is one of the world's leading seafood commodities. Precise figures are unavailable, but the lowest estimate places the total value of the world's seaweed crop in 1976 at over $1 billion. Most of this amount was derived from the sale of edible seaweeds in Japan, Korea, and Taiwan. Attempts to introduce seaweed to the West have met with limited success. In Hawaii, only 66,000 pounds of marine algae were consumed in 1976, but it is estimated that local demand could utilize an additional 250,000 pounds per year by the year 1982 (Aquaculture Planning Program, 1977).

The most important use of marine algae in the Western Hemisphere is to provide components for the production of numerous food and industrial products. Such seaweed extracts (marine colloids) as agar, algin, carrageenan and furcellaran are found in dairy products, processed meats, instant or convenience foods, pharmaceuticals, textiles, cosmetics, paints, beer, explosives, fertilizers, and chemicals. In 1974, the marine colloid industry had an estimated value of $300 million from production of 32,700 tons. The annual growth of the industry is conservatively estimated to be 10 to 20 percent (Doty, 1978).

Hawaii has several species of algae that may prove valuable for marine colloids. Two projects are currently under way to farm *Eucheuma*, a major source of carrageenan. If these projects prove to be successful, they could produce a projected revenue of approximately $7 million within a three-year period (Doty, 1978).

Other opportunities for culturing aquatic algae in Hawaii involve the application of algae-based technology to a variety of local problems, including animal feed production, waste recovery, waste water benefaction and energy production. Feed costs, for example, may be reduced if the bluegreen alga *Spirulina* can be cultured for use as an animal food supplement.

Brine shrimp. Brine shrimp, *Artemia salina*, is a convenient, important, and highly utilized source of protein for larval and adult fish and shellfish. Brine shrimp eggs are used extensively by aquaculturists for larval feeding. The eggs are hatched and the nauplii are fed to the larvae, usually within 24 hours. The nauplii's nutritional value is high and its size is well-suited for feeding aquatic animals during their early stages of development. Brine shrimp adults and meal, and freeze-dried brine shrimp are in demand as feed for adult fish. The adults are often purchased by aquarium hobbyists who cannot afford the time and cost involved in hatching the eggs and rearing the nauplii.

An estimated 14,000 gallons of brine shrimp eggs are consumed annually in the U.S., Japan, and Europe (Helfrich, 1973). This figure primarily reflects usage by aquarium hobbyists, nor aquaculturists. In 1977, the wholesale price of grade A eggs increased dramatically from between $40 and $50 to $70 and more per gallon. Currently exploited sites of natural production have come under increasing environmental stress from urbanization and industrilization. This is thought to be adversely affecting the viability, quantity and quality of the eggs obtained from the wild, creating an even larger demand for high quality eggs.

In the United States, sales of live adult brine shrimp have been estimated at 25,000 to one million quarts per year (Cohlan, personal communication, 1977). At the average wholesale price of $6 per cup, the market has been estimated at $1.5 million to $6 million, with an unfulfilled demand for one million quarts of adults.

The demand for brine shrimp—eggs in particular—is expected to increase substantially as aquaculture continues to grow in importance. It has been estimated that an international demand for 40,000 to 50,000 gallons of eggs at a wholesale price of $25 per gallon will result by 1982 (Helfrich, 1973). In that same year, an estimated 1,270,000 quarts of adults will also be required at a wholesale price of $5 per quart.

These estimates indicate potential local and export markets for cultured brine shrimp. The actual size of the market, however, will depend in large on the discovery of new sources of brine shrimp and the viability, quality and quantity of the products, State assistance—currently available—is needed to expand both local and export markets. Two segments of Hawaii's local seafood market are shown here: a restaurant (an institutional market) and prawn sellers (retail markets).

One way of letting people know that prawns are on the menu: tanks with live prawns in the middle of Won Ke's Restaurant, Honolulu.

A scramble at Tamashiro Market, Honolulu: customers place prawns in plastic sacks.

Fresh and alive: customers can choose their own prawns at Farm Fresh, Inc., Honolulu.

engineering designs for hatching live brine shrimp, and the development of prepared larval feed for aquaculture.

Recreational fishing. "Pay and fish" centers are commercial establishments that charge an entrance fee and/or charge for each fish caught. These centers are generally in a convenient location and supply equipment bait. This form of commercial, recreational fishing is popular in the United States and Europe, and offers new opportunities for Hawaii's aquaculturists. Another recreational fishery opportunity for aquaculture is the production of juveniles, such as *moi* and *opihi* for the enhancement of natural stocks.

By-products. With sufficiently large production, opportunities arise for processing by-products for animal feeds and fertilizers. As a result, the product can be efficiently utilized, its waste minimized, and its total value increased.

Constraints to Marketing Cultured Seafood

The local market for cultured aquatic products is presently a small one, with all production consumed within the State. There do not appear to be any major constraints to the market at this time. With greater production, however, it will become increasingly important to consider those factors which can become constraints if they are not properly addressed and dealt with. These are examined below.

Price and competition. Price is an important factor to the consumer when comparing various products. Cultured aquatic products must compete in price with beef, pork, and chicken, as well as fishery products. Since 1970, seafood has been, on the average, the highest priced source of protein. As the price of seafood is sensitive to price changes in meat and poultry, a major challenge for aquaculturists will be competition from meat and poultry producers, as well as production from countries with low costs per unit of caught and cultured seafood. If production costs can be reduced, the aquaculturist will be in a more price-competitive position, and his share of the market would most likely be greater. Research aimed at increasing production efficiency and decreasing production costs will be needed.

Perishability. Consumers generally purchase seafood in the fresh, chilled and frozen forms. More than 60 percent of the fish consumed in the U.S. are consumed in these forms. A problem with fresh and chilled seafood is that they can normally be kept no longer than a week without seriously affecting their taste and flesh tone. This problem has a tendency to reduce the volume retailers are willing to inventory at any one time. Freezing seafood allows storage for extended periods. However, freezer capacity must be allocated among a variety of food products, and seafood has to compete with other frozen items.

It is anticipated that Hawaii producers will eventually process their products into frozen forms in order to permit inventorying, product diversification and exportation. The capability to process and hold cultured seafoods in inventory will be important in maintaining constant supply and prices.

The cost of establishing and operating processing and packaging facilities may be cost-prohibitive to most small farmers. Cooperatives are a means of achieving the justifiable volumes and capital required of such a facility. The State can be instrumental in encouraging such cooperatives.

Lack of promotion. Advertising and other forms of direct and indirect promotion have not been used effectively to stimulate active interest in seafood. Promotional efforts can play a major role in increasing demand. One isolated incidence of successful promotion is in the catfish industry. Catfish was once regarded as a "poor man's food," but is now served in many of this country's finest restaurants.

Studies have shown that customers who know the product, and know how to prepare that product will be more likely to purchase it. Consumer awareness and education programs are, therefore, needed. In addition, consumer preferences should be assessed so that producers can be more responsive to changes in consumer demand.

Product development and diversification. Product development and diversification can enhance the size and growth of the market. The processing expertise and facilities needed for product development and diversification are, however, currently unavailable. The various market segments have differing needs and preferences which, if met, can substantially expand sales.

Timeliness in market development programs. The importance of, and need for, timely and orderly market development programs cannot be overemphasized. If market development activities begin prematurely, demand could exceed supply and result in market instability. On the other hand, if market development activities begin too late, a surplus of production could result in price depressions and adversely affect small producers.

Market accessibility and cooperatives. Small producers may find it difficult to gain access to large markets. The needs of large markets are often voluminous and exceed the production capability of a single, small producer. The small producer may have to yield to a larger producer, or work cooperatively with other small producers to meet the needs of large markets.

The formation of cooperatives can be instrumental in developing markets for cultured aquatic products and benefit aquafarmers. Quality standards and distribution procedures can be established to ensure consumers of consistent quality and supplies. Processing, a capital-intensive activity, can also be more easily supported by cooperatives. Consolidated purchases can result in greater discounts to individual producers. Marketing, a time-consuming activity in itself, can become more effective, with small farmers cooperatively gaining access to large markets. By pooling their resources, small producers can more effectively compete with large producers in the marketing of their products.

The importance of a Maui fishing cooperative was mentioned above. In 1977, Hawaii's prawn farmers joined together to form the Hawaii Prawn Farmers Association as a first step toward evolving into a cooperative. This association is expected to take an active role in developing prawn marketing activities.

Quality control. Quality control is essential to marketing cultured aquatic products. Such factors as taste, texture, and freshness must be continually monitored to establish and preserve the reputation of the product. Each aquafarmer can set his own quality control standards. However, for consistency, it is more desirable for the farmers to join an association of producers and determine set, uniform standards.

Recommendations

Substantial opportunities exist for marketing cultured seafood if certain key constraints—discussed above—can be reduced or eliminated. The following recommendations address these constraints:

1. **Support research directed at increasing production efficiency and reducing production costs** in order to make cultured aquatic products more competitive with other sources of protein, including meat, chicken and imported seafood.

2. **Support the promotion of aquaculture products through advisory and extension services.** This can be especially important with respect to expanding markets, reducing imports and increasing consumer awareness of locally cultured aquatic species.

3. **Investigate the most efficient means of marketing various species of cultured products.** These means may not fall under the present market structure and may require the establishment of new channels of distribution.

4. **Establish processing facilities in the State.** This is a necessity in order to (a) ensure consistently high quality products, (b) prolong shelf-life, and (c) provide opportunities for small farmers to enjoy the advantages of large-scale processing, packaging, distribution and marketing.

5. **Coordinate marketing programs with levels of production.** Timeliness of marketing programs ensures that demand does not increase faster than initial production levels. As production levels increase, market programs must be designed to provide new markets and increase demand within these markets.

6. **Encourage the formation of producers' cooperatives.** Such cooperative efforts can help in stabilizing prices and meeting demand. It can also be beneficial to small farmers who may not have the capital nor the time to devote to marketing products and purchasing sophisticated equipment.

7. **Establish quality standards for aquaculture products.** These standards can play an important role in gaining consumer confidence in, and preference for, cultured aquatic products.

Markets for Cultured Aquatic Products: 1977 and 1982

Table 22, "1976 Consumption of Aquatic Products and Estimated Future Markets for Aquatic Products Cultured in Hawaii," summarizes the 1977 market for different species, and also estimates the 1982 market potential for these species. These estimates are based on numerous factors, including the state of technology, costs of production, market development opportunities and activities, and constraints to the market. A change in any of the aforementioned factors would affect market estimates.

Table 22. 1976 Consumption of Aquatic Products and Estimated Future Markets for Aquatic Products Culture in Hawaii

(Volume in 1,000 of pounds, round-weight except where noted; value in $1,000)

	1976 Consumption						Estimated Potential Markets for Hawaii's Cultured Aquatic Products							
	Hawaii				Mainland		1977				1982			
	From Local Aquaculture		From All Sources		From All Sources		Hawaii		Mainland		Hawaii		Mainland	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
Baitfish (topminnow)	--	$ --	--	$ --	--	$ --	150	$ 14	--	$ --	300	$ 333	--	$ --
Brine shrimp[a]	31	3	694	42	264	6,560	1,238	78	286,000	6,100	8,031	104	881,941	23,200
Catfish	30	38	82	103	116,300	68,600	600	750	1,000	500	635	793	2,000	1,000
Chinese carp[b]	6	13	6	13	--	--	946	560	35,900	18,600	1,176	688	4,030	20,900
Clams	--	--	570	204	1,248	46,800	300	225	--[c]	--[c]	750	560	--[c]	--[c]
Freshwater prawns	43	152	48	160	1,000	3,500	1,100	3,850	5,000	17,500	1,800	6,300	5,700	20,000
Marine algae[d]	--	--	66	39	4,800,000	765,000	239	287	52,643[e]	16,180	253	304	77,263[e]	23,660
Marine shrimp	--	--	2,200	6,600	446,900	1,600,000	620	3,000	103,500	469,300	657	3,100	118,000	536,800
Moi	--	--	3	4	--	--	120	240	--	--	129	212	--	--
Mullet	2	4	248	211	35,200	3,800	250	225	--	--	500	450	--	--
Opihi	--	--	14	25	--	--	60	120	--	--	72	144	--	--
Oysters	--	--	437	391	62,100	60,000	500	600	1,088	1,500	1,100	1,300	1,500	1,800
Total[f]	81	$207	3,674	$7,760	5,586,564	$2,547,700	4,750	$9,871	199,131	$522,050	7,372	$14,184	244,763	$601,910

a Volume figures expressed in gallons
b Volume expressed in product weight
c Unknown
d Actual consumption for mainland represents world utilization in 1974.
e Volume expressed in dry, cleaned weight; represents estimated potential world market.
f Total values are exclusive of brine shrimp estimates.

F. Funding and Financing

This section covers two general areas: external non-State funding of public aquaculture development activities, and financing of private, commercial aquaculture operations.

Federal Sources of Funding

Substantial financial resources will be required to assure a high rate of growth for aquaculture development in Hawaii. Since the State's financial resources are limited, Hawaii must seek non-State sources of funds to match the State resources available for developmental activities.

Since there is presently no lead agency for aquaculture in the Federal government, current sources of Federal support for aquaculture are *diverse*—residing in several agencies, *limited*—not generally available for technical services, pilot demonstrations or facilities, and *inadequate*—since aquaculture must compete with other sectors. Over the past four years, numerous pieces of legislation have been submitted to Congress to remedy this situation. Major legislation is discussed below.

Current sources. Nine Federal sources of funding for publicly-supported aquaculture development activities are listed in Table 23. To date, only the first two have been exploited. Possibilities for obtaining funds from the remaining seven sources should be studied immediately. Moreover, current pending Federal legislation, if passed and signed into law, can provide significant additional Federal funding.

Pending legislation. Several aquaculture bills are pending before Congress. The discussion surrounding these bills centers on (1) the designation of the lead Federal agency, and (2) the best approach to aquaculture development. Two separate bills, S. 2582, introduced by Senator Lowell P. Weicker (R-Conn.), and H.R. 9370, introduced by Congressman Robert Leggett (D-Calif.) would designate the U.S. Department of Commerce (USDOC) as the lead agency. These have already passed the House. Two other companion bills, S. 2218, introduced by Senator Richard Stone (D-Fla.), and H.R. 9976, introduced by Congressman Rommie G. Flippo (D-Ala.), would make the U.S. Department of Agriculture (USDA) the lead agency. A fifth bill, S. 2762, introduced by Senator Mike Gravel (D-Alaska), would designate the USDOC as the agency with ultimate responsibility for aquaculture activities, but would require the USDOC to work in close conjunction with the USDA and the U.S. Department of Interior (USDOI).

The Food and Agriculture Act of 1977 (P.L. 95-113), which was introduced as S. 275 by Senator Herman Talmadge (D-Ga.), authorizes the USDA to include aquaculture as one of its missions. Those generally favoring the USDA as the lead agency argue that this law formally bestows that role upon the USDA. However, those generally favoring the USDOC as lead agency, contend that this is not the intent of the bill.

The second major area of controversy relates to the relative emphasis on freshwater versus saltwater aquaculture. Freshwater aquaculturists generally favor the USDA because of USDA support of catfish farmers over the past 20 years. Moreover, they fear that were USDOC to be named lead agency, freshwater aquaculture would suffer. On the other hand, saltwater aquaculture interests generally favor USDOC because of a history of NOAA and Sea Grant support of saltwater aquaculture (mariculture). Many mariculturists fear commercial development of saltwater aquaculture would suffer if the USDA were to be assigned lead agency responsibilities.

* Total values are exclusive of brine shrimp estimates

Table 23. Federal Sources of Funding, Activities They Support and Principal Recipients

Agency	Activities Funded	Principal Recipients
Department of Commerce		
Aid to Commercial Fisheries Programs (PL 88-309)	Research and development activities	State agencies
National Marine Fisheries Services (NMFS)	Research, support services (marketing)	Mainly in-house activities
Economic Development Administration (EDA)	Facilities construction projects	State and county agencies
Office of Sea Grant	Research and development, education, training, extension and advisory services	Universities, public and private nonprofit research organizations
Department of Agriculture		
Soil Conservation Service, Cooperative Extension Service, and the Agricultural Research Service	Research, extension/advisory and other support services	Land grant colleges and in-house activities
Amended Food for Peace Act (new, Section 406)	Research, education, and training	Universities
Department of State		
Title XII of the Foreign Assistance Act of 1975 (new)	Research and development, training and technology transfer	Land and sea grant colleges
Department of Interior		
Fish and Wildlife Service	Research, hatcheries and support services (disease programs)	Cooperative fisheries at universities and in-house programs
National Science Foundation	Research	State agencies, private organizations, and universities

A third agency with an extensive history of involvement in aquaculture is the USDOI. The USDOI has operated trout hatcheries throughout the United States for more than 100 years and has traditionally provided disease prevention services through their cooperative fisheries units.

It appears clear then, that in order for aquaculture legislation to be passed and become law, some compromise must be reached. Moreover, it is certain that each of the three departments (USDA, USDOC, USDOI) has played, and will continue to play, a key role in the development of aquaculture–the USDA with technical services and loan programs, the USDOC with support of developmental research, and the USDOI with technical assistance to hatcheries and disease prevention services. Therefore, any compromise decision regarding the lead agency issue should recognize the vested responsibilities for aquaculture in all three agencies and provide each agency with an expanded role in aquaculture development.

The successful passage of aquaculture legislation is expected to contribute significantly to aquaculture development nationwide, and especially in Hawaii. Anticipated benefits include a Federal aquaculture loan program, a Federal aquaculture disaster loan program, technical services such as extension and advisory aid, market development assistance, disease prevention services and others, and funds for facilities and developmental research. Hawaii should strongly support the passage of Federal aquaculture legislation.

Private and Other Non-State Sources of Funding

Private sources of funding are philanthropic foundations and international organizations whose principal focus is increasing food production, mainly in the lesser-developed countries. However, inasmuch as Hawaii is a major crossroad between the East and West, with a climate similar to many Asian and Pacific locations, and inasmuch as Hawaii possesses considerable expertise in tropical aquaculture with the likelihood of becoming a major center for tropical aquaculture research, demonstration and training, it is anticipated that the State may receive some private foundation funds as well as support from major international organizations with similar objectives. Some of these organizations are listed in Table 24.

More details on sources of support. Additional details regarding sources of support for developmental activities are presented in other sections of this report with the subject matter to which they relate. See also Chapter I ("Introduction"), Chapter IV ("Implementation"), Chapter V ("Budget and Timetable"), and Appendix C ("Tropical Aquaculture Center").

Credit and Financing

The ability to obtain start-up capital is vital to establishing an aquaculture operation. A lender's principal requirements for granting loans include: (1) front money (similar to a down payment), (2) a track record (a history of success), and (3) a reliable market for the loan recipient's product. Like nearly any new industry, the availability of adequate credit is a critical constraint in the early stages of development. Reluctance on the part of lenders to extend credit for aquaculture operations generally stems from the lack of an established track record. In other words, the risk is considered high because no record exists to give an indication of potential for success.

Two types of loans available to aquafarmers are:

Table 24. Some Possible Private and International Sources of Support for Aquaculture Development Activities

Name of Organization	Type of Organization
Asian Development Bank	quasi-government
Doherty Foundation	private, nonprofit
Ford Foundation	private, nonprofit
Foundation for the Peoples of the South Pacific	private, nonprofit
Japanese Foundation	private, nonprofit
Rockefeller Foundation	
International Center for Living Aquatic Resources Management (ICLARM)	private, nonprofit
United Nations	
UN Development Program (UNDP)	quasi-governmental
Food and Agriculture Organization (FAO)	quasi-governmental
Southeast Asian Fisheries Development Center (SEAFDC)	quasi-governmental
World Bank	private, nonprofit

1. **Capital improvement loans**, for purchasing or improving land or buildings (usually long-term, from 10 to 40 years), and

2. **Operating loans**, for providing operating capital (usually short-term, from one to ten years).

In order to receive a loan from a private lending institution, a *loan guarantee* is sometimes needed. The guarantee, which is usually offered by State or Federal programs, assures repayment of a certain percentage of the value of the loan. The Farmers Home Administration, for example, guarantees loans for up to 90 percent of their value. The term "*participation loan*" indicates that the loan is contingent on two or more lending institutions agreeing to lend the necessary funds.

The State of Hawaii has an aquaculture loan program which is administered by the Department of Agriculture's Farm Loan Division. This program together with other sources of credit are presented in Table 25. As initially established in 1972, the Aquaculture Loan Program was authorized to make direct loans up to $75,000. The 1977 Legislature substantially modified the program by increasing the amount which can be loaned to $150,000 and providing for loan guarantees and participation loans. At the time of initial establishment of the Aquaculture Loan Program, an Aquaculture Revolving Loan Fund was established with an initial balance of $500,000. Loans are drawn from this account and repayments, together with interest, are deposited to the Fund.

Table 25. Possible Sources for Aquaculture Loans and Types of Loans

Aquaculture Loan Program of the Hawaii State Department of Agriculture's Farm Loan Division	Capital Improvement Loans Operating Loans
Commercial Banks	Capital Improvement Loans Operating Loans
Farmers Home Administration	Capital Improvement Loans Operating Loans Loan Guarantees
Federal Land Bank	Capital Improvement Loans
Hawaii Production Credit Association	Operating Loans
Small Business Administration	Capital Improvement Loans Operating Loans Loan Guarantees

to the Fund. As of the close of the 1978 State Legislature, no additional amounts were appropriated. With the recent increase in loan applications, additional appropriations will be required in order to meet expanded needs.

A Credit and Financing Subcommittee, consisting of members of the Hawaii Aquaculture Planning Program Advisory Committee, was formed in 1976 to provide recommendations on increasing the availability of credit to aquaculturists. The Subcommittee offered the following recommendations:

1. The State should offer proof that potentially significant species are economically viable. This should be done through prototype demonstrations.

2. The State should provide information to the lending community on the costs of construction and operation of various aquaculture enterprises.

3. The State's Aquaculture Loan Program should be broadened to include participation loans and loan guarantees in addition to direct loans.

4. The maximum amount which can be loaned by the State Aquaculture Loan Program should be raised to levels comparable to agriculture loans.

5. The amount in the Aquaculture Revolving Loan Fund should be increased by at least $500,000.

Recommendations (3) and (4) were acted upon by the 1977 State Legislature. The State should make every effort to implement the remaining recommendations.

G. Economic Projections and Future Considerations

Economic Projections

Economic projections are presented in this section together with a discussion of some trends and anticipated future developments which are expected to have an effect on the growth of aquaculture in Hawaii. The market considerations of the projections are particularly complex, for they must consider a number of diverse factors, both positive and negative. For example, per capita world seafood consumption is increasing, but Hawaii's cultured aquatic products must compete with both foreign aquaculture and world capture fisheries. Another significant area affecting these projections is the current state-of-the-art of aquaculture and the associated time to develop a species from candidacy to commercial culture. The economic projections also attempt to include the effects of external influences such as increasing energy shortages, rising energy costs, and the effects of rising feeds and fertilizer costs.

Commercial production sector. In order to project the growth of the commercial production sector of Hawaii's aquaculture industry, it was necessary to consider the technical assessments of each species, either presently cultured or being recommended for culture in Hawaii (summarized in Section D of this chapter). Each species assessment summary includes projections of production, employment and revenue through the year 2000, and the specific assumptions used to form the projections. The summaries were added in order to determine total growth projections. These totals appear in Table 26.

Table 26. Projected Production, Employment and Revenues from Aquaculture in Hawaii: 1978 to 2000*

Year	Production		Employment			Wholesale Revenues (1000s of 1978 $)
	Yield (1000 lbs)	Acres	Direct Jobs	Indirect Jobs	Total Jobs	
1978	427	149.0	34	49	83	$ 931
1980	2,600	606.5	82	157	239	6,382
1985	16,785	2,429.0	313	641	954	32,644
1990	47,075	5,768.0	644	1,490	2,134	71,410
1995	93,975	12,109.0	1,273	2,879	4,152	147,988
2000	198,125	28,100.0	2,805	6,217	9,022	334,567

*This table is a summation of the individual species or species-groups projections found in Section D of this chapter. The projections are based on the assumptions included in the assessment of each species.

The projections are generally more conservative than those found in the DPED's Technical Report, *The Hawaii State Plan–Economy* (1977). The principal reason for this difference is the fact that the projections indicated here are based on considerably more information than was available in late 1976. Furthermore, this present report assumes a longer, more conservative commercial growth rate, and a longer period of development. After the initial five years of commercial culture, projected growth rates are essentially similar between the two reports.

Aquaculture is expected to contribute significantly to other sectors of Hawaii's economy. Table 27 relates gross annual wholesale revenue projections to various economic sectors based on a typical percentage of wholesale revenues, production costs, amount of profit, and taxes. These sectors are expected to expand to meet the emerging needs of the aquaculture industry. It is particularly important that the feeds and fertilizer sector expands, as feeds and fertilizers represent a major production expense that is second only to the cost of labor.

Table 27. Projected Benefits to Other Industries Based on Percentage of Wholesale Revenues

Industry or Segment	*	Projected Revenues (Wholesale, Thousands of 1978 Dollars)					
		1978	1980	1985	1990	1995	2000
Lease or Payment on Land Purchase	3.5	$ 33	$ 223	$ 1,143	$ 2,499	$ 5,179	$ 11,710
Engineering and Consulting Industry	2.0	19	128	653	1,428	2,960	6,691
Construction and Equipment Industries	18.0	168	1,149	5,876	12,854	26,638	60,222
Insurance Industry	1.2	11	77	392	857	1,776	4,015
Feeds and Fertilizer Industries	16.0	149	1,021	5,223	11,426	23,678	53,531
Electricity and Utilities Industries	3.8	35	242	1,240	2,714	5,623	12,713
Supplies, Goods, and Services Industries	15.4	143	983	5,027	10,997	22,790	51,523
Employment	19.0	177	1,213	6,202	13,568	28,118	63,568
Profit	19.5	181	1,244	6,366	13,925	28,858	65,241
Property Taxes	1.1	10	70	359	785	1,628	3,680
General Excise Taxes	.5	5	32	163	357	740	1,673
Totals	100.0	$931	$6,382	$32,644	$71,410	$147,988	$334,567

*Percent of Wholesale Revenues. Percentages are expected to vary from firm to firm and type of culture (e.g., extensive or intensive). These figures are based on semi-intensive, earthen pond culture which is expected to be used to raise freshwater prawns, marine shrimp, baitfish, freshwater finfish, etc.

Research, training and technology transfer sector. The significance and potential of the aquaculture research, training and technology transfer sector's contribution to Hawaii's economy were discussed in Chapter I, as well as Section B of this chapter. Initially, the majority of non-State funding for this sector is anticipated to come from the Federal government through two programs: Title XII of the Foreign Assistance Act of 1975, and Section 406 of the Food for Peace Act of 1966 as amended in 1972. Additional funds are expected from the U.S. Department of Agriculture as a result of the recently enacted Comprehensive Farm Act of 1977. By 1985, the total contribution from these and other funding sources for Hawaii is expected to be as much as $6 million to $10 million per year, and directly or indirectly employ as many as 300 to 400 people. This effort would be only one component of a larger program in tropical food production administered by the University of Hawaii's College of Tropical

Agriculture. Since these activities are essentially an R&D in nature they are not only environmentally attractive, but promise to provide additional economic benefits through a multiplier effect, i.e., at least 50 percent of each dollar brought into the State is usually spent on salaries and wages, which are respent many times over for goods and services (*Hawaii Business News*, February, 1978).

Future Considerations

The discussion of aquaculture's role in Hawaii's future will be presented in two parts. The first discusses aquaculture's relationship to, and effect on, several existing State goals. The second considers the impact of future trends on key elements of the aquaculture industry in Hawaii.

Relationship to some existing State goals. Various aquaculture technologies can contribute to the realization of many Stare goals for maintaining and improving the quality of life in Hawaii. These goals include: preservation of open spaces, reduced development pressures on prime agricultural lands, diversification of the economies of all Islands leading towards State self-sufficiency in food production, provision of opportunities for rural residents to preserve their agrarian life-styles, provision of an increased and a wider range of employment opportunities, improvements in the balance of trade by increasing exports and encouraging the substitution of locally-farmed aquatic products for imports, and finally, preservation of existing and development of new recreational and commercial fisheries resources for the people of Hawaii.

Aquaculture relates to these important State goals in a number of ways:

Open space. Open space qualities of land can be preserved because aquaculture production units do not generally utilize tall structures under the management strategies practiced today, e.g., ponds, raceways and cages (Bardach et al., 1972).

Land utilization. Many forms of aquaculture can utilize land that is of a lower quality than prime agricultural land, thereby not contributing to further increases in developmental pressure.

Self-sufficiency. Since aquaculture's primary function is growing food, it can help reduce the State's reliance on imports, while contributing towards self-sufficiency. In a similar fashion, certain forms of aquaculture (aquatic algae) can produce animal feeds and further reduce the volume of other important imports.

Diversification. The anticipated growth of the commercial production industry can be directed to the Neighbor Islands because of its close affinity to certain forms of agriculture which predominate there, e.g., sugarcane. Such growth would provide the opportunity for much needed diversification of Neighbor Island economies.

Employment. The potential expansion of the aquaculture industry can increase and diversify employment opportunities for semi-skilled as well as skilled workers—particularly on the Neighbor Islands.

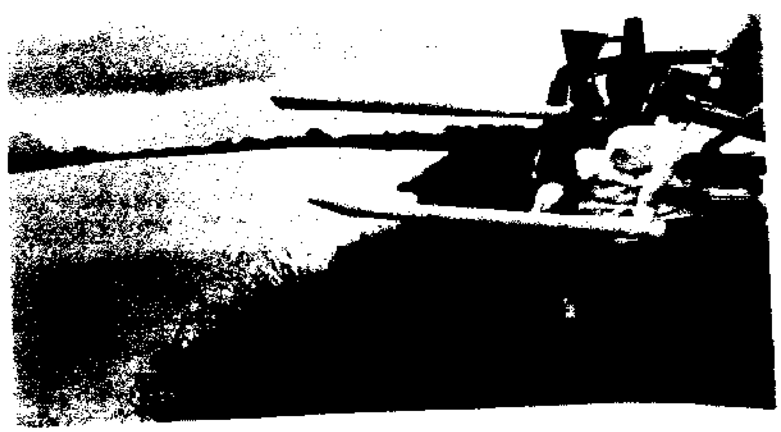
Life-styles. Aquaculture technologies can be readily integrated with current forms of agriculture and can help people preserve rural agrarian life-styles by providing opportunities for additional economic alternatives.

Aquaculture in Hawaii has the potential to provide more jobs and significant spin-off benefits in such areas as feeds, construction, and goods and services. Equally important, aquaculture is expected to maintain rural life-styles and preserve the environment.

Aquaculture can contribute to the State goals set forth in The Hawaii State Plan.

Aquaculture can increase and diversify employment opportunities.

Aquaculture may be a component of alternate energy sources, such as Ocean Thermal Energy Conversion. (Drawing by R. Young.)



New technological developments, such as this prawn feeder, are expected to accelerate the growth of the aquaculture industry. (Courtesy of UH Department of Agricultural Engineering.)

Resources. Aquaculture can preserve existing, and develop new, recreational and commercial fishing resources through natural stock enhancement activities (Rao, 1977) and through assisting in the development of commercial fisheries (*Hawaii Tuna Fishery Development Plan,* 1977).

It is important to note that production strategies which are projected for general use in future aquaculture systems are not likely to pollute the environment or have a pollution potential that is easily controlled. Therefore, the development of these systems can contribute to Hawaii's economy, while helping to preserve the overall quality of life.

In summary, a dynamic, growing aquaculture program will help to achieve State goals and provide Hawaii's citizens with many opportunities to aid in their own future economic, social, and environmental well-being.

Impact of Future Trends on the Growth of Aquaculture

Aquaculture, like other economic activities, can be described as a process with inputs (land, water, labor, energy, etc.) into the production of a product, transportation of the product from the production site to a market, and the sale of the product at the market. The future cost, availability and feasibility of these components will be determined–to a large extent–by several important trends. Three such trends that will undoubtedly have an impact on local aquaculture are (1) increases in population, (2) rising energy costs, and (3) competition from capture fisheries and out-of-State aqua-production. In order to determine the future growth of aquaculture in Hawaii, the impact of these trends on key elements of the industry must be considered.

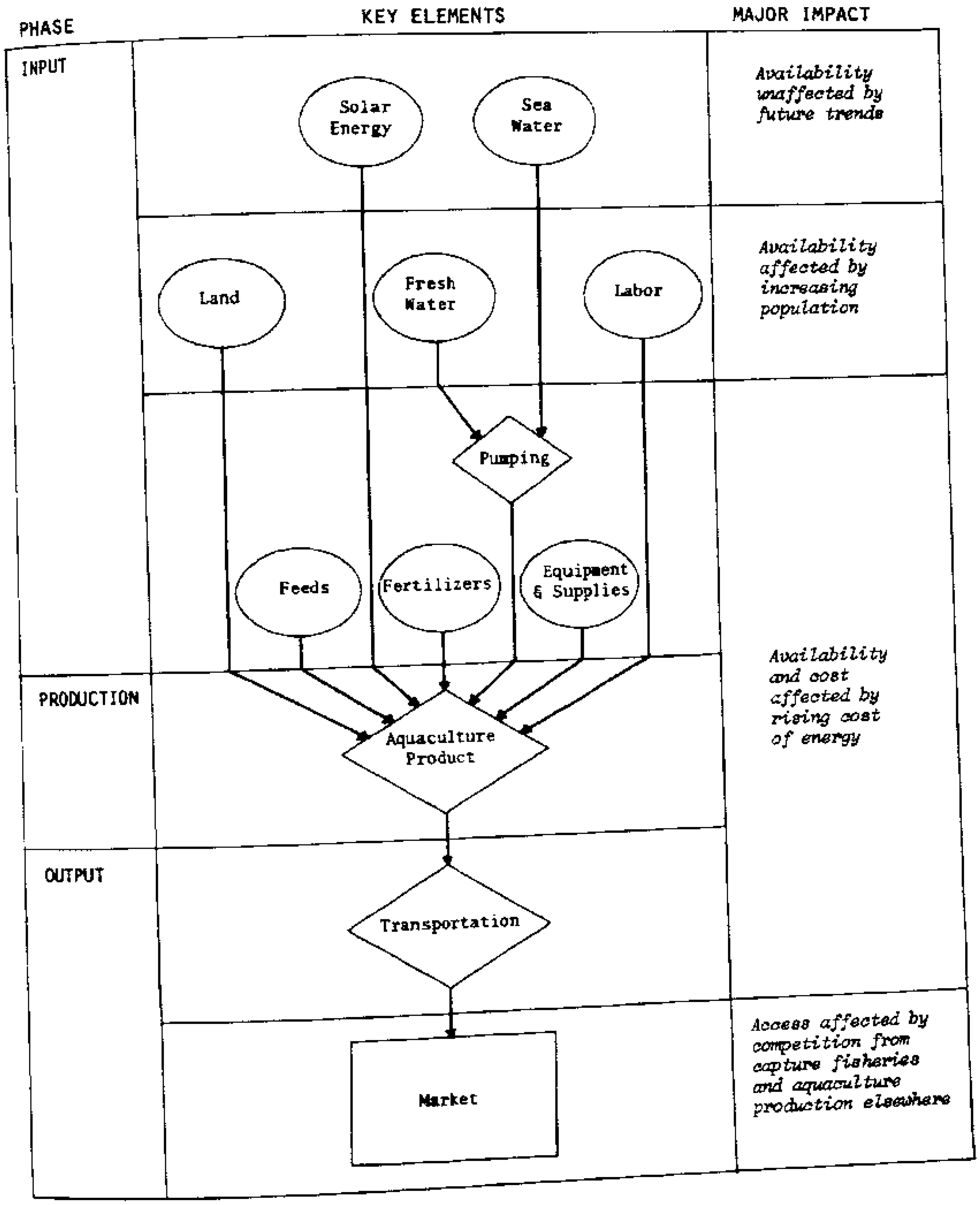
Figure 3, which depicts a simplified aquaculture process chart, relates the three trends to the various elements of the aquaculture process. The relationship between the key elements of aquaculture and these trends are presented in four major categories: (1) those elements whose availability is relatively unaffected by future trends, (2) the effects of increasing population pressure, (3) the effects of rising energy costs and (4) the effects of competition from capture fisheries and aquaculture production elsewhere.

Elements unaffected by future trends.

Solar energy. Year-round sunshine and warm temperatures are valuable resources for Hawaii's agriculture and aquaculture industries. Solar energy has been captured and utilized through production of sugarcane and pineapple. In addition to providing a warm climate for the growth of aquatic life, solar energy can be exploited in other ways (e.g., solar energy power and heating systems). Aquaculture operations of the future should stress efficient energy conversion systems based on exploitation of natural productivity and food chains to produce a diversity of products, including food for human consumption, terrestrial and aquatic animal feed, and biomass for energy conversion (see "Rising Energy Costs" below).

Salt and brackish water. Another of Hawaii's most important resources is an abundance of clean, warm seawater. Unlike fresh water, salt water is not limited in quantity nor is there a large number of competitive uses for the supply. Moreover, brackish water (a mixture of fresh and salt water), which is also abundant, is similarly not subject to a number of competing uses since it cannot be used to satisfy irrigation or domestic water requirements. Brackish water has numerous applications in aquaculture. Moreover,

Figure 3. Impact of Recognized Future Trends on Key Elements of Aquaculture



many freshwater species, such as freshwater prawns, catfish, topminnows, and tilapia are salinity-tolerant to some extent, which allows them to be cultured in less than fresh water. For example, the freshwater prawn exhibits comparable growth rates in salinities up to 18 ppt (half salt water) and the topminnow and tilapia can tolerate salinities ranging from fresh water to straight seawater.

Aquaculture systems of the future should strive to utilize brackish and salt water wherever possible, in order to make maximum use of Hawaii's resource base and relieve pressure on Hawaii's freshwater resources (see "Fresh water" below).

The effects of increasing population pressures. The availability and costs of land, fresh water and labor will unquestionably be affected by population increases. Approximately half of Hawaii's population growth is due to natural population increases (births minus deaths) which are influenced by social, medical and legal not economic-factors (*The Hawaii State Plan*, 1977). The remainder is attributable to immigration from the Mainland and Asia. Here, too, non-economic factors play an important role. Asian immigrants are primarily influenced by such factors as Federal immigration laws and the presence of their relatives in Hawaii. Therefore, the major controllable factors that can determine the future growth of Hawaii's population will be Federal immigration laws and State-controlled growth policies (*The Hawaii State Plan*, 1977).

Land. Land is perhaps Hawaii's most valuable resource because the supply is limited, and there is intense competition to use that which is available. The major competitors are agriculture, tourism and urban/industrial development. Section A of this chapter indicated that there are 135,000 acres of primary lands and nearly 500,000 acres of secondary lands within the State which are suitable for aquaculture development. An important question is, how much of this land will be available for aquaculture?

It is envisioned that industrial agriculture (sugarcane and pineapple) and diversified agriculture (all other agriculture, e.g., flowers, macadamia nuts, papayas, etc.) will compete for primary lands for some time to come. Moreover, future decisions on the use of these primary lands will probably be made on the basis of economics, i.e., what is the best, most profitable use of the land? Aquaculture can be expected to compete favorably with industrial agriculture and diversified agriculture. For example, the average acre of irrigated sugarcane yields a gross annual per acre revenue of approximately \$1,000. Freshwater prawn production, however, can realize a gross annual per acre revenue that is greater than \$10,000. Moreover, a comparison of the labor-to-land ratio indicates that aquaculture would employ two-and-a-half times more people than sugar (one man per 25 acres for sugarcane production versus one man per 10 acres for freshwater prawn farming). To summarize, then, aquaculture can compete favorably in land use decisions when comparisons are made with industrial and diversified agriculture as long as the productivity and profitability of aquaculture are defined and publicized.

There are, however, other factors which will have a profound effect on reducing the number of sites available for aquaculture. For example, land will be needed for urban expansion. Inasmuch as aquaculture is a "clean" industry, consistent with State goals of preserving open spaces, maintaining rural life-style, providing employment and contributing to the balance of trade, urban planners should be encouraged to direct urban and residential growth to those areas which are not otherwise suitable for aquaculture and diversified agriculture. Valleys, hills and ridges are examples of such areas.

There is intensive competition for the use of Hawaii's coastal lands. Urban development, tourism, and recreation are among the major competitors. Brackish and salt water culture systems require access to seawater—hence coastal areas. Aquaculture has the advantage of being able to utilize such lands as wetlands, mudflats and estuaries which may be less than ideal for many forms of recreation and tourist development. Aquaculture operations in coastal lands can be encouraged through land use policies which establish aquaculture as a preferred activity in this area.

Hawaii's more than 500,000 acres of secondary lands present significant opportunities for aquaculture. There is little competition for secondary lands which are made up, for the most part, of gently sloping lava flows on the island of Hawaii. For example, the South Kohala and Kona regions possess an abundance of secondary lands, with some of the warmest temperatures and highest solar intensities in the State. The development of an effective, low-cost means of sealing ponds dug in lava and/or the development of semi-intensive or intensive, above-ground culture systems would create a tremendous economic potential for these secondary lands.

Fresh water. Hawaii possesses an abundance of high quality fresh water, although such areas as Maui, parts of Hawaii and Oahu intermittently experience water shortages. It has been estimated that Oahu's demands for water will begin to tax the total available supply by the year 2000 (*Hawaii Regional Water Resources Study,* 1977).

Several existing and envisioned aquaculture systems can lessen future demands on the State's fresh water supplies through water conservation and multiple-use practices. For example, in cases such as freshwater prawn farming, water flow rates can be reduced through implementing water quality management procedures (see "Pumping," "Feeds," and "Fertilizers" below). In other cases where a flow-through system is desirable, aquaculture effluents can be reused for terrestrial crop irrigation, thus providing for multiple-use. In addition, aquaculture growth policies can stress the development and exploitation of brackish and saltwater aquaculture systems (see "Seawater").

Finally, aquaculture holds significant promise as a mechanism for both livestock and domestic waste-water recovery. Several pilot and commercial-scale waste-water recovery systems in operation around the world today utilize aquaculture for reclaiming both water and nutrients (see "Feeds" and "Fertilizers" below). Aquaculture should, therefore, be considered in the planning of future waste treatment facilities.

Labor. Current aquaculture operations embody all levels of technology, from the most extensive pond systems with low-level management and no supplemental feeding, to highly sophisticated, totally automated, closed systems. Nearly all forms of aquaculture—with the possible exception of ocean ranching—are likely to be practiced in Hawaii (*Hawaii Aquaculture Planning Program—Interim Report,* 1977) and, all levels of skills and technical training are, therefore, likely to be needed. The types of labor that might be required include unskilled and semi-skilled laborers, technicians, farm managers, food processing specialists, and marketing personnel, as well as a broad range of professionals from many disciplines including biologists, algologists, nutritionists, chemists, engineers, food scientists, geneticists, economists, and business management analysts.

For the present and near future, the aquaculture industries' greatest demand will be for unskilled and semi-skilled laborers and technicians. It will be necessary, then, to provide educational opportunities in aquaculture at the secondary and community college levels. Ultimately, the commercial production sector, as well as the research, training and technology transfer sector, will need significant numbers of highly trained individuals. This is particularly true if aquaculture becomes increasingly specialized and mechanized—

the pattern of development experienced by modern industrial agriculture. Ultimately, the development of an undergraduate and graduate aquaculture curriculum will be required in the University of Hawaii system.

The effects of rising costs of energy. Hawaii currently imports all of the petroleum products needed to fulfill the State's energy demands. The cost of these products has risen steadily over the past years and is expected to continue to increase. Because of these factors, energy is a top priority issue in the State.

Hawaii has recently taken some bold and aggressive steps toward solving its energy problems by establishing a program with an emphasis on renewable and inexhaustible energy sources that will eventually lead to energy self-sufficiency. Promising new sources of energy for Hawaii include geothermal, biomass, ocean thermal energy conversion (OTEC), direct solar energy conversion, and wind energy conversion (Energy Resources Coordinator, *1977 Annual Report*). Aquaculture can be an important component of biomass and OTEC energy systems.

Biomass energy conversion consists of growing plant life, such as algae, sugarcane or trees, and converting this into a more convenient energy form such as biogas (mostly methane), alcohol or electricity. Several biomass demonstration projects for working out the feasibility of key system components are currently in progress.

Ocean thermal energy conversion utilizes the temperature difference between surface water and the colder deep water to run turbines for generating electricity. The cold water which is eventually discharged is higher in nutrients compared to surface waters and may be used for an aquaculture operation. Small-scale experiments are currently taking place at Ke-ahole Point on the island of Hawaii to test component systems. Large-scale pilot tests may begin next year.

The successful development of the various alternate energy sources for Hawaii will undoubtedly help the State to become more energy self-sufficient and provide certain energy cost savings. The cost of energy and energy-related items, however, will probably still continue to increase. The inputs most seriously affected are feeds, fertilizers, pumping, equipment, supplies and transportation.

Feeds. Hawaii presently imports nearly all of its animal feed ingredients (*State of Hawaii Data Book,* DPED, 1977). This problem is shared by both diversified agriculture and aquaculture. Past attempts at producing feed ingredients locally have not always proven economically successful. From a purely economic perspective, feed ingredients should be produced locally only if they are able to compete with imported ingredients.

Perhaps the most significant means of reducing the State's dependence on formulated feeds is the encouragement of integrated aquaculture systems based on primary productivity (photosynthesis) or nutrient recovery from plant, animal or domestic waste (see "Fresh water" above).

Fertilizers. The major ingredients for primary aquatic productivity are sunlight, water and nutrients. Hawaii must import nearly all its fertilizer ingredients. Moreover, nitrogen fertilizers are extremely sensitive to rising fuel costs because a tremendous amount of energy is used in their production. Aquaculture's dependence on fertilizers can be reduced through the recovery of nutrients from animal and domestic waste (see "Feeds" and "Fresh water" above). Other mechanisms include the use of deep ocean (OTEC) water to supply nutrients.

Pumping. Pumping accounts for a substantial percentage of production costs. These costs are directly related to the cost of energy, no matter what form of energy is used. Fortunately, there are several ways to make pumping less expensive. The development of alternate energy sources, together with the implementation of conservation practices, will most certainly reduce costs. Pumping costs can be further reduced by practicing good water quality management (see "Fresh water" above). In addition, the design of commercial operations can utilize gravity flow wherever possible. Finally, as aquaculture technology continues to develop, the design of closed and semi-closed systems could not only reduce water requirements, but also reduce pumping costs.

Equipment and supplies. Much of the equipment and supplies necessary for aquaculture businesses are currently available through agriculture and fishing equipment suppliers. For example, pumps and piping for water distribution systems are readily available from irrigation supply companies. However, much of the more specialized equipment, such as feeders, processing and handling equipment, aerators and water quality test equipment, must often be ordered from the Mainland. As the demand for such goods and services increases, local distributors and dealers are likely to be established. This scenario provides another illustration of the beneficial secondary and tertiary effects of the growth of aquaculture on Hawaii's economy.

Transportation. Transportation plays an important role in the marketing of aquaculture products. Chapter I and Sections D and E of this chapter have emphasized that major opportunities for aquaculture as an industry for Hawaii lie in the production of export products. Each priority species in this report has a significant export potential. As local demands are satisfied and export markets explored, the producer must consider how to deliver his product to the marketplace in the most timely and efficient manner. Transportation costs, which are reflected in the sale price of the product, are particularly sensitive to rising energy costs. This is expected to have mixed effects on the prices for Hawaii's cultured aquatic products in Mainland markets. The rates for shipping from Hawaii to the Mainland are often lower than shipping from the Mainland to Hawaii. This is due to the fact that more products are shipped to Hawaii than are shipped out, often resulting in partially filled vessels returning to the Mainland. Therefore, aquaculture exporters may expect preferential back-haul rates to the Mainland.[20] Moreover, shipping rates between the Mainland and Hawaii are generally lower than comparable distances to other locales due to the higher volume of traffic between Hawaii and the Mainland. Hawaii is, therefore, in a more favorable position than other locations with respect to the cost of transporting products to the Mainland marketplace.

The possibility exists, however, that increased aquaculture production and exportation may have a cancelling effect on the preferential back-haul rates. In the long run, this intensifies the need for developing efficient, low-cost, high density shipping devices. The transportation industry has a history of providing assistance to their customers in meeting their specific transportation needs and can be expected to provide similar assistance to aquaculture exporters.

Competition from capture fisheries and out-of- State aquaculture production. The successful development of aquaculture in Hawaii is predicated on the ability of the State's cultured aquatic products to compete in the marketplace with products cultured elsewhere.

---

[20] From an Aquaculture Planning Program survey of surface and air transportation companies, 1977.

and with worldwide capture fisheries. The decline in world capture fisheries is expected to result in significant opportunities not only for aquaculture in Hawaii, but for aquaculture in many foreign countries. Hawaii's aquafarmers are likely to experience the most competition from producers in Asia, Central and South America. While it is reasonable to assume that locally cultured products may—through import quotas and tariffs—have an advantage over foreign-produced items, price and quality are, nonetheless, the major determinants at the marketplace.

This chapter has discussed various factors affecting the price and quality of Hawaii's cultured aquatic products. Major advantages include Hawaii's warm climate, strategic geographic location, an abundance of land suitable for aquaculture, the likelihood that the State will become a major center for technology transfer and development, and Hawaii's political stability relative to many lesser-developed countries. Most important, perhaps, is the fact that the State is planning now for aquaculture development and for self-sufficiency in areas—such as energy—that are crucial to the future of aquaculture. Planning is important in anticipating trends and solving problems before they become major constraints for development.

CHAPTER III

GUIDELINES FOR DEVELOPMENT

The rate of aquaculture development in Hawaii can be accelerated through the coordinated use of resources and the implementation of the actions recommended in this chapter and further elaborated upon in Chapter IV, "Implementation." This will require the appropriate timing and scheduling of activities as well as provisions for long-range direction. The goal of aquaculture development, together with its objectives, policies and recommended actions, offer guidelines for the expansion of both sectors of the industry.

Goal

The goal of aquaculture development in Hawaii is *the realization of commercial aquaculture production as a major economic activity, and the establishment of the State as a national and international center of aquaculture expertise.*

Concerted efforts to achieve this dual goal can contribute to the attainment of several widely recognized State objectives. These are listed below.

- Provision of more, and a diverse range of, employment opportunities.
- Diversification of the economies of all Islands.
- Greater self-reliance in food supply by substituting locally farmed aquatic products.
- Improvement in the balance of trade by increasing exports of aquatic products.
- Reduction of development pressure on prime agricultural lands.
- Assurance of opportunities for rural residents to preserve their life-styles.

- Maintenance of open spaces.

- Enhancement of the State's quality of life, involving economic, social, cultural and environmental components, by the wise use of Hawaii's natural and human resources.

Objectives

Six broad objectives targeted at expanding the rate of growth in commercial aquaculture production and supporting aquaculture research, training and technology transfer are listed below. The objectives, underscored by key-word subject areas, exhibit a high degree of overlap with respect to meeting the needs of the two sectors. This is understandable because the activities of both fully complement each other.

1. Achieve a *unified approach* to State-supported aquaculture and aquaculture-related activities to insure that Hawaii and its people derive maximum economic and social benefits.

2. Improve the *business climate* for commercial aquaculture operations.

3. Identify *new economic opportunities* in aquaculture which make wise use of Hawaii's resources.

4. Achieve leadership and *excellence* in national and international aquaculture *research and development, training and technology transfer.*

5. Provide a wide range of opportunities in *vocational training and formal education* at all levels to meet the needs of Hawaii's aquaculture industry.

6. Establish Hawaii as a *world center* for the collection and dissemination of tropical aquaculture *information.*

Policies and Recommended Actions

Each objective is presented and followed by a statement of rationale and a set of policies that provide long-term guidance on how to achieve the objective. The policies, in turn, are followed by a series of recommended actions which include a suggested agency or agencies for implementing these actions and an appropriate schedule for implementation. Some recommendations concern the initiation and continuation of new activities, while others suggest that single, one-time-only actions are necessary. Several recommendations confirm the need for continuing existing services, while others are of a tentative nature because of uncertainties in financing and possible changes in organization.

Additional recommended actions which will contribute to effective implementation are found in Chapter IV, "Implementation," which follows this chapter. The areas covered will be procedure, management, organization, and budget.

Unified Approach

Objective 1

Achieve a unified approach to State-supported aquculture and aquaculture-related activities to insure that Hawaii and its people derive maximum economic and social benefits.

Rationale

In order to achieve the goal of accelerated aquaculture development through the wise use of Hawaii's resources, it is important to develop mechanisms which can provide a focal point for visibility, accountability, coordination and planning. Moreover, the recommended actions require a high degree of interaction and coordination and stress the necessity of the multiple use of personnel and facilities. The present status does not permit effective implementation of the recommendations without some consolidation and the establishment of formalized relationships among the various components.

Policies

a. Encourage the formation of mechanisms that will provide unified, timely and efficient responses to aquaculture development needs.

b. Encourage State efforts to share the cost of developing aquaculture with private and other government sources.

c. Encourage a high degree of interaction with commercial producers in order to insure that State-supported aquaculture activities are responsive to industry needs.

d. Encourage a high level of governmental interaction to insure the timely and effective implementation of aquaculture development activities.

Recommended Actions

a. **Assign responsibilities for aquaculture development to either the DOA or the DLNR** as the lead agency to implement the recommended actions of this report. Assure that the administration of those aquaculture facilities currently housed at the AFRC be under the administration of the lead agency. (Appendix A, "A Lead Agency for Aquaculture Development in Hawaii"). Appropriate necessary operating funds (Chapter V, "Budget and Timetable"). *Action agency*: Legislature. *Timing*: 1979.

b. **Actively pursue national, international and private funds** to share the cost of developing aquaculture in Hawaii, and assist the University of Hawaii and other groups in grant development activities with emphasis on achieving the highest possible ratio of non-State to State funds. *Action agency:* Lead agency. *Timing*: Continue this ongoing service.

c. **Establish a hatchery revolving fund** whereby State hatchery activities can eventually become self-supporting. *Action agency:* Legislature. *Timing:* 1979.

d. **Interact with other State and County agencies** to insure that aquaculture is considered in their planning and development decisions. *Action agency:* Lead agency. *Timing:* Continue this service.

e. **Regularly assess producers' needs for support services** so that the State can consider providing those services that are not available or limited in the private sector. *Action agency:* Lead agency. *Timing:* Begin in 1978 and continue.

f. **Establish appropriate existing and new aquaculture facilities** as jointly designated lead agency/University of Hawaii facilities. *Action agency:* Lead agency and the University of Hawaii. *Timing:* Begin discussions in 1978 to designate the AFRC as a joint facility and consider joint designation of new facilities during the initial planning stages.

g. **Establish cooperative programs** in research and extension and determine the most appropriate procedures for joint appointment of the lead agency/University of Hawaii personnel involved. *Action agency:* Lead agency and University of Hawaii. *Timing:* Initiate upon establishment of a permanent lead agency.

h. **Establish a program review panel** to provide input from producers, distributors, researchers, funding sources, feed suppliers and lenders, and to perform external review of State-supported aquaculture activities. *Action agency:* Governor. *Timing:* Create upon establishment of a permanent lead agency.

i. **Appropriate funds for the construction of outdoor experimental research and training facilities**, including fresh- and saltwater experimental ponds, laboratories, and classrooms to meet current and near-term needs (see Appendix B, "Tropical Aquaculture Center for Hawaii"). *Action agency:* Legislature. *Timing:* 1978.

j. **Plan, design and construct outdoor experimental research and training facilities** (see Appendix B). *Action agency:* Lead agency and University of Hawaii. *Timing:* 1978–1980.

k. **Appropriate funds for the construction of additional outdoor experimental research and training facilities** to meet the expanded needs of research and development, and training programs (see Appendix B). *Action agency:* Legislature. *Timing:* 1981.

l. **Plan, design and construct additional experimental research and training facilities** to meet expanded program needs (see Appendix B). *Action agency:* Lead agency and University of Hawaii. *Timing:* 1981–1983.

Business Climate

Objective 2

Improve the business climate for commercial aquaculture operations.

Rationale

The term *climate* refers to various activities affecting the establishment of a successful aquaculture business. State policies and the associated development activities can have a profound effect on this climate through the removal of institutional constraints, and the provision of loans, incentives, extension and advisory services, hatchery-produced stocking material, market development assistance and other support services. Research aimed at improving the efficiency of production and reducing production costs can make the difference between a marginal and profitable investment. The recommendations offered in this section are aimed at fostering the successful coexistence of all scales of commercial aquaculture enterprises.

Policies

a. Reduce or remove institutional constraints to commercial aquaculture development.

b. Help assure reasonable access to credit for commercial operations.

c. Increase the capabilities of existing and potential commercial aquafarmers in establishing and managing their operations through the provision of needed technical support services and activities until such time as they are made available by the private sector.

d. Encourage an increased rate of expansion in aquaculture production through the provision of appropriate incentives.

e. Provide activities which contribute to the identification and reduction of risks to commercial aquaculture operations.

f. Encourage the continued assessment of sites well-suited for commercial aquaculture and promote public policies which specifically identify aquaculture as an alternate use of land and water resources.

g. Encourage the provision of State assistance to identify and develop local and export markets for Hawaii's cultured aquatic species.

h. Encourage the coexistence and viability of all scales of commercial aquaculture operations.

i. Encourage the expansion of Hawaii's feed industry to meet the increasing needs of aquaculture producers.

Recommended Actions

a. **Provide assistance to prospective aquafarmers regarding permit and environmental requirements** for aquaculture operations, including time and sequence of filing, data requirements, issuing agency, cost and problem areas. *Action agency:* Counties and lead agency. *Timing:* Continue this service.

b. **Increase awareness and understanding among Federal, State, and County regulatory agencies** of the activities and processes involved in aquaculture production by the dissemination of information. This will enable agencies to review applications more rapidly, effectively and efficiently. *Action agency:* Lead agency. *Timing:* Begin in 1978 and continue.

c. **Establish simplified administrative approval procedures** for issuance of permits for aquaculture activities through enabling legislation. *Action agency:* Legislature. *Timing:* 1979.

d. **Establish a central permit coordinating agency** with one master permit application form and consolidated notices and hearings at the State level. The Federal government should also be encouraged to consolidate permit requirements and coordinate with the State. *Action agency:* Legislature. *Timing:* 1979.

e. **Review the Aquaculture Revolving Loan Fund** periodically and, when necessary, make additional appropriations to the Fund. *Action agency:* Legislature. *Timing:* Begin in 1979 and continue as needed.

f. **Provide lenders with information** on the costs of construction and operation of various types of aquaculture systems. *Action agency:* Lead agency. *Timing:* Begin in 1979 and continue.

g. **Provide such support services** as disease diagnosis and prevention, stocking material, water chemistry and soil analyses, as well as advice on site selection, permits and business and pond management to existing and prospective aquafarmers as needed (refer to Chapter IV, "Implementation"). *Action agency:* Lead agency and University of Hawaii. *Timing:* Continue existing services and provide new services as needs arise and resources allow.

h. **Provide property and excise tax incentives** to aquaculturists for specifed periods. *Action agency:* Legislature. *Timing:* 1979–1984.

i. **Provide long-term leases of State lands** to aquaculturists at reasonable rates. *Action agency:* Department of Land and Natural Resources. *Timing:* Begin in 1978 and continue.

j. **Continually identify and publicize through brochures and bulletins significant risks** associated with operating aquaculture enterprises. *Action agency:* Lead agency. *Timing:* Begin in 1979 and continue.

k. **Establish additional agriculture/aquaculture parks** so that aquafarmers can benefit from production and distribution economies as well as special land-use regulations. *Action agency:* Department of Agriculture and Department of Land and Natural Resources. *Timing:* Begin in 1979 and continue.

l. **Interact with economic, land and water-use, and other resource planning efforts** to:

   1. Encourage aquaculture operations on lands identified as suitable for aquaculture development.

   2. Discourage the urbanization of lands well-suited for aquaculture.

   3. Encourage projects which increase the availability of water for aquaculture.

4. Provide input concerning uses of aquaculture technologies and their economic, social and environmental impacts.

Action agency: Lead agency. *Timing:* Begin in 1978 and continue.

m. **Establish aquaculture activities as permitted uses within conservation districts.** *Action agency:* Department of Land and Natural Resources. *Timing:* 1978.

n. **Consider the feasibility of restoring representative Hawaiian fishponds** as historical features, tourist attractions and possible sites for commercial aquaculture operations. *Action agency:* Legislature. *Timing:* 1979.

o. **Continue to assess sites for aquaculture** with particular attention to sites suitable for coastal or open-sea mariculture as well as unutilized and underutilized lands. *Action agency:* Lead agency. *Timing:* Continue this service.

p. **Establish and maintain a reporting activity** for Hawaii's cultured aquatic products. *Action agency:* Lead agency. *Timing:* Begin in 1980 and continue.

q. **Assist producers in the timely implementation of product development projects** for freshwater prawns and other cultured products, addressing such areas as consumer awareness and the establishment and expansion of local and export markets. *Action agency:* Lead agency and the Department of Planning and Economic Development. *Timing:* Begin immediately and continue.

r. **Assist in the establishment of high quality standards** for Hawaii's cultured aquatic products. *Action agency:* Lead agency. *Timing:* Begin immediately and continue.

s. **Monitor national and international levels and prices of production, sales and inventories** which affect aquatic products cultured in Hawaii. *Action agency:* Lead agency. *Timing:* Begin in 1980 and continue.

t. **Work with other agencies to provide assistance to commodity associations and/or cooperatives.** *Action agency:* Lead agency and Hawaii Cooperative Extension Service of the College of Tropical Agriculture, University of Hawaii. *Timing:* Continue this service.

u. **Support directed research** to reduce production costs, increase yields, and develop new product forms of species currently under culture in Hawaii. (New facilities are required. See Objective 1, Actions j, k, l and m.) *Action agency:* Lead agency. *Timing:* Continue this service.

New Economic Opportunities

Objective 3

Identify new economic opportunities in aquaculture which make wise use of Hawaii's resource base.

Rationale

In order for aquaculture in Hawaii to reach its full potential while appropriately utilizing available resources including both fresh and salt water and both prime and marginal lands, diversity of species and culture systems is essential. A phased approach to species development is recommended and presented in Chapter IV, "Implementation." This methodology will insure that the proper candidate species is selected and brought from candidacy to commercial culture on a least-cost basis.

Policies

a. Encourage the development of culture techniques for species which can substitute for imported aquatic products or which have significant potential for export.

b. Promote the use of unutilized or underutilized land and water resources for aquaculture.

c. Encourage the examination of energy production, waste-recovery and water conservation techniques for application in aquaculture.

d. Encourage aquaculture activities which contribute to both commercial and recreational fisheries.

e. Promote efforts towards increasing the efficiency of aquaculture systems through polyculture and integration with other food systems, and the multiple use of resources.

Recommended Actions

a. **Support the demonstration, under local conditions, of the commercially viable culture of species or species-groups** whose culture technologies have been developed elsewhere. (New facilities are needed. See Objective 1, Actions j, k, l and m.) *Action agency:* Lead agency. *Timing:* Continue this service.

b. **Provide funds for research on a cost-sharing basis** aimed at providing a basic understanding of life cycles and environmental requirements of promising species. (New facilities are needed. See Objective 1, Actions j, k, l and m.) *Action agency:* Lead agency. *Timing:* Continue this service.

c. **Provide funds for testing the applicability of using aquaculture technologies** as components in Ocean Thermal Energy Conversion (OTEC) and biomass energy systems. *Action agency:* Lead agency. *Timing:* Begin in 1979 and continue.

d. **Provide funding to investigate the technical and economic feasibility** of using aquaculture for livestock waste recovery and wastewater recylcing and/or disposal. *Action agency:* Lead agency. *Timing:* Begin in 1978 and continue.

e. **Provide funding to determine the potential of aquaculture effluents** for terrestrial crop fertilization and irrigation. *Action agency:* Lead agency. *Timing:* Begin in 1979 and continue.

f. **Demonstrate the feasibility of using various cultured species as bait** for pole-and-line (skipjack tuna) and long-line fishing as well as for recreational fishing. *Action agency:* Lead agencies for fisheries and aquaculture development. *Timing:* Continue this service.

g. **Study the potential of enhancing natural populations** of popular sport fishes through release of hatchery-reared juveniles. *Action agency:* Lead agencies for fisheries and aquaculture development. *Timing:* Continue this service.

Excellence in Research and Development, Training and Technology Transfer

Objective 4

Achieve leadership and excellence in national and international aquaculture research and development, training and technology transfer.

Rationale

Significant opportunities exist for Hawaii to become a leader in national and international aquaculture R&D, training and technology transfer. Hawaii's strategic location relative to Asian and Pacific countries, its diverse climate which represents nearly all the major climatic regions, soils, and other conditions found in the developing world, and its acknowledged expertise in aquaculture are essential ingredients for success. In addition to bringing substantial research and training dollars into the State, creating additional jobs and an increased demand for goods and services, the realization of this objective will contribute to the achievement of nearly all other aquaculture development objectives.

Policies

a. Increase local, national and international awareness of the advantages of Hawaii's geographic location, climate, resources and long-standing ties with Asian and Pacific countries in research, training and technology transfer programs.

b. Strengthen Hawaii's technical resource base.

c. Encourage the development of additional facilities.

Recommended Actions

a. **Bring aquaculture meetings**, conventions, seminars, conferences, workshops, symposia, etc., to Hawaii, and support the participation of Hawaii's aquaculture community when these gatherings are held out-of-State. *Action agency:* Lead agency, DPED, University of Hawaii, East-West Center. *Timing:* Begin in 1979 and continue.

b. **Initiate advanced training programs** for foreign government administrators, technicians, instructors and advisers involved in aquaculture development. *Action agency:* University of Hawaii and East-West Center. *Timing:* Begin in 1979 and continue.

c. **Develop cooperative programs** with other leading universities or organizations which would include exchanges of aquaculture specialists, and provisions for visiting professors and researchers. *Action agency:* University of Hawaii and East-West Center. *Timing:* Begin in 1978 and continue.

d. **Develop interdisciplinary programs** which would encourage a lateral movement of specialists in traditional disciplines in other areas of investigation into the field of aquaculture. *Action agency:* University of Hawaii. *Timing:* Begin in 1978 and continue.

Vocational Training and Formal Education

Objective 5

Provide a wide range of opportunities in vocational training and formal education at all levels to meet the needs of Hawaii's aquaculture industry.

Rationale

The availability of a sufficient pool of qualified personnel for all aspects of aquaculture is fundamental to the realization of Hawaii's aquaculture goal. Vocational training and formal educational curricula should be planned to be in harmony with the expanding needs of the industry.

Policies

a. Encourage the development of aquaculture courses and/or curriculum to meet the needs of secondary, community college and university undergraduate and graduate students.

b. Encourage practical training activities which address the needs of Hawaii's aquaculture community.

Recommended Actions

a. **Develop a curriculum plan** in aquaculture for the entire University of Hawaii system including instruction, field experience and advance training to provide a base of skilled technicians and researchers. *Action agency:* University of Hawaii. *Timing:* Begin in 1978 and continue.

b. **Include the subject of aquaculture** in vocational agricultural or marine science studies at the secondary educational level to provide a labor base for Hawaii's aquaculture producers. *Action agency:* Department of Education. *Timing:* Begin in 1980 and continue.

c. **Initiate training programs** to meet the specific needs of Hawaii's aquaculture technicians and managers for refinement of skills. *Action agency:* Lead agency and University of Hawaii. *Timing:* Begin in 1979 and continue.

Information Center

Objective 6

Establish Hawaii as a center for the collection and dissemination of tropical aquaculture information.

Rationale

The rapid rate of new technological developments in aquaculture points to the need for a mechanism to provide for the efficient collection and dissemination of information. This mechanism will contribute to the effective management of State aquaculture development activities, to the improvement of the business climate, to the identification of new economic opportunities, and to the establishment of Hawaii's leadership and excellence in national and international programs.

Policies

a. Encourage the development of formal relationships with national and international organizations and agencies for the purpose of information exchange.

b. Promote Hawaii's geographic and cultural advantages as a focal point for information exchange.

c. Encourage the establishment of effective mechanisms to address the informational needs of both the commercial production and scientific communities.

Recommended Action

Establish an aquaculture information center for compiling and exchanging information on aquaculture research and commercial development activities of local, national and international entities to assure informed funding decisions and early application of the most recent results, and to avoid duplication of effort. Joint State/Federal and international funding of this activity should be actively pursued. *Action agency:* Lead agency, University of Hawaii and Legislature. *Timing:* Begin negotiations in 1978 to establish formal arrangements with Federal and international agencies and continue to phase in activity as relationships are established.

CHAPTER IV

IMPLEMENTATION

Accelerating the rate of aquaculture development in Hawaii will require the implementation of specific actions by the principal "action agencies" recommended in the previous chapter: (1) the Governor and the Legislature, (2) the various State and County agencies, (3) the University of Hawaii, and (4) the aquaculture lead agency. The first section of this chapter presents the actions recommended for the first three listed. The remainder of the chapter offers suggestions on how to achieve effective implementation of those actions to be carried out by the lead agency through an incremental approach in response to emerging needs. Several actions call for the combined efforts of the lead agency and the University of Hawaii (joint implementation). This emphasizes the need for joint programs, appointments and facilities to avoid duplication, as well as to increase effectiveness. Where there is joint implementation with the lead agency, the action is discussed under "Lead Agency."

Governor, Legislature, State and County Agencies and University

The Governor and the Legislature

The Governor and the Legislature have demonstrated their commitment to aquaculture development by designating aquaculture as a priority economic endeavor, enacting measures to reduce *red tape*, establishing a loan program, and making appropriations for support services, facilities, and research and demonstration. The following recommendations would build upon this strong support:

1. Assign responsibilities for aquaculture development to either the DOA or the DLNR to implement the recommended lead agency actions of this report. Assure that the administration of those aquaculture facilities currently housed at the AFRC be under the administration of the lead agency (see Appendix A, "A Lead Agency for Aquaculture Development in Hawaii"). Appropriate necessary operating funds (see Chapter V, "Budget and Timetable"). *Action agency: Legislature (Objective 1, Action a).*

2. Establish an advisory body to provide input from producers, distributors, researchers, funding sources, feed suppliers and lenders, and to perform external review of State-supported aquaculture activities. *Action agency: Governor (Objective 1, Action h).*

3. Appropriate funds for the construction of outdoor, experimental research and training facilities, including fresh- and saltwater experimental ponds, laboratories, and classrooms, to meet current, near-term, and expanded needs (see Appendix B, "Tropical Aquaculture Center for Hawaii"). *Action agency: Legislature (Objective 1, Actions i and k).*

4. Provide property and excise tax incentives to aquaculturists for specified periods. *Action agency: Legislature (Objective 2, Action h).*

5. Review the Aquaculture Revolving Loan Fund periodically and, when necessary, make additional appropriations to the Fund. *Action agency: Legislature (Objective 2, Action e).*

6. Establish a hatchery revolving fund whereby State hatchery activities can eventually become self-supporting. *Action agency: Legislature (Objective 1, Action c).*

7. Establish a central permit coordinating agency with one master permit application form and consolidated notices and hearings at the State level. *Action agency: Legislature (Objective 2, Action d).*

8. Establish simplified administrative approval procedures for issuance of permits for aquaculture activities through enabling legislation. *Action agency: Legislature (Objective 2, Action c).*

9. Consider the feasibility of restoring representative Hawaiian fishponds as historical features, tourist attractions and possible sites for commercial aquaculture operations. *Action agency: Legislature (Objective 2, Action n).*

State and County Agencies

State and County agencies have a broad spectrum of responsibilities affecting aquaculture, from education to economic development, to planning and regulating land and water uses. Since many State and County planning documents recognize aquaculture as a desirable economic activity, a greater degree of participation in aquaculture development can be expected in the future. The following actions identify specific areas for long-term contributions.

1. Provide assistance to prospective aquafarmers regarding permit and environmental requirements for aquaculture operations, including time and sequence of filing, data requirements, issuing agency, cost and problem areas. *Action agency: Counties and lead agency (Objective 2, Action a).*

2. Provide long-term leases of State lands to aquaculturists at reasonable rates. *Action agency: DLNR (Objective 2, Action i).*

3. Establish additional agriculture/aquaculture parks. *Action agency: DOA and DLNR (Objective 2, Action k).*

4. Establish aquaculture activities as permitted uses within conservation districts. *Action agency: DLNR (Objective 2, Action m).*

5. Include the subject of aquaculture in vocational agricultural or marine science studies at the secondary educational level. *Action agency: DOE (Objective 5, Action b).*

University of Hawaii

The University of Hawaii has the opportunity to play a major role in local, national and international aquaculture development programs. As pointed out in Chapter I, recently enacted Federal legislation, with important provisions for funding, could result in an increased number of significant research and training programs at the UH. It is anticipated that these will draw upon the resources of State agencies, the East-West Center, the Oceanic Institute, and other private institutions.

The UH's College of Tropical Agriculture, the principal eligible State recipient for this funding, has submitted proposals which, if approved, will greatly expand the University's role in RT&TT activities and contribute to substantial growth in Hawaii's RT&TT sector (*Hawaii Business*, February, 1978).

By implementing the actions listed below and working closely with other State agencies and private concerns, the University can establish Hawaii as a center of aquaculture expertise. This effort will also provide considerable benefits for commercial aquaculture in Hawaii as well as many countries of Southeast Asia and the Pacific Basin.

1. Develop cooperative programs with other leading universities or organizations (*Objective 4, Action c*).

2. Develop interdisciplinary programs which would encourage a lateral movement of specialists in traditional disciplines in other areas of investigation into the field of aquaculture (*Objective 4, Action d*).

3. Develop a curriculum plan in aquaculture for the entire University of Hawaii system (*Objective 5, Action a*).

4. Initiate advanced training programs for foreign government administrators, technicians, instructors and advisers involved in aquaculture development (*Objective 4, Action b*).

Lead Agency

It is essential that State efforts in aquaculture planning, research and development, and support be effectively coordinated. At present, no single State agency has the continuing authority to bring consistency of purpose to aquaculture development, nor is any single organization assigned to conduct a comprehensive program for stimulating private sector involvement. A lead agency can provide the necessary authority, responsibility, visibility, and accountability for continued State aquaculture development.

Criteria and candidates for the lead agency were examined as part of the Aquaculture Planning Program (see Appendix A, "A Lead Agency for Aquaculture Development in Hawaii"). It is recommended that the State Legislature designate either the

DOA or DLNR as the lead agency to implement recommendations of this report. It is further recommended that the administration of those aquaculture facilities currently housed at the AFRC be a function of the lead agency (Objective 1, Action a).

There are 30 recommended actions, including those currently performed by the ADP or AFRC, which are the sole or joint responsibility of the lead agency. All of the lead agency actions for both new and ongoing activities can be implemented through a State aquaculture program (see Figure 4). This aquaculture program contains three program areas: (1) Management, (2) Support Services, and (3) Species Development. Management is essential not only to coordinate support services and species development programs, but also to direct their activities towards the achievement of the following:

1. Consolidate current and future State aquaculture development activities within the lead agency.

2. Institutionalize mechanisms for program planning, management and review.

3. Develop formalized arrangements and cooperative programs between the lead agency and the University of Hawaii in research and extension services.

4. Provide technical and business management support services.

5. Fund research directed at reducing production costs and increasing yields.

6. Develop new species or systems through applied research and economic feasibility demonstrations.

Figure 4 is not a recommended organization, nor is it predicated on the choice of a lead agency. It points, rather, to the need for establishing an organizational structure within the lead agency which would encompass those activities essential for accelerating the rate of aquaculture expansion in Hawaii. Descriptions of the program areas must, therefore, be presented in general terms since specific points of internal organization can be addressed following the designation of a lead agency and the legislative confirmation of its functions.

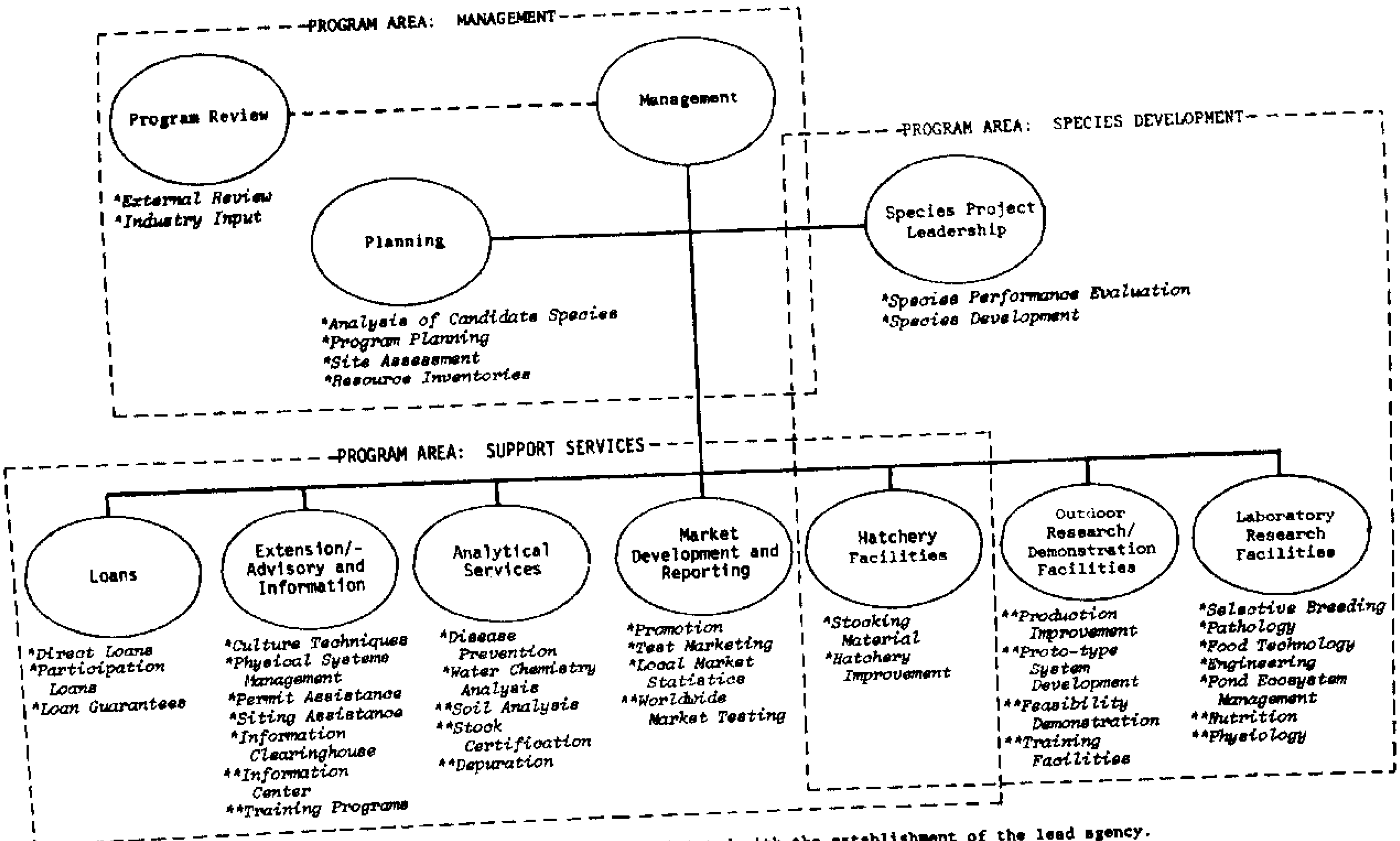
The three program areas contain a total of 11 essential functional elements. Some of the activities identified under each element presently exist, while others may be provided as additional needs arise and resources permit. Those activities identified by a single asterisk should receive immediate consideration. Those activities identified by a double asterisk should be implemented on a priority basis over the next three to five years.

The following section of this chapter describes the program areas together with their functional elements. The discussion of each element includes the principal purpose (in italics), a representative list of activities, a statement on the element's relevancy, a description of the present organizational status and proposed changes.

Management

The management program area consists of three functional elements: (1) Management, (2) Review, and (3) Planning. Benefits likely to be realized from effective managements include an increased responsiveness to industry needs, a more favorable cost/benefit ratio for State investment and a greater consistency of purpose through long-range direction.

Figure 4. Program Areas, Functional Elements, and Activities for Aquaculture Development in Hawaii



*Either ongoing activities or activities to be concurrently initiated with the establishment of the lead agency.
**Activities to be implemented as resources permit.

Several points of consideration for managing the State aquaculture program are: (1) industry involvement, (2) joint arrangements, (3) non-State matching funds, and (4) multiple-use of facilities and personnel. Each is discussed below. Additional management recommendations will be found in Chapter V, Budget and Timetable.

Early industry involvement in setting program priorities should be emphasized, particularly in areas of research directed at improving production and support services. A program review panel, including persons from the State's aquaculture community, can provide this type of communication. (See Objective 1, Action h for recommended panel composition.) However, in addition to this formal group, a high level of informal interchange should be maintained with local industry members and/or their representatives to identify present and potential problem areas and to follow through with appropriate solutions.

The possibility of joint program arrangements between components of the lead agency and the University of Hawaii should be explored in order to optimize the use of State resources. Such arrangements could be implemented through the joint designation of research facilities, and joint appointments of personnel for extension/advisory services and research. In addition to enabling both to share resources more efficiently, this strategy can result in: (1) a more competitive position for both entities in developing new sources of funds, (2) opportunities for mutual exchange of information, (3) opportunities for a common technical resource pool, and (4) opportunities for the transfer of commercially proven aquaculture technology.

Aquaculture in Hawaii is expanding at such a rapid rate that sole financial support of development activities is beyond the State's capabilities. There necessarily must be a high level of cost-sharing with Federal and private groups. Efforts should be made to establish joint programs with the National Marine Fisheries Service in marketing, and the U.S. Fish and Wildlife Service in disease prevention. It is particularly important to continue research funding support from the Office of Sea Grant and other sources. Available Federal sources of funding should be continually explored and areas where private industry can contribute to development should be identified and pursued.

The State's resource base for aquaculture development, e.g., personnel and facilities, can be utilized most effectively through the application of the multiple-use concept. This concept can apply to species projects concurrently or sequentially using a State outdoor pond complex for performance evaluation tests and/or development projects. Multiple-use would relieve a species program coordinator from the responsibility of operating and maintaining the facility and allow concentration on other responsibilities. The individual would be free, for example, to conduct and evaluate performance evaluation tests and formulate species development plans. Depending on the availability of facilities and other resources, four or more projects (two species performance evaluation projects and two species development projects) could be carried out simultaneously.

Management

The principal purpose of the Management function element is to *plan, organize, coordinate, and direct the use of personnel, facilities, and other resources for carrying out aquaculture development programs.* The major activities are:

1. Formulates State priorities for aquaculture development.

2. Works toward establishing unified State policies for aquaculture development.

3. Provides a visible contact point for aquaculture interests.

4. Actively seeks non-State funds to support aquaculture research and development, and demonstration projects.

5. Coordinates State development activities with national and international programs.

6. Provides a balanced program for support services, and for research and development through the allocation of State funds.

7. Establishes lines of communication between agencies carrying out activities relating to aquaculture development.

8. Reviews research proposals requesting State funds and eliminates duplication of effort through the exercise of fiscal control.

Act 12 of the first Special Session of the 1977 Legislature authorized the establishment of the Aquaculture Development Program (ADP) within the Department of Planning and Economic Development (DPED) to serve as the interim lead agency for aquaculture development. As the interim lead agency, the ADP prepares a consolidated budget, reviews proposals for State funds in accordance with established priorities, and allocates funds for research and development projects, advisory projects, and support services. The ADP's management functions should be assimilated by the permanent lead agency upon its establishment.

Review

The major purpose of the Review section is to *insure that State priorities and programs meet current and emerging needs of the industry.* Representative activities are:

1. Obtains input from representatives of the industry, funding agencies and the scientific community.

2. Evaluates and reports on the effectiveness of ongoing programs and the timeliness and need of implementing new programs.

3. Performs annual review of support service programs, and species performance evaluation and development programs.

The Aquaculture Advisory Council and Liaison Committee, appointed by the Governor, has periodically advised the Director of the DPED on aquaculture planning, research, and development matters. Concurrent with the establishment of the permanent lead agency, a program review panel, composed of representatives from the industry (producers, distributors, feed suppliers, lenders), funding organizations and scientific community, should be appointed to provide an annual review of State-supported aquaculture projects and programs.

Planning

The Planning function element will *assess constraints and resource potentials for aquaculture expansion and make recommendations for the development of new species and products.* Six initial activities are:

1. Formulates recommendations for State policies and programs for aquaculture development;

2. Assists in preparing aquaculture budget requests and legislation.

3. Interacts with State and County economic and resource planning agencies.

4. Provides initial biotechnical and economic evaluations of candidate species for culture.

5. Assists project team leaders in designing development programs for selected species.

6. Acquires baseline data and periodically updates resource inventories.

The examination of aquaculture potentials is an ongoing function of the ADP. Continued planning is necessary to guide the selection of appropriate species for Hawaii, and to design programs for the development of commercial production. Assessments should continue to recognize the dynamic nature of aquaculture with respect to advances in culture technologies and the emergent needs of producers. The planning function should be assumed by the designated lead agency with input provided by representatives from industry, funding organizations, and the scientific community via a program review panel.

Support Services

Once first commercial culture has been demonstrated, public provision of support services becomes a major factor in the rapid and effective growth of the private sector. This has certainly been the experience of agricultural commodities and most aquaculture species, including catfish and trout. Such support services include a broad array of technical and business management-related activities which, by helping to solve production and post-production problems, can contribute to both technical and financial success of individual enterprises. Public provision of this support to a young industry can be justified because both small- and large-scale aquafarmers often have inadequate "in-house" capabilities. Moreover, expertise in a particular area may not be available in the private sector.

In Hawaii, the State has the opportunity to provide key support services through enhancing existing activities, establishing joint arrangements with Federal and University programs or developing new services. Five somewhat overlapping elements are needed: (1) loans, (2) extension/advisory information, (3) analytical services, (4) market development and reporting, and (5) hatchery facilities. These elements are reflected in numerous national and international planning documents and should form the core of available public support services in Hawaii.

Initial emphasis should be on freshwater prawn farming. However, the resources used to support this sector can be applied to a wide variety of existing and proposed species and systems.

Loans

The principal purpose of this functional element is to *administer the State Aquaculture Loan Program which makes direct loans, participation loans and loan guarantees.*

This program works closely with commercial banks, the Farmers Home Administration, and the Small Business Administration, in helping private industry secure capital.

The Aquaculture Revolving Loan Program, since its inception in 1972, has been administered by the Farm Loan Division (FLD) of the Department of Agriculture (DOA). The number of loans granted under the Aquaculture Loan Program has not approached the volume of agriculture loans; however, the demand for loan funds is expected to increase in the future. It is recommended that the administration of aquaculture loans remain in the DOA until such time as circumstances suggest a reevaluation for transferring the Loan Program to the aquaculture development unit of the designated lead agency.

Extension/advisory Information

The extension/advisory element *provides advisory, educational, and extension services to Hawaii residents and aquafarmers.* Some of the representative activities include:

1. Participates in joint extension/advisory programs with the University of Hawaii.
2. Provides advice on permit requirements.
3. Provides assistance in locating sites for commercial aquaculture ventures.
4. Continually identifies information needs and undertakes efforts to fill them.
5. Maintains cognizance of research and industry developments.
6. Transfers information through workshops, symposiums, training sessions and other means.
7. Develops a library of aquaculture films, slides, books, pamphlets, photographs, news clipping documents, and other materials for use by the aquaculture community and the general public.
8. Provides reference services.
9. Improves the efficiency in the flow of communication by designing and implementing an in-State and out-of-State computer information network.

The AFRC provides extension services in all biotechnical phases of prawn farming, including site selection (topography of the site and layout of ponds, permeability of soil and volume and reliability of the water source, design and construction of ponds, stocking and management techniques, harvesting methods, and post-harvest handling and preparation of prawns for marketing. The ADP augments the AFRC's extension services by providing prospective farmers with information on the suitability of lands for aquaculture and permit requirements. The ADP works together with the Sea Grant/Marine Advisory Program (MAP) and the AFRC to prepare brochures, slide presentations and films on aquaculture in general, and on prawn farming in particular. The Hawaii Cooperative Extension Service (HCES) of the College of Tropical Agriculture is not currently involved in aquaculture extension activities. However, since the College has been named as the coordinating unit for all aquaculture activities within the University, it is recommended that the College's extension programs in agriculture expand to include aquaculture. It is particularly important to maintain the close relationship of aquaculture advisory service activities and research programs. As such, the State's capabilities in extension services and training can be significantly increased by the establishment of cooperative arrangements between the State's lead agency, the MAP, and the HCES.

Analytical Services

Analytical services *provide commercial producers with analytical laboratory services.* Three initial activities of this element are:

1. Identifies and catalogues diseases and recommends treatments.

2. Examines shipments to certify that stocks entering the State are disease-free, and provides quarantine services.

3. Provides soil and water chemistry analyses.

Analytical services are closely aligned with extension/advisory services. On July 1, 1978, the ADP, in close cooperation with the AFRC and the DOA's Plant Quarantine Division began providing disease identification and prevention services to Hawaii's aquaculture community for species that are presently commercially cultured or bring investigated for culture. This service is essential to assure that aquacultured species remain disease-free and should be assumed by the designated lead agency. The lead agency should explore the possibility of forming a cooperative program with the U.S. Fish and Wildlife Service to further increase the State's capability to provide disease prevention services. This program is especially important for establishing an aquaculture "seed" production industry in Hawaii.

Upon completion of construction of a biology/chemistry laboratory, the AFRC will be equipped to provide aquaculturists with water chemistry analyses. In addition, its capabilities in water quality and pond ecology studies will be greatly strengthened. Soil analysis services are not provided by the ADP, but should be made available if resources permit.

Market Development and Reporting

Market development and reporting *undertakes market development activities for aquaculture products and collects, evaluates, and reports market statistics.* The major activities of this element are:

1. Promotes Hawaii-grown aquaculture products by undertaking consumer-awareness and market-testing programs.

2. Assists producers in developing quality standards for aquaculture products.

3. Develops and maintains a periodic market reporting service on market outlets, prices, and volumes sold.

4. Projects trends in prices and the absorption capacity of markets in terms of prices, and evaluates demand potentials.

There is currently no specific State-assisted activity for market development and sales promotion for cultured aquatic products. However, the Economic Development Division (EDD) of the DPED has provided assistance to aquaculturists through its Industry and Product Promotion Program and intends to continue this valuable service. The ADP has allotted a portion of its budget for FY 1978-79 to assist the Hawaii Prawn Farmers Association in expanding the market for freshwater prawns. Market promotion and development activities are expected to be undertaken through a cooperative effort involving the EDD, the AFRC, the University's Cooperative Extension Service, and the Marketing and Consumer Services Division (MCSD) of the DOA. The lead agency should explore the possibility of establishing a market reporting and analyses service for cultured aquatic products through cooperative efforts with the National Marine Fisheries Service.

Hatchery Facilities

The principal purpose of the Hatchery Facilities functional element is to *provide stocking material to commercial operations and researchers.*

The provision by the AFRC of juvenile prawns to farmers under two-year cooperative agreements is the most important reason that freshwater prawn farming has been established and expanded. After the initial period of the agreement, stocking material is provided on a cost basis. As the industry expands, the demand for stocking material will exceed the State's capacity for producing juvenile prawns, and will likely lead to establishment of private hatcery operations to meet market demands for juveniles. Since the AFRC's facility is designed to spawn most forms of aquatic animals in fresh, brackish or salt water, research efforts could be focused towards the gradual development of mass-rearing technologies for producing stocking material for other commercially important species. The administration of these facilities should be assumed by the designated lead agency.

Species Development—Establishing Commercial Culture of Other Species for Hawaii

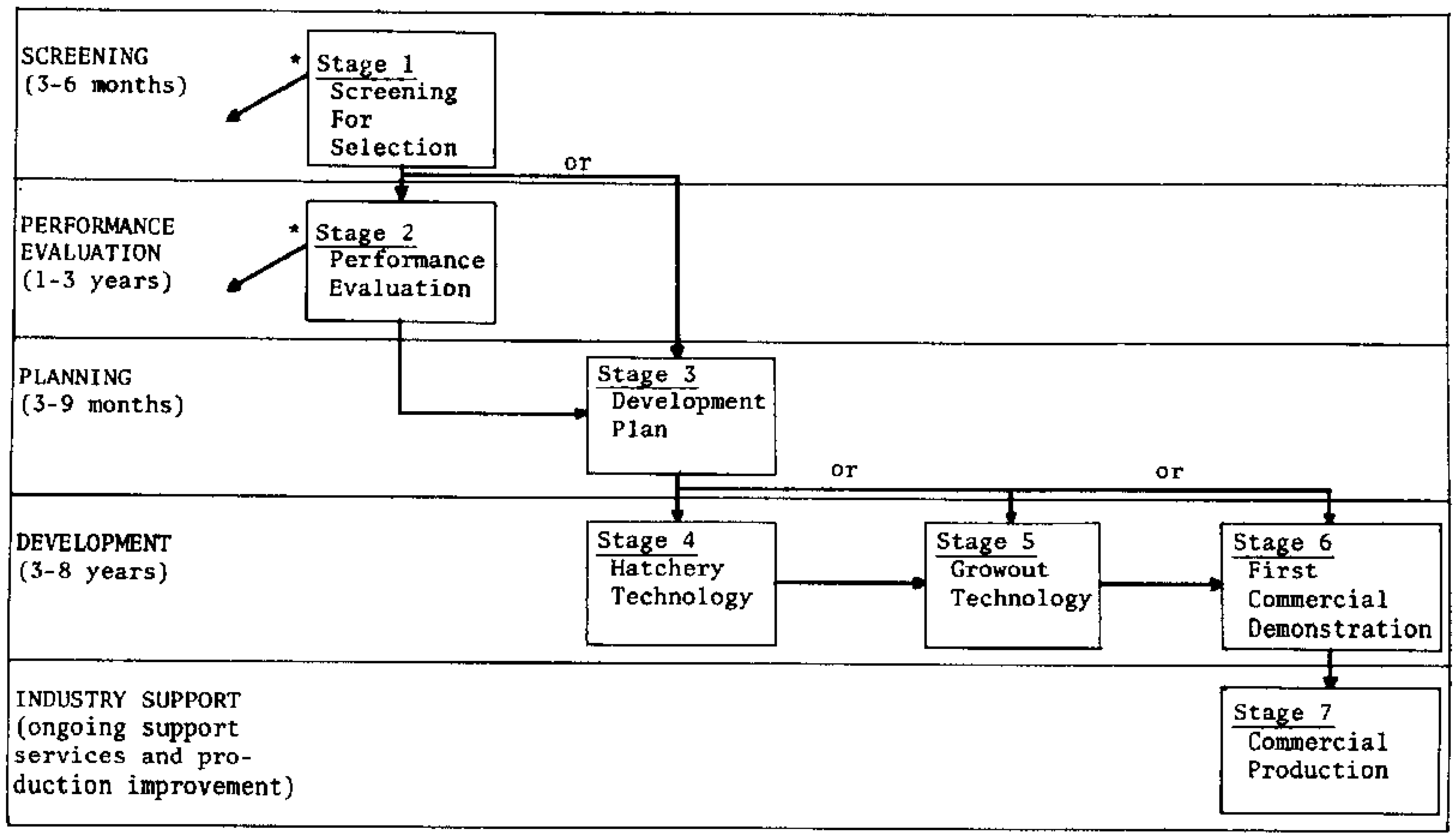
Economic benefits for Hawaii can be increased by encouraging the commercial culture of species which utilize different sets of resources and/or supply different segments of the fisheries market. The first requirement is the identification of those aquacultured species suitable for local climatic, economic and resource conditions. The following section first presents a procedure for identifying, testing and developing new commercial species, and also discusses the functional elements of the State's aquaculture development program that would bring the species from candidacy to commercial culture.

Developmental Stages for an Aquaculture Species from Candidacy to Commercial Culture

An essentially sequential approach to identifying and developing new commercial aquaculture species for Hawaii (Figure 5) is recommended. The major categories are (1) Screening, (2) Performance Evaluation, (3) Planning, (4) Development, and (5) Industry. The approach is modeled after the selection process utilized in identifying the nine priority species-groups and three secondary species-groups discussed in Chapter II.

A systematic approach will help insure that the best candidate species are chosen for development activities and effective development is carried out maximizing the

Figure 5. Developmental Sequence for an Aquaculture Species from Candidacy to Commercial Culture



*Species eliminated. Future re-evaluation possible.

State's investment. It should be emphasized that this is a recommended course of action for State-supported developmental efforts. Private producers have the option of not following this sequence. As Figure 5 illustrates, there are cases where certain stages may be by-passed. For example, private producers may feel that the technology for a species is sufficiently advanced for Stage 6, First Commercial Demonstration (the case of channel catfish), or they may be able to obtain stocking material from outside the State (the case of oysters and clams). The use of State hatchery technology (Stage 4) would not, therefore, be required. It should be understood, however, that before State resources (dollars, personnel, etc.) are organized in a development effort, an evaluation of the information that would be gained by completing each stage should be made by the State aquaculture program.

The activities encompassing each stage of development are discussed below. The process assumes that all candidate species in a State-supported effort would pass—at a minimum—through Stages 1, 3 and 6 before proceeding to Stage 7.

Screening

Stage 1. The first stage, Screening for Selection, selects candidate species with significant potential for commercial culture in Hawaii. Suggestions for candidates can come from both public and private sources. This process, which is expected to take from three to six months, consists of a thorough review of the pertinent literature, letters of inquiry to leading researchers familiar with the species and, perhaps, site visits to research and commercial culture operations. Emphasis will be on acquiring information in the following areas: biological and biotechnical state-of-the-art, markets, necessary resources, economics, and legal/social/environmental considerations. Information gathered will be evaluated utilizing an information display system illustrated in Appendix C. This initial evaluation procedure favors the selection of those species which, because they have fewer or less baffling problems associated with their culture, can be developed into an industry with a minimum State investment. Species identified as warranting more intensive evaluation will generally show (1) a high probability of cost-effective culture in Hawaii, and (2) good potential to develop into a significant export industry for Hawaii. Candidate species with serious technical problems associated with their culture and/or questionable market potential are eliminated from consideration at this stage without expenditure of research funds. However, these species may be re-examined at a later time.

Performance Evaluation

Stage 2. The second stage, Performance Evaluation, consists of a preliminary evaluation of the growth performance in Hawaii of those species that have passed Stage 1. This activity is estimated to take from one to three years. Critical areas such as environmental tolerances, reproductive biology, production methods, physical holding systems and elementary production economics are investigated. Those biotechnical problems identified are studied to find workable solutions, although further refinement will probably be necessary at a later date to reduce costs. In many cases, Stage 2 will consist of a demonstration in Hawaii of technology developed elsewhere. If the problems identified prove to be beyond local resource capabilities for short-term (1 – 3 years) solution, the species should be rejected without additional expenditure. Again, decisions at this point can be reevaluated and researched further at a later time.

Planning

Stage 3. The third stage, Planning, requires the preparation of a development plan for the potential commercial species. This activity, which should last three to nine months, is a prerequisite to the initiation of Development (stages 4, 5 and 6). The plan includes an evaluation of the species' current state-of-the-art for culture (based on data gathered from stages 1 and 2) and recommends specific actions necessary to develop commercial culture. The plan also includes detailed discussions of hatchery, growout, harvesting, post-harvest handling, and processing methods, as well as the extension/advisory, analytical support, and product promotion services needed for commercialization and the future expansion of the industry. The plan also provides a preliminary cost/benefit analysis for the State and allows for the identification of critical areas; for example, the timing of market development activities to supply and demand.

Development

State development of selected species is estimated to take from three to eight years, and consists of three stages: Hatchery Technology, Growout Technology, and First Commercial Demonstration.

Stage 4. The fourth stage, the provision of stocking material from either the State (free or at cost) or private sources is viewed as a major factor in initiating commercial aquaculture operations. The main purpose of the fourth stage, Hatchery Technology, is to encourage commercialization through the development of techniques for mass-rearing stocking material once routine reproduction in captivity has been accomplished. These techniques can be based on technologies developed in Hawaii or elsewhere.

Stage 5. The fifth stage, Growout Technology, consists of the scientific demonstration and evaluation of essential growout techniques. The State can support private commercial-scale demonstrations of techniques used in stage 2. Critical areas of investigation include the determination of optimum physical rearing systems, stocking densities and intervals, feeding regimes, systems management and harvesting methods. In situations where well-established technology is brought into the State, this stage may be effectively combined with stage 6.

Stage 6. The sixth stage, First Commercial Demonstration, demonstrates the technical and economic feasibility of culturing candidate species. This is a pivotal point in the development process because it represents the first private sector investment in commercial activities. Profitability may, at first, be low so the State or private groups may have to undertake directed research aimed at reducing production costs. During this period of commercial demonstration, such support services as extension and advisory, marketing, water chemistry and soil analyses, and disease and pathology monitoring, are examined and modified to accommodate the new species.

Industry Support

Stage 7. The seventh stage, Commercial Production, occurs some time after First Commercial Demonstration when total production of the species becomes significant. This stage generally corresponds to the recognition by both the aquaculture community and private lending institutions that viable commercial production has been clearly demonstrated and a record of proven success, or a "track record," has been established.

The provision of the aforementioned support services (stage 6) will play a key role in the expansion of the industry. Research directed at improving production and reducing costs would continue to the point of diminishing returns. As production expands, the timely implementation of species specific market development and promotion activities are essential for an effective balance of supply and demand. The formation of cooperatives should be encouraged whenever possible, so that small-scale farmers can cost-effectively address such areas as product labeling, quality control, processing, packaging, distribution and promotion areas with the least possible cost. These services should be provided by the State until they are adequately available in the private sector.

Relating the development stages to species currently investigated or cultured in Hawaii. At present there are fourteen species-groups, made up of one or more species, cultured or under investigation for culture in Hawaii. Eleven of these are represented in Table 28, together with their relative stage of development in Hawaii and the world, and the principal sector (public or private) responsible for aquaculture development in Hawaii. Table 28 is a simplification of a highly technical and complex subject. (For additional information on species, see Chapter II.)

Species development: functional elements. The principal functional elements responsible for identifying and developing new economic opportunities in aquaculture for Hawaii are Species Project Leadership, Hatchery Facilities, Outdoor Research/Demonstration Facilities and Laboratory Research Facilities. It should be noted that Hatchery Facilities, which was discussed earlier in this chapter, is also an element of the Support Services program area. In fact, once commercial culture is demonstrated, all of the Support Service elements will play a major role in successful expansion. Several of the aforementioned Management considerations–especially joint arrangements and the multiple-use of facilities and personnel–will contribute substantially to the effective implementation of this program area.

Species Project Leadership

The principal purpose of the Species Project Leadership is to provide *scientific team leadership for Species Performance Evaluation and/or Species Development activities.* The major activities are:

1. Conducts research and demonstration projects aimed at establishing the commercial culture of new species or improving production of currently cultured species.

2. Seeks Federal and private funds to support species development programs.

3. Works with planners in the formulation and design of development proposals and plans.

Improvements in commercial production and/or the development of new systems or species can most effectively be attained by a systems-oriented research approach involving many disciplines. The need for teamwork in designing and executing multidisciplinary research for solving fundamental biological, engineering, and economic problems is recognized. The multi-disciplinary University of Hawaii Sea Grant Hawaiian Prawn Aquaculture Program has established a close working relationship with the AFRC to aid in the development of the freshwater prawn industry. This arrangement for

Table 28. Stages of Development of Some Species Investigated or Cultured in Hawaii

Species Group	Stage in Hawaii	Principal Sector Responsible in Hawaii	Stage Worldwide[a]
Aquatic Algae	2	Public	5
Baitfish (topminnow)	5	Public	5[b]
Brine Shrimp	*[c]	Private	*[c]
Chinese Carps[d]	6	Private	7
Catfish	6	Private	7
Clams	5	Private	7
Freshwater Prawns	7	Public	6
Limpets (*Opihi*)	2[e]	Public	2[e]
Marine Shrimp	2	Public & Private	5[f]
Milkfish	2	Private	7[g]
Mullet	7[h]	Public & Private	7
Threadfin (*Moi*)	2[i]	Public	2[i]

[a]Refers to technologies and management systems that are transferable to Hawaii.
[b]Other species, many of which are used for recreational fishing, are at stage 7.
[c]Adult production is at stage 6 in Hawaii and worldwide. Commercial egg production is at stage 2 in Hawaii and worldwide.
[d]Many locations in the world are at stage 7 using extensive culture methods which may not be applicable to Hawaii.
[e]Investigation of *opihi* for culture is presently limited to Hawaii.
[f]Commercial culture exists worldwide at stage 7; however, these operations are based on broodstock captured in the wild. Commercial culture in Hawaii must be based on controlled reproduction of candidate species in Hawaii. This has not yet been achieved.
[g]Although milkfish culture is widespread in the Philippines and other Asian countries, its commercial culture is based on the collection of fry from the wild. The control of reproduction has not been achieved.
[h]There are two commercial operations in Hawaii which generally rely on wild-caught juveniles for stocking material. The successful expansion of the species will require an economical supply of hatchery-reared juveniles and a demonstration of cost-effective culture.
[i]Interest in culturing *moi* has thus far been limited to Hawaii.

undertaking production improvement research can serve as a model for the development of additional species of commercial importance. The lead agency should explore the possibility, workability, and mutual benefits that may be derived from creating joint positions for State/University scientists, and formalized arrangements for the joint designation of programs and facilities.

Outdoor Research/demonstration Facilities

Outdoor Research/demonstration Facilities *provides a field location for conducting production improvement research, for species growth performance evaluations, and for species development projects.* The six principal activities of this element are to provide facilities for:

1. Conducting multidisciplinary team research under field conditions directed at reducing production costs and increasing yields of commercially cultured species.

2. Testing alternative growout strategies under conditions that simulate the environments of commercial production units.

3. Testing the design of prototype rearing systems beyond the laboratory scale.

4. Transferring, testing, and adapting culture technologies developed elsewhere.

5. Conducting economic feasibility demonstrations.

6. Conducting training programs.

Outdoor research and demonstration facilities are essential for transferring applied research from the laboratory to full-scale testing. The lack of these facilities has been a major constraint to aquaculture development in Hawaii. Highest priority should, therefore, be given to the initiation of their planning, design, and construction. It is recommended that outdoor facilities be developed, designated and used jointly by the State lead agency and the University of Hawaii.

Laboratory Research Facilities

The principal purpose of Laboratory Research Facilities is to *provide laboratory facilities for research directed at finding solutions to basic biotechnical problems, and for applied research to improve production efficiency.* The six principal activities are:

1. Provides facilities to carry out selective breeding and domestication research.

2. Provides facilities to carry out reproduction research, and for defining the optimal environmental parameters for the growth of species, including their larval stages.

3. Provides facilities for defining basic nutritional requirements of aquatic organisms leading to the least-cost formulation of feeds.

4. Provides adjunct laboratories for pathology research.

5. Provides engineering laboratories to design feeding and harvesting equipment, and for testing improvements in the design of physical systems.

6. Provides food technology facilities for research on post-harvest handling, processing, and shelf-life extension of aquaculture products.

Laboratories located within several departments and units of the University of Hawaii have been employed for aquaculture research on various species. The University's Sea Grant Hawaiian Prawn Aquaculture Program conducts a portion of its research at the AFRC. The State lead agency should strive to strengthen and formalize cooperative efforts with the College of Tropical Agriculture which is responsible for coordinating aquaculture research at the University of Hawaii.

CHAPTER V

BUDGET AND TIMETABLE

Sustaining a high rate of growth in aquaculture will require a commitment by the State to provide support services (loans, extension/advisory services, marketing, disease prevention/assistance, water and soil analyses, stocking materials, and funding for research and development to improve current production and identify new economic opportunities. This will in turn require the State to make a sound fiscal commitment, together with the active pursuit of Federal and other non-State sources of matching support.

Before presenting the recommended budget, certain underlying assumptions must be considered. In addition, this chapter offers fiscal policies and guidelines, and discusses both the opportunities for, and constraints to, expanded growth.

Assumptions

1. In order for aquaculture development programs to be effective, there must be a balance of support services to existing producers and species development efforts.

2. Current plans, subject to the availability of resources, call for two species performance evaluation projects and two species development projects to be concurrently supported. New species projects will be phased into the development program as others are phased out. Additional concurrent programs will require a greater input of State and/or non-State funds.

3. The budget reflects a phasing-in of needed services over a three-year period and, with the exception of additional appropriations to the Aquaculture Loan Fund and allowance for cost of living increases, represents near-level funding.

4. Grant development activities will attempt to achieve a matching ratio of at least two non-State dollars for every State dollar spent on aquaculture. Federally-sponsored international development programs, however, will, for the

most part, not require State matching funds. The availability of State-operated research and demonstration facilities will enhance Hawaii's chances of attracting Federal monies for staff and program support.

5. Increases in the Federal contribution to aquaculture development are expected from (a) the continued involvement of current Federal sources, (b) recently enacted Federal legislation, (c) pending Federal legislation, and (d) current trends in Federal expenditures.

Fiscal Policies

Fiscal policies can be valuable tools for increasing effectiveness and guiding development if they (1) reflect industry needs (hence, program priorities), (2) contain sufficient flexibility to respond to emerging needs, and (3) incorporate mechanisms for maintaining high cost/benefit effectiveness.

Fiscal policies for aquaculture development will be based in part on: (a) three funding categories which indicate the State's funding priority of species or species-groups, and (b) specific guidelines for distributing funding between and within these categories.

State funding: (a) priorities. Suggested State priority classifications for aquaculture funding are listed below. These categories place prime emphasis on existing industries and reflect a pragmatic approach to development. Priority species refers to those species recommended in Chapter II, for priority consideration.

1. PRIORITY ONE FUNDING

   Activities related to the support and expansion of existing commodity sectors.

   These activities include research that is likely to increase profitability for existing commercial producers, as well as information, advisory, extension, market development and other support activities which serve aquaculturists. Advice concerning funding decisions should be sought from all components of private industry.

2. PRIORITY TWO FUNDING

   Activities related to the research and development of first priority species or species-groups not included in A.

   These activities include research, development and demonstration or proof-of-concept projects which focus on species or species-groups not presently under commercial culture (e.g., baitfish and marine shrimp).

3. PRIORITY THREE FUNDING

   Other research and development activities of species or species-groups not included in A and B, but with a distinct potential for economic and/or social benefits.

   These activities focus on species whose potential for economic and/or social benefits is apparent, but not clearly defined (e.g., *opihi*), or species not presently identified.

State funding: (b) guidelines. It is important to consider several points when funding projects. The recommended distribution of funding envisioned for the three priorities listed above is as follows: the largest sum for Priority One, the next largest sum for Priority Two, and the remainder for Priority Three. Some funding should be allotted each year, whenever possible, for each type of activity. Moreover, it is important that flexibility be maintained to allow the State to adequately investigate new opportunities (Priority Three). In this manner, the State can be innovative and respond appropriately to future developments. Continuity of funding for those projects undertaken should likewise be stressed; that is, a successful project should be assured funds for its entire proposed duration. Finally, to determine if stated objectives are being achieved, all projects should be subjected to a periodic review by both the aquaculture lead agency and an external review panel.

Proposed Budget and Some Considerations

If appropriations and expenditures are made at the recommended levels and in accordance with the proposed programs, the budget reflected in Table 29 can (1) sustain the present high level of expansion of freshwater prawn production, (2) contribute to the development of other species sectors that are currently undergoing economic proof-of-concept, such as oysters and catfish, (3) provide for the commercial demonstration and establishment of new product sectors, such as marine shrimp, baitfish and Chinese carps, and (4) continue the search for new economic opportunities. Growth can be further accelerated by increasing the level of activity within species development projects and adding species development projects. There are, however, limits to this growth.

Major constraints during the developmental stages will be expertise (people), funding and facilities. During the commercialization stage, institutional constraints can hopefully be minimized through positive legislative and administrative actions. Important limiting factors would then be the acquisition of production sites and adequate credit. Because obstacles to aquaculture development are continually changing, actions to accelerate the growth of aquaculture should be carefully evaluated at the time of implementation. This, of course, assumes that other critical requirements, such as marketing and technical assistance, will be adequately addressed by the lead agency.

Timing. The time factor should also be taken into consideration. To bring a species or species-group (polyculture) from candidacy to commercial culture may take from three to five years if the culture technology has been developed elsewhere. Species with less developed culture systems will undoubtedly require more time—perhaps five to eight years longer. This factor should be given serious consideration in development decisions.

Table 29. Proposed Five-year Budget and Timetable for Aquaculture Development Activities

Operating (Op) and Capital Improvement Project (CIP) funds in thousands of dollars with "C" denoting State funds and "N" denoting Federal and other non-State funds.

Activity		FY 1978-79		FY 1979-80		FY 1980-81		FY 1981-82		FY 1982-83	
		Op	CIP	Op	CIP	Op	CIP	Op	CIP	Op	CIP
Management	C	50	-	93	100[a]	89	1,962[b]	90	-	95	-
	N	-	-	-	100	50	1,962	55	-	60	-
Planning	C	34	-	41	-	42	-	45	-	50	-
	N	-	-	41	-	42	-	45	-	50	-
Species Projects (Performance Evaluation and Development)	C	513	-	576	-	548	-	550	-	577	-
	N	688	-	750	-	1,000	-	1,100	-	1,154	-
Loans[c]	C	-	-	500[d]	-	-	-	-	-	500[d]	-
	N	-	-	-[e]	-	-[e]	-	-[e]	-	-[e]	-
Extension/advisory Information	C	146	-	173	-	167	-	170	-	180	-
	N	50	-	75	-	234	-	340	-	360	-
Analytical Services	C	40	90[f]	92	-	89	-	90	-	95	-
	N	-	-	184	-	178	-	180	-	190	-
Market Development and Reporting	C	35	-	58	-	63	-	65	-	70	-
	N	-	-	50	-	126	-	130	-	140	-
Hatchery Facilities	C	72	330[g]	81	-	79	-	80	-	84	-
	N	40	-	60	-	158	-	160	-	168	-
Outdoor Research/demonstration Facilities	C	-	1,250[h]	-	-	50	-	100	-	105	-
	N	-	-	-	-	50	-	100	-	105	-
Laboratory Research Facilities	C	30	-	46	-	47	-	50	-	54	-
	N	20	-	30	-	47	-	50	-	54	-
Total	C	920	1,670	1,660	100	1,174	1,962	1,240	-	1,810	-
	N	798	-	1,190	100	1,885	1,962	2,160	-	2,281	-

[a]Plans and designs for the construction of facilities at the AFRC, Sand Island, Oahu, to provide facilities for administrative, planning, species projects, extension/advisory, analytical, market development and reporting, and laboratory research services, equipment, and personnel.

[b]Construction of the facilities in "a" above and purchase of the necessary equipment.

[c]Remains in the Farm Loan Division, Department of Agriculture.

[d]Additional appropriations to the Aquaculture Loan Fund.

[e]Federal loan program is expected to be established.

[f]Remodeling of the existing AFRC laboratory and purchase of water quality equipment for the AFRC. Project began in FY 1977-78 and is expected to be completed in FY 1978-79.

[g]Enclosure and thermo-regulation of the existing AFRC prawn hatchery. Project began in FY 1977-78 and is expected to be completed in FY 1978-79.

[h]Plans, site selection, site acquisition, designs, and construction of the Tropical Aquaculture Center and purchase of the necessary equipment.

REFERENCES

Asano, I. 1976. Strategy for Future Development of Aquaculture in Japan. FAO, FIR:AQ/Conf/76/E. 82, 4 pp.

Bank of Hawaii. 1978: personal communication.

Bardach, John E., J. H. Ryther, and W. D. McLarney. 1972. *Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms.* Wiley Interscience, New York.

Beleau, M. H., N. D. Heidelbaugh, and D. Van Dyke. 1975. Open-ocean Farming of Kelp, *Food Technol.* 45:27-30.

Bell, F. W. and E. R. Cantebery. 1976. *Aquaculture for Developing Countries, A Feasibility Study.* Ballinger Publishing Company, Cambridge, Mass.

Brown, E. E. 1977. *World Fish Farming: Cultivation and Economics.* The AVI Publishing Company, Inc., Westport, Conn.

Cattell, Alan. 1978. President, Environmental Consultants, Inc.: personal communication.

Cato, J. C. and W. L. McCullough. 1976. *Economics, Biology and Food Technology of Mullet.* Florida Sea Grant Program, No. 15, Florida.

Chen, T. P. 1976. *Aquaculture Practices in Taiwan.* Page Brothers, Ltd., Norwich, U.K.

Cobb, J. N. 1902. Commercial Fisheries of the Hawaiian Islands in U.S. *Fish Commission Report for 1901.* Washington, D.C., pp. 383–499.

Cohlan, Bernard F. 1977. Consultant in Engineering and Physics, Los Angeles: personal communication.

Corbin, John S. 1976. *Aquaculture in Hawaii 1976, Progress, Resources and Organization.* Hawaii State Department of Planning and Economic Development, Honolulu.

Crawford, K. W., D. R. Dunseth, C. R. Engle, M. L. Hopkins, E. W. McCoy, and R. O. Smitherman. 1978. Marketing Tilapia and Chinese Carps. Unpublished manuscript. 18 pp.

Deveau, L. E. and J. R. Castle. 1976. The Industrial Development of Farmed Marine Algae: The Case History of *Eucheuma* in the Philippines and the USA. FAO, FIR: AQ/Conf./76/E. 56, 5 pp.

Doty, Maxwell S. and V. Alvares. 1975. Status, Problems, Advances, and Economics of *Eucheuma* Farms, *Marine Tech. Soc. J.* 9(4):30-35.

————. 1978. Principal Investigator, Seaweed Marine Agronomy Research Project, and Professor, Botany Department, University of Hawaii: personal communication.

Dugan, G. L., C. G. Goleuke, and W. J. Oswald. 1972. Recycling systems for poultry wastes. *J. Water Pollution Cont. Fed.* 44(3):432-440.

Environment and Natural Resources Policy Division. 1976. *Prognosis and Prescription for Development of Commercial Aquaculture in the United States.* Congressional Research Service, Washington.

Faison, E. W. J. 1976. The Prime Marketing Opportunity for the Hawaiian Prawn. Unpublished manuscript. College of Business Administration, University of Hawaii. 6 pp.

————. 1977. Seafood Consumption in Hawaii. Unpublished manuscript. College of Business Administration, University of Hawaii. 50 pp.

Fujimoto, Michael, T. Fujimura, and K. Kato. 1977. An Idiot's Guide to Prawn Ponds in *Shrimp and Prawn Farming in the Western Hemisphere.* eds. J. A. Hanson and H. L. Goodwin. Dowden, Hutchinson & Ross, Inc., Stroudsburg, Penn.

Garrod, Peter U. and Ku Chai Chong. 1978. *The Fresh Fish Market in Hawaii.* Department of Agricultural and Resource Economics, College of Tropical Agriculture, University of Hawaii, in press.

Gates, G. M., G. C. Matthiessen, and C. A. Griscom. 1974. *Aquaculture in New England.* Marine Technical Report Series No. 18. Sea Grant College Program, University of Rhode Island, Kingston.

Gibson, Richard T. and Jaw-Kai Wang. 1977. *An Alternate Prawn Production Systems Design in Hawaii*, TR 77-05, HAES Journal Series Paper No. 2142. Sea Grant College Program, University of Hawaii.

Glude, John B. 1976. Oyster Culture–A World Review. FAO, FIR:AQ/Conf./76/R. 16, 11 pp.

————, ed. 1977. *NOAA Aquaculture Plan.* U.S. Department of Commerce National Oceanic and Atmospheric Administration, National Marine Fisheries Service and Office of Sea Grant, Seattle, Washington.

Goldman, J. C. and J. H. Ryther. 1977. Mass Production of Algae: Bioengineering Aspects in *Biological Solar Energy Conversion*, eds. A. Mitsui, S. Miyachi, A. San Pietro, and S. Tamuri. Academic Press, N.Y., pp. 367–378.

Guillory, V. and R. Gasaway. 1978. Zoogeography of the Grass Carp in the United States. *Trans. Am. Fish Soc.* 107(1):105-112.

Hanson, Joe S. 1974. *Open Sea Mariculture.* Dowden, Hutchinson and Ross, Inc., Stroudsburg, Penn.

________ and Harold L. Goodwin, eds. 1977. *Shrimp and Prawn Farming in the Western Hemisphere.* Dowden, Hutchinson and Ross, Inc., Stroudsburg, Penn.

Hawaii Institute of Marine Biology, University of Hawaii. 1973. *Proceedings of the Pacific Island Mariculture Conference*, February 6–8, 1973. Honolulu.

Hawaii Natural Energy Institute, University of Hawaii, and the Hawaii State Department of Planning and Economic Development. 1976. *Hawaii's Natural Energy Resources*, 1976. Honolulu.

________ and ________. 1975. *Alternate Energy Sources for Hawaii.* State Advisory Task Force on Energy Policy Committee on Alternate Energy Sources for Hawaii, Honolulu.

Hawaii (State). 1960–1970. *Annual Reports.* Department of Land and Natural Resources, Honolulu.

________. 1960–1977. *Commercial Fish Catch by Species*, Department of Land and Natural Resources, Division of Fish and Game, Honolulu.

________. 1969. *Hawaii and the Sea, A Plan for State Action.* Governor's Task Force on Oceanography, Department of Planning and Economic Development, Honolulu.

________. 1974. *Hawaii and the Sea–1974.* Governor's Task Force on Oceanography, Department of Planning and Economic Development, Honolulu.

________. 1976. *Hawaii Coastal Zone Management Program, Second Year Summary Report: 1975–1976.* Department of Planning and Economic Development, Honolulu.

________. 1977. *Data Book 1977, A Statistical Abstract.* Department of Planning and Economic Development, Honolulu.

________. 1977. *Hawaii Aquaculture Planning Program Interim Report.* Department of Planning and Economic Development, Honolulu.

________. 1977. *Hawaii's Scientific Resources, 1977 Directory*, 8th ed. Department of Planning and Economic Development, Honolulu.

________. 1977. *Hawaii State Plan, the Economy, A Technical Study.* Department of Planning and Economic Development, Honolulu.

________. 1977. *Hawaii Tuna Fishery Development Plan.* Department of Planning and Economic Development, Honolulu.

———. 1977. *Permits and Environmental Requirements for Aquaculture in Hawaii.* Department of Planning and Economic Development, Honolulu.

———. 1977. *Report to the Ninth Legislature.* Government Organization Commission, Honolulu.

———. 1978. *1977 Annual Report.* Energy Resources Coordinator, Department of Planning and Economic Development, Honolulu.

Hawaii Business News. February, 1978. Long Wait About to Pay Off?

Hawaii Visitors Bureau, 1978: personal communication.

Hawaii Water Resources Regional Study. 1977. *Hawaii Water Resources Plan* (Review Draft). Honolulu.

Helfrich, Philip, et al. 1973. *The Feasibility of Brine Shrimp Production on Christmas Island,* TR-73-02. Sea Grant College Program, University of Hawaii, Honolulu.

Herrick, Samuel F. and Wayne J. Baldwin. 1975. *The Commercial Production of Topminnows: A Preliminary Economic Analysis,* AR-75-002. Sea Grant College Program, University of Hawaii, Honolulu.

Hoffman, Robert G. and Hiroshi Yamauchi. 1973. *Impact of Recreational Fishing Expenditures on the State and Local Economies of Hawaii,* AR-72-02. Sea Grant College Program, University of Hawaii, Honolulu.

Honolulu Advertiser. Maui Is Wowie for Fresh-fish Fans, May 5, 1978.

Horimoto, Ken. 1977. Owner, Horimoto Fish Market, Inc.: personal communication.

Huet, Marcel. 1970. *Textbook of Fish Culture, Breeding and Cultivation of Fish.* Fishing News (Books), Ltd., Surrey, England.

Huguenin, J. E. 1976. An Examination of Problems and Potentials for Future Large-scale Intensive Seaweed Culture Systems. *Aquaculture* 9:313-342.

Iverson, E. S. 1968. *Farming the Edge of the Sea.* Fishing News (Books), Ltd., Surrey, England.

Kay, E. Alison and W. Magruder. 1977. *The Biology of the Opihi* (October 1975–October 1976). Hawaii State Department of Planning and Economic Development, Honolulu.

Keller, Marilyn and D. Murata. 1977. *Marine Plantations in Biomass Energy for Hawaii.* Hawaii Natural Energy Institute, University of Hawaii, and Institute for Energy Studies, Stanford University. pp. 1-71.

Kikuchi, William R. 1976. Prehistoric Hawaiian Fishponds. *Science* 23 July:193, 295-299.

Living Marine Resources. 1977. Shrimp Market Reports, January to December. San Diego, Calif.

Madden, William D. and C. L. Paulsen. 1977. *The Potential for Mullet and Milkfish Culture in Hawaiian Fishponds.* Hawaii State Department of Planning and Economic Development, Honolulu.

May, Robert C. 1976. Studies on the Culture of the Threadfin, *Polydactylus sexfilis,* in Hawaii. FAO, FIR:AQ/Conf./76/E. 5, 5 pp.

. 1978. Cage Culture of *Moi* (*Polydactylus sexfilis*): A Preliminary Analysis of Production Economics. Unpublished manuscript, 9 pp.

Malecha, Spencer, 1978. Principal Investigator, Hawaii Prawn Aquaculture Program, and Assistant Professor, Department of Genetics, University of Hawaii: personal communication.

McGrath, Bill. 1977. Director, Mariculture Division, Ralston Purina Company: personal communication.

Moav, Rom. 1977. Visiting Professor, Department of Genetics, University of Hawaii, and Director of Research, Ministry of Agriculture, Israel: personal communication.

Motoh, H. 1977. An Annotated List of Scientific and English Common Names of Commercially Important *Penaeid* Prawns and Shrimps," Technical Report No. 2. Southeast Asian Fisheries Development Center, 14 pp.

Nash, Colin. 1974. Crop Selection Issues in *Open Sea Mariculture, Perspectives and Prospects,* ed. Joe Hanson, Dowden, Hutchinson & Ross, Inc., Stroudsburg, Penn., pp. 183–210.

National Research Council. 1978. *Aquaculture in the United States, Constraints and Opportunities.* National Academy of Sciences, Washington, D. C.

Naylor, J. 1976. *Production, Trade and Utilization of Seaweeds and Seaweed Products.* FAO Fisheries Technical Paper No. 159, 73 pp.

Neal, R. A. 1976. *Penaeid* Shrimp Culture Research at the National Marine Service Galveston Laboratory. FAO, FIR:AQ/Conf./76/E. 23, 6 pp.

Neish, I. C. 1976. Culture of Algae and Seaweeds. FAO, FIR:AQ/Conf./76/R. 1, 13 pp.

North, W. J. 1977. Possibilities of Biomass from the Ocean: The Marine Farm Project in *Biological Solar Energy Conversion,* ed. A. Mitsui, S. Miyachi, A. San Pietro, and S. Tamuri. Academic Press, N.Y., pp. 347–361.

Oceanic Foundation, The. 1974. *Annual Report.* Waimanalo, Hawaii.

Oceanic Institute, The. 1975 and 1977. *Annual Report.* Waimanalo, Hawaii.

Oceanic Institute, The. 1972. *Grey Mullet (Mugil Cephalus L.): Induced Breeding and Larval Rearing.* National Sea Grant Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Rockville, Md.

Oswald, W. J. and J. R. Benemann. 1977. A Critical Analysis of Bioconversion with Microalgae in *Biological Solar Energy Conversion*, eds. A. Mitsui, S. Miyachi, A. San Pietro, and S. Tamuri. Academic Press, N. Y. pp. 379–396.

Pillay, T. V. R. 1974. *Planning Aquaculture Development–an Introductory Guide*. United Nations Food and Agriculture Organization, Rome.

Quick Frozen Foods Co. 1976: personal communication.

Rao, T. R. 1977. *Enhancement of Natural Populations of Moi (Polydactylus Sexfilis) in Hawaii Through the Release of Hatchery-reared Juveniles–A Feasibility Study of Sea Ranching*. Technical Report No. 33. Hawaii Institute of Marine Biology, University of Hawaii, 46 pp.

Ryther, J. H., W. M. Dunstar, K. R. Tenore, and J. E. Huguenin. 1972. Controlled Eutrophication--Increasing Food Production from the Sea by Recycling Human Wastes. *Bioscience* 22(3):144-151.

Saila, S. B. and V. J. Norton. 1974. *Tuna: Status, Trends and Alternative Management Arrangements*, Paper No. 6. The Program of International Studies of Fishery Arrangements, Resources for the Future, Inc. 59 pp.

Saito, Y. 1976. Seaweed Aquaculture in the Northwest Pacific. FAO, FIR:AQ/Conf./76/R. 14, 16 pp.

Sandifer, P. A., J. S. Hopkins, and R. I. J. Smith. 1977. Status of Macrobrachium Hatcheries, 1976 in *Shrimp and Prawn Farming in the Western Hemisphere*, eds. J. A. Hanson and H. L. Goodwin. Dowden, Hutchinson & Ross, Inc., Stroudsburg, Penn. Pp. 220–231.

Santerre, Michael. 1977. Researcher, Hawaii Institute of Natural Energy, University of Hawaii: personal communication.

Sea Grant College Program, University of Hawaii. 1976. *Sea Grant Institutional Program, Year 09*, 1976–77, Volumes 1 & 2.

________. 1977. *Sea Grant Institutional Program, Years 10–11*, 1977–1979.

Shang, Yung Cheng and T. Fujimura. 1977. The Production Economics of Freshwater Prawn (*Macrobrachium Rosenbergii*) Farming in Hawaii. *Aquaculture* 11(2):99–110.

________. 1978. An Evaluation of the Market Potential for *Moi, Polydactylus Sexfilis*, in Hawaii. Unpublished manuscript, 6 pp.

Sorgeloos, P. 1976. The Brine Shrimp, *Artemia Salina*: A Bottleneck in Mariculture. FAO, FIR:AQ/Conf./76/E. 77, 5 pp.

Sunday Star Bulletin & Advertiser. Hawaii State Plan–A Presentation, Supplement, October 2, 1977. 22 pp.

Trimble, Gordon M. 1972. *Legal and Administrative Aspects of an Aquaculture Policy for Hawaii, an Assessment*. Hawaii State Department of Planning and Economic Development and Western Interstate Commission for Higher Education Resources Development Internship Program.

Tsukada, O., T. Kawahara, and S. Miyachi. 1977. Mass Culture of Chlorella in Asian Countries in *Biological Solar Energy Conversion.* eds. A. Mitsui, S. Miyachi, A. San Pietro, and S. Tamuri. Academic Press, N.Y. Pp. 363-365.

U. S. Congress. House. 1975. *Aquaculture. Joint Hearings* before two Subcommittees of the Committee on Merchant Marine and Fisheries, House of Representatives, on H.R. 370, H.R. 1800, H.R. 2231, H.R. 2795, H.R. 2814, H.R. 5565, H.R. 6628, H.R. 11028, H.R. 14695, H.R. 7153 and H.R. 9893, 94th Congress, 1st and 2nd sess.

U.S. Department of Commerce. 1975. *Basic Economic Indicators: Clams 1947-74.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Economic and Marketing Division, Washington.

________. 1976. *Current Economic Analysis S-35, Shellfish Market Review and Outlook.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington.

________. 1977. *Fisheries of the United States, 1976.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington.

________. 1972. *The Mardella Report.* National Oceanic and Atmospheric Administration, Washington.

Vergne, Philippe, P. Bryan, and G. Broadhead. 1978. *Large-scale Production of the Top Minnows (Poecilia Mexicana) in American Samoa and the Testing of Their Efficiency as Tuna Bait,* Technical Bulletin No. 1, Pacific Tuna Development Foundation, Honolulu.

APPENDIX A

A LEAD AGENCY FOR AQUACULTURE IN HAWAII

A lead agency is needed to consolidate efforts and provide a focal point to promote and expedite the development of aquaculture production in Hawaii. This need has evolved with the expansion of freshwater and marine aquaculture activities. The number of aquaculturists engaged in commercial production in Hawaii has nearly doubled each year over the past four years. Research and development have increased to the point where State, Federal and private sources presently spend nearly $2 million per year to support these activities.

The need for a lead agency has recently intensified as a result of a growing local, national, and international interest and involvement in aquaculture. State and County economic development planners have indicated that aquaculture has the potential to stimulate local economies by increasing employment opportunities and general revenues to the State, while at the same time helping to preserve rural life-styles and agricultural lands. The *Hawaii State Plan* (1977), the *Hawaii Coastal Zone Management Program* (1976), and the *Hawaii Water Resources Plan* (1977) have all expressed an interest in aquaculture, both as an alternative use of Hawaii's land and water resources and as an economic development activity.

The Federal government is preparing a massive push in aquaculture development aimed at benefiting this country[1] and developing countries overseas.[2] Internationally, the World Bank, the Food and Agriculture Organization of the United Nations, the

---

[1] For example: the pending National Aquaculture Organic Act (H.R. 9370) and the NOAA Aquaculture Plan (1977).

[2] The United States Agency for International Development (USAID), for example, is expected to provide major funding for developing aquaculture overseas through Title XII of the Foreign Assistance Act (1975).

Asian Development Bank, and the Southeast Asian Fisheries Development Center have expressed a desire to develop aquaculture to its fullest potential.

Aquaculture activities in Hawaii are presently dispersed among six State agencies: The University of Hawaii (Sea Grant College Program and College of Tropical Agriculture), the Department of Health (Shellfish Sanitation Program), the Office of the Marine Affairs Coordinator, the Department of Planning and Economic Development (Aquaculture Development Program), the Department of Land and Natural Resources (Anuenue Fisheries Research Center) and the Department of Agriculture's Farm Loan Division (Aquaculture Loan Program). The scattering of these activities is disadvantageous to aquaculturists, the general public, and others involved in aquaculture research and development because the establishment and expansion of the industry and the realization of its potential benefits are dependent on efficient and effective planning, coordination and implementation. Another disadvantage is that the agencies involved in aquaculture require coordination to eliminate overlapping and duplicating functions. A focal point at the State government level is needed to provide visibility, responsibility, accountability, and planning for aquaculture activities.

Duties of the Lead Agency

The lead agency would provide services to local entrepreneurs and investors, international governments and businesses, Federal Agencies, other State agencies, and County governments. In addition, the lead agency would act as a central agency for State participation in local, national or international aquaculture activities. Furthermore, the lead agency would determine funding support levels for various aquaculture research projects. In short, the lead agency would coordinate State manpower and financial resources for the expansion of the aquaculture industry.

The duties of the lead agency would include the following:

Program Management

- Recommends State policies and priorities for aquaculture development.
- Develops and manages State aquaculture facilities (e.g., hatcheries and experimental and demonstration centers).
- Actively seeks non-State sources of funds to support aquaculture research and development activities.
- Provides a visible contact point for aquaculture for in-State and out-of-State interests.
- Reviews research proposals requesting State funds and eliminates duplication of effort through the exercise of fiscal control.
- Acquires baseline data and periodically updates resource inventories and assessments for aquaculture development.
- Interacts with other State agencies and County economic and resource planning efforts.

- Provides economic assessments on specific projects and undertakes feasibility studies.
- Designs and plans programs aimed at creating new aquaculture industries (new species and projects).

Support Services

- Provides advisory, educational, and extension services to Hawaii residents and aquafarmers.
- Transfers information; conducts or assists in conducting workshops, symposiums, etc., on critical issues.
- Maintains cognizance of research and development by the industry and international, Federal, State, County, and private agencies.
- Develops an in-State and out-of-State information network.
- Provides for the continuous identification of information voids, and organizes and/or conducts efforts to fill them.
- Assists aquaculturists with required permit applications and siting.
- Assists in the development of training programs to provide a work force for the aquaculture industry.
- Undertakes market development activities for aquaculture products and collects and evaluates market data.
- Encourages the formation of cooperatives for the purpose of ensuring uniform, high quality, Hawaii products (e.g., processing, marketing, and quality control).
- Administers the Aquaculture Loan Program. (Note: For the present time, it is recommended that the Loan Program stay within DOA's Farm Loan Division.)
- Provides disease diagnosis, treatment and prevention services.
- Provides water chemistry and soil analyses, stock certification and depuration services.

Species Development

- Undertakes or funds research directed towards improving present production systems and reducing production costs.
- Undertakes or funds research directed at developing and testing new culture methods and/or systems, thereby identifying new economic opportunities.

Placement Considerations

Stature

At present, the scope and magnitude of aquaculture development does not warrant the creation of a separate department.[3] However, the resources which will be needed for aquaculture development, the current local and national interests in promoting aquaculture as an important source of food production and a component of energy projects and its potential economic impact all point to the need to consolidate and centralize State aquaculture activities as a division in one of the 17 principal State agencies. In order to determine the most suitable agency for lead agency, three important requirements for placement must be considered.

Requirements

Ideally, the lead agency would fulfill the following requirements: (1) it is involved in economic development, (2) its functions are compatible with aquaculture, and involve fisheries, natural resource management and/or food production, and (3) it has adequate facilities and support services.

Economic development. Aquaculture's major objective is to promote economic development, which includes the creation of jobs, and increasing personal income and economic activity. Economic development programs are administered by the Department of Planning and Economic Development (DPED), the Department of Agriculture (DOA), the Department of Land and Natural Resources (DLNR) and the Office of the Marine Affairs Coordinator (MAC).[4] While the University of Hawaii is also involved in economic development programs, the University's principal focus is on education and research.

Compatibility with other activities within the lead agency. Compatibility with activities within an agency provides aquaculture development with distinct advantages. For example, three important activities that are directly related to aquaculture are fisheries, natural resource management and food production.[5] Complementary activities such as these, housed together, can enhance communication and combine expertise. Reliable and timely communication, in turn, facilitates effective and efficient decision-making, planning, coordination, and the performance of individual functions. In addition, information on the latest developments in the industry can be quickly disseminated, public services can be maximized, and duplication of effort can be minimized.

The DPED, the DLNR and the DOA have activities that are complementary to aquaculture. The Office of the MAC, however, serves primarily as a funding and coordinating agency for marine and marine-related programs. The Office of the MAC would not, therefore, be the best choice for the lead agency.

---

[3] A resolution to investigate the feasibility of establishing a separate "Department of Marine Resources and Aquaculture" (SR 186) was adopted by the Ninth Legislature. The discussion in this appendix will be limited to the selection of a lead agency from among existing State agencies.

[4] The Office of the MAC funded 12 projects relating to aquaculture development berween the years 1971 and 1976 (*Aquaculture in Hawaii 1976*, 1976).

[5] There are, for example, similarities between hatchery technology, processing, and market distribution channels for both fisheries and aquaculture products.

Availability of adequate facilities and support services within the agency. The joint, or multiple-use, of existing facilities and support services is highly desirable because of the increased rate of return and the possibility of minimizing costs and effort. In addition, the joint use of existing facilities and support services would allow the State to make maximum use of its limited resources.

The DLNR's Anuenue Fisheries Research Center is presently the most important aquaculture facility in the State. Anuenue also has a wide range of extension/advisory services--principally to prawn farmers. The DOA has veterinary laboratory facilities, and provides assistance to aquaculturists through their loan program. The DPED does not possess the necessary facilities and support services, and would not, therefore, meet criteria required of a lead agency.

The Aquaculture Process

An examination of the three most important criteria for the lead agency indicates that the two most suitable candidates are the DOA and the DLNR. Another method of evaluation is to consider the entire aquaculture process and constraints to development in the next five to ten years. Which agency would most effectively address these constraints?

The first stage of the aquaculture process is usually hatchery and seed production. As the problems here are similar to fisheries, an agency incorporating both aquaculture and fisheries programs would be able to effectively deal with constraints in this area.

Growout (production) constitutes the next stage of the process. Aquaculture growout activities are similar but not the same as those activities surrounding the husbandry of plants and animals. Therefore, an agency with such traditional agricultural support services as extension/advisory, loans, and disease control would be equipped to solve constraints at this level.

The third stage, post-production, includes processing, distribution, marketing, etc. These are related to fisheries output activities. Inasmuch as similar equipment and technology are used in harvesting and processing and cultured products enter the market through traditional fisheries channels, constraints arising here could be most adequately solved by an agency with fisheries responsibilities.

Several conclusions can be drawn from the above analysis. First, aquaculture would be best served if the State's resources for aquaculture could be developed to achieve the greatest efficiency for the least cost. If agriculture, aquaculture, and fisheries development were under a single administration, the sharing or joint use of facilities, personnel and other resources would be permitted. This is the case in many countries that have made considerable progress in stimulating their aquaculture industries (Japan, Taiwan, and Israel, for example).

Secondly, this analysis verifies the previous conclusions that the DOA and the DLNR are the most logical candidates for the lead agency. Which agency would be more appropriate? As mentioned above, the answer to this question depends on the ability to determine the agency that would be better able to address major constraints over the next five to ten years. Since there are numerous constraints throughout the entire aquaculture process, and since it is impossible to state which of these are the most important, this study finds no distinct advantage in selecting one department over the other.

The DOA and the DLNR

Department of Agriculture. The Department of Agriculture (DOA) promotes the conservation, development, and utilization of agricultural resources through a variety of activities which include conducting research projects, disseminating information, and providing crop and livestock reporting and market news services. The DOA administers the programs of the State relating to animal husbandry, entomology, farm credit, development of agricultural products, and the establishment and enforcement of the rules and regulations on the grading and labeling of agricultural products.

The following DOA programs presently relate to aquaculture or may complement or support aquaculture activities at some future time.[6]

AGR 102:	Financial Assistance for Aquaculture	Funds from the Aquaculture Revolving Loan Program may be used for such purposes as plant construction, conversion, expansion, acquisition of equipment, and working capital.
AGR 121:	Plant Quarantine	In addition to preventing plant-harming pests and diseases, this program assists agriculture industries to ascertain the degree of acceptance of their products by other states or foreign countries. Producers of various species of seaweed may find this program useful.
AGR 132:	Animal Disease and Pest Control	This program prevents, controls, and eradicates animal diseases. Aquaculture development is dependent upon the prevention and eradication of disease among newly introduced species. An aquaculture disease specialist is presently assigned to this program on a part-time basis.
AGR 151:	Distribution System Improvement	This program currently provides quality control for fish products. Additional services that would benefit aquaculture include support for developing export markets, and improvement of the quality of marketing procedures for export products.
AGR 189:	Production and Marketing Data Collection for Agriculture	Aquaculture development would benefit from the data collection and processing services of this program. AGR 189's Crop and Livestock Reporting Services prepares estimates for acreage, yield, value of crops, production, farm wages, etc. In addition, aquacultural activities may be included in the program's Market News Service which reports wholesale prices and shipment data for agricultural commodities.

---

[6] Program identification numbers and titles are taken from *State of Hawaii Program Structure,* Department of Budget and Finance, 1976.

AGR 810:	Testing and Certification of Consumer Goods	The testing and certification of food products is crucial to the development of a new industry like aquaculture as consumer confidence in the product needs to be established. By requiring compliance with inspection laws, this program assures the consumer that only wholesome products will be marketed.

Department of Land and Natural Resources. The Department of Land and Natural Resources (DLNR) manages and administers the public lands, including the water and mineral resources on these lands, and the State's forests, fish, and game resources. The DLNR also manages the forest reserve and State parks, including historic sites.

The following DLNR programs presently relate to aquaculture or may complement or support aquaculture activities at some future time.

LNR 153:	Commercial Fishery and Aquaculture	This program's key facility, the Anuenue Fisheries Research Center (AFRC), has been, and continues to be, integrally involved in the development of aquaculture in the State. In addition to supplying prawn juveniles to local ponds, the AFRC has assisted aquafarmers with advisory and extension services, including training. Aquaculture techniques have been developed for commercial scale prawn production, and pilot ponds are being managed for research and demonstration purposes. An aquaculture disease specialist is presently assigned to this program on a part-time basis.
LNR 101:	Public Lands	This program administers State lands by selling and leasing land, and issuing executive orders and permits. The Aquaculture Development Program report, *Permits and Environmental Requirements for Aquaculture in Hawaii* (DPED, 1977), recognized that permit requirements are a major obstacle to aquaculture development. The close association of an aquaculture program with LNR 101 could possibly result in a greater clarification and coordination of permit regulations.
LNR 141:	Water Development and Irrigation	Various aspects of this program could benefit aquaculture development. LNR 141 locates and allocates the State's water resources. In addition, irrigation systems and other related water facilities are developed, operated and maintained by this program.
LNR 401:	Fish and Wildlife	This program preserves and protects native fish and wildlife by, among other devices, reviewing permit applications, including applications for the importation of new species. With the expansion of aquaculture ventures, it is likely that permission will be sought for new species to be introduced into the State. As with LNR 101, the close association of aquaculture with LNR 401 may help the two programs to better

understand each other's needs and thereby increase cooperation and efficiency.

LNR 404: Water Resources

Aquaculture development is highly dependent upon the wise utilization of the State's water resources. Aquaculture could benefit from this program's activities relating to water resources management and data collection.

APPENDIX B

TROPICAL AQUACULTURE CENTER FOR HAWAII

The following presents the need for and description of the proposed Tropical Aquaculture Center for Hawaii as requested in the Governor's supplemental CIP requirements for fiscal year 1978–79. The Aquaculture Planning Program has identified the current lack of outdoor research and development facilities as one of the major constraints to aquaculture development and recommends that the highest priority be given to the establishment of this facility. The Executive Supplemental Budget for Fiscal Year 1978–79 contained a CIP item for such a facility and the sum of $1,250,000 in State General Obligation Bond Funds has been appropriated by Act 243, SLH 1978, to the University of Hawaii with the Department of General Accounting Services as the expending agency.

Construction of this facility is in keeping with the State's goal to develop and expand commercial aquaculture production in Hawaii. In addition, the Center would provide a facility for such emerging Federal programs as Title XII of the Foreign Assistance Act and Section 402 of the amended Food for Peace Act of 1966 (Public Law 89-808), and such pending Federal aquaculture legislation as S. 2444, The Aqua-Culture Policy Act, and H.R. 9370, the Organic Aquaculture Act. Every attempt will be made to maximize the use of existing laboratory and hatchery facilities[1] and to avoid duplication of effort.

In preliminary discussions, the Aquaculture Development Program (ADP) and the University of Hawaii's College of Tropical Agriculture (UH/CTA) have agreed in concept to the joint designation with the designated lead agency. This is in keeping with one of *Aquaculture Development for Hawaii*'s major recommendations for effective aquaculture development.

---

[1] At the Anuenue Fisheries Research Center, the University of Hawaii, the Oceanic Institute, and other private institutions, for example.

The Need for a Tropical Aquaculture Center

Aquaculture research generally falls into three interrelated categories: (1) laboratory research aimed at providing a basic understanding of the life cycle of promising species, and a definition of environmental requirements, (2) applied research directed at reducing production costs and increasing yields of species currently under culture, and (3) programs for adapting technologies for species successfully cultured elsewhere and demonstrating their commercial viability under local conditions. Progress in all of these categories is needed to accelerate the development of commercial aquaculture in Hawaii.

Research to Improve Production Strategies

Research can be made more relevant to industry by constructing pilot-scale facilities for extending research results beyond the laboratory to experimental ponds which closely approximate or—ideally—duplicate the conditions of production units. The fact that such facilities are not presently available in the State has seriously limited the expansion of prawn farming in Hawaii.

The lack of experimental ponds has made it necessary for prawn researchers to negotiate for the use of commercial ponds. Cooperative arrangements with farmers normally require yield guarantees and management fees to compensate for disruptions of farm operations. These arrangements preclude total control over experimental design, manipulation of variables affecting growth, and replication of experiments for testing the statistical significance of research results.

Research to Adapt Technologies Developed Elsewhere

Aquaculture research has indicated that laboratory results in growth performance in one location do not necessarily predict the behavior of a species at a different location. Therefore, such standards of performance as growth, survival, feed conversion, and disease resistance must be evaluated under local conditions before new species development programs are initiated. Similarly, evaluative experimentation aimed at selecting the most effective culture method (e.g., pond, cage, and raceway culture) requires facilities for demonstrating the relative economic viability of each method in Hawaii regardless of the method's success elsewhere. A Tropical Research Center would enable analyses of these factors for the expansion of aquaculture in Hawaii.

Research to Understand Promising New Species

The efforts of the University's marine agronomy program have focused on effectively starting economically important seaweed industries in the Philippines, the U.S. Trust Territories, and elsewhere. Recently, the program has redirected its attention to Hawaii. Siting experiments on reef flats have demonstrated the impossibility of total control over variables affecting growth. Because of environmental problems, there is a need for experimentation on land-based locations. Marine agronomy can be used in aquaculture operations to utilize waste products from ponds to meet effluent discharge requirements, and produce a saleable product. While initial research in this direction has been undertaken in cooperation with Kahuku Seafood Plantation, the application of such research to a broader range of potential aquaculture operations requires experimental facilities.

Other examples of research areas that require experimental facilities include the use of: (1) pond water for crop irrigation, (2) animal wastes for food for certain aquatic species or for pond fertilization, and (3) aquatic plants as ingredients in animal feeds. Research in these areas could yield inexpensive livestock feeds and protein-rich food for human consumption. Aquatic scientists should be able to conduct outdoor experimental research to enhance aquaculture production much as agricultural scientists study agriculture commodities of importance to Hawaii. The aquaculture center would be similar to the University of Hawaii's Agricultural Experiment Station.

Basic Facility Requirements

The design of a facility to house multi-purpose research programs must be flexible. Approximately 30 acres of land are needed for the initial construction of experimental pond complexes to serve the immediate needs of the prawn research program and for an administrative office, a manager's residence, a basic wet laboratory and storage buildings for equipment and feeds. The site should, however, encompass over 100 acres to allow for additional ponds for experimentation on new species, for the construction of prototype rearing systems, and for the anticipated expansion of programs resulting from Federally-sponsored national and international aquaculture development programs.

Water delivery systems capable of providing a wide range of salinities and flow rates are essential. Water transmission and discharge systems are also necessary. In addition, instrumentation for the monitoring of water properties, nutrients, metabolic wastes, and oxygen levels is needed. There should be complementary laboratory facilities for on-site field support, but existing laboratory facilities at the University, the Anuenue Fisheries Research Center, the Oceanic Institute (OI), and other private research institutions may be utilized in concert with the applied research and training programs of the Center.

The Center will be used as the principal locale for demonstration projects, for training personnel to provide direct technical assistance to farmers, for community information and for student participation in research projects. A seminar-classroom and reading room should, therefore, be provided.

Experimental Pond Complexes

A series of small experimental ponds which closely simulate the environment of commercial growout units is essential for testing the effects of different variables on yields. Some experiments relating to prawn growth variables can test the following: (1) the effects of stocking different densities of post-larvae, both with and without shelter provisions; (2) the effects of using nursery animals in stocking growout ponds instead of post-larvae; (3) the effects of adding organic wastes to stimulate phytoplankton production; (4) the effects of adding compost materials to stimulate the growth of bacteria, insect larvae, and worms as food for prawns; (5) the effect of monosex culture on yields; and (6) the effects of different genetic strains on production.

Forty-eight experimental ponds, each one-twentieth of an acre in size, are needed for conducting replicative experiments to test the statistical significance of each of these variables and their interactions against a control situation. These "applications" need to be evaluated against expected increases in production levels to determine costs. There is a further need for conducting experiments in a like number of ponds scaled up to one-tenth of an acre in size in order to determine—among other things—the effects of pond size on production yields and costs.

Prototype Rearing Systems

There are additional areas that can only be evaluated through applied research programs under field conditions. Some examples are: (1) the effects of different pond shapes on ease of harvesting and mechanization; (2) the effects of batch harvesting (draining ponds to determine whether uniform growth rates can be achieved), versus the current practice of culling market-size animals by periodic seining; and (3) the effects of culturing other species (e.g., carps and tilapia) with prawns.

Experimentation on the pond production of prawns is applicable to other species. However, additional space will be needed for testing alternative prototype rearing systems (e.g., raceways, cages, and tanks) for such species as catfish and marine shrimp. How different culture methods reuse discharge water for various species of shellfish is another research area that needs biotechnical and economic evaluation.

Phase I

A facility master plan will be developed to insure the orderly construction of the Center's essential components. Table B-1 provides preliminary estimates of the individual construction costs. In order to complete Phase I construction, capital requirements will amount to $1,075,000, including $130,000 for design and permits.

Phase II

An expansion of activities is anticipated in pending Federal legislation for national aquaculture development, and in existing legislation for an international thrust in aquaculture research, training and technology transfer through competitive grants to land grant and sea grant colleges. The infusion of significantly increased Federal research funds into the University of Hawaii will have a positive impact on aquaculture development in the State. As Phase II is scheduled to begin two to three years after completion of Phase I, it should be designed to address additional needs identified in the interim. The tentative estimated cost of Phase II is $3,925,000 for a total construction cost of $5,000,000.

Possible Sources of Federal Funds for the Construction and Operation of the Tropical Aquaculture Center

If Congress passes pending aquaculture measures, the appropriation of State matching funds for an Aquaculture Center would place Hawaii in an excellent position to receive matching Federal funds for research and development laid out by these measures. Moreover, provision of funds for an Aquaculture Center would enhance the State's competitiveness for existing Federal funds.

National Aquaculture Organic Act

The "National Aquaculture Organic Act" (H.R. 9370), scheduled shortly for a floor vote in the U.S. House of Representatives, names the Department of Commerce as the lead agency for promoting aquaculture development in the United States.[2] H.R.

---

[2] Passed the U.S. House of Representatives on February 14, 1978, by a vote of 24 to 13.

Table B-1. Preliminary Estimates of Construction Costs for a Tropical Aquaculture Center of Hawaii

Description			Cost
Phase I			
Facility Master Plan Design and Permits			$ 130,000
Construction			
1.	Grading and grubbing of site, and construction and paving of access roads	$ 45,000	
2.	Forty-eight 1/20-acre ponds at $400 each	19,200	
3.	Forty-eight 1/10-acre ponds at $700 each	33,600	
4.	Prototype production systems	100,000	
5.	Fresh- and saltwater settling basins and injection wells at $15,000 each	30,000	
6.	Freshwater well	5,000	
7.	Saltwater well	5,000	
8.	Well-head pumps, four at $2,500 each	10,000	
9.	Chain-link fence, 4,600 feet at $16 per linear foot	73,150	
10.	Manager's residence, 1,200 square feet at $50 per square foot	60,000	
11.	Wet laboratory, 1,000 square feet at $100 per square foot	100,000	
12.	Laboratory equipment	100,000	
13.	Feed storage, 2,000 cubic feet at $5 per cubic foot	10,000	
14.	Equipment storage, 2,000 square feet at $30 per square foot	60,000	
15.	Classroom, 800 square feet at $40 per square foot	32,000	
16.	Office, and bathroom and shower facility, 800 square feet at $50 per square foot	40,000	

Table B-1. (Cont'd)

	Description	Cost	
17.	Fresh and saltwater distribution systems, 5,000 feet each at $4 per foot	$ 40,000	
18.	Discharge distribution systems, 5,000 feet each at $7 per foot	70,000	
19.	Power/transmission hook-up	5,000	
20.	Domestic water hook-up	2,000	
21.	Domestic sewage hook-up	5,000	
22.	Tractor and attachments	20,000	
23.	Four-wheel drive pick-up	10,000	
24.	One and one-half ton truck	20,000	
25.	Miscellaneous field equipment	50,000	
	Total Phase I Construction	$ 944,950	
	TOTAL PHASE I		$1,074,950
Phase II			
	Facility Expansion	$3,925,000	
	Total Phase II Construction		3,925,000
	TOTAL PHASE I & II		$4,999,950
	Rounded to		$5,000,000

9370 authorizes the Secretary of Commerce to carry out any function under this Act

> by contacts or grants to any other Federal Agency, any agency of any state, any agency of any political subdivision of *any state if the state approves the grant or contract . . . any educational institution,* or any other person, *except that no contract or grant may be made unless the applicant submits a certificate* from each appropriate state agency stating that nothing in the laws administered by such agency prevents the carrying out of the project for which the contract or grant is being made.

Conducting scale tests, and the construction, operation, and maintenance of *developmental* aquaculture facilities for assessing the biological and economic feasibility of any aquaculture system are among the purposes of H.R. 9370. *Contracts and grants may not exceed 50% of the estimated cost of the project involved.* Under H.R. 9370 authorizations for aquaculture contracts and grants are apportioned in the following manner: Department of Commerce–$4 million, $15 million, and $17 million for FY's 1979, 1980, and 1981, respectively. Department of the Interior and Agriculture–$2 million, $7.5 million and $8.5 million *each* for FY's 1979, 1980, and 1981.

Aquaculture Policy Act

The "Aquaculture Policy Act," Senate Bill 2444, recently introduced, proposes to make the Department of Agriculture the national lead agency for aquaculture. It calls upon the Secretary of Agriculture to conduct aquaculture assessments and prepare a status report within one year after enactment of the law. Once this is completed, it will serve as the basis for a national aquaculture strategy. In comparison to H.R. 9370, S. 2444 is a short form bill. *As such, there are no authorizations for the USDA to undertake assessments and no authorization for contracts or grants to the states.*

Food and Agriculture Act of 1977

The "Food and Agriculture Act of 1977" (P.L. 95-113) was signed into law on September 29, 1977. For the first time, this law establishes aquaculture as a mission of the USDA by including aquaculture within the definition of Food and Agricultural Sciences. The law did *not* explicitly assign aquaculture lead agency responsibilities to the USDA. It did, however, provide for a Federal agency subcommittee, chaired by the USDA, to coordinate Federal programs that are related in any manner to Food and Agricultural Sciences. While this law contains sizeable authorizations for research programs and facilities for "eligible institutions"–principally state agricultural universities–Congress did not provide a specific breakdown for aquaculture. It simply included aquaculture within the research, extension, and teaching responsibilities of the USDA. Aquaculture is buried by the omnibus nature of this law which includes a variety of programs from dairy farming and beekeeping to food stamps. Except for the *implication* of lead agency designation in the farm law, the authority of the USDA specific to aquaculture is not clear. It remains for Congress to settle the lead agency issue, to determine spending levels, to specify authorizations for aquaculture research grants and facilities, and to appropriate funds.

Title XII of the International Development and Food Assistance Act of 1975

This title calls specifically for land grant and sea grant colleges to help alleviate the problems of food and nutrition throughout the developing world. In aquaculture, programs will probably focus on species which can be reared with extensive culture methods and processed into acceptable low-priced food products, rather than species in high demand and limited supply- mostly high value products employing fairly intensive technological methods. This new thrust must include an international effort to be guided by the Board for International Food and Agriculture Development (BIFAD), established by the Act.

While its focus is clearly on international food development (principally research, training, and technology transfer), the direct benefits of this program on the State's efforts to develop a commercial production industry in Hawaii are still unclear. It does not appear that Title XII can provide funds for capital improvements and land acquisition. It does, however, provide substantial sums for research and development contracts to universities. The University of Hawaii's College of Tropical Agriculture could become a major contractor because of its expertise. The infusion of large, Federal research funds into the University could result in positive spill-over effects for aquaculture development in the State. Provision of State facilities (through joint designation with the University) could strengthen the College's competitive position for Federal funds. Another institution that can play a major role in this program is the Oceanic Institute. OI has had a long history of aquaculture research sponsored by the U.S. Agency for International Development (USAID).

Economic Development Administration

The Economic Development Administration (EDA) administers the Public Works and Economic Development Act of 1965 through programs of technical assistance, public works and business development, as well as Title IX, which was added to the Economic Development Act in 1974. Under this title, the EDA provided funds for seven selected aquaculture projects in FY 1975. Since 1976, the EDA has provided matching funds totaling more than $41 million for 73 projects in Hawaii. Such outdoor demonstration facilities as those intended for the Center for Tropical Aquaculture appear to qualify under the EDA's Technical Assistance Program. Approved projects receive Federal matching funds on a 60 percent Federal, 40 percent State matching basis. *This source of funds will be one of the first to be pursued.*

Future Outlook

Hawaii has a long history of successful research in prawns, mullet, and marine agronomy. The State's highly trained personnel, with years of involvement in worldwide aquaculture programs, provide a valuable technical resource. The existence of other resources- Hawaii's strategic location, tropical climate, and excellent research institutions, for example–indicates that the Islands can readily become a world center for tropical aquaculture research and development, heavily supported by Federal dollars. Research, demonstration, education, and training programs at the Center would address both the needs of the State's commercial aquaculture sector and national and international aquaculture development.

APPENDIX C

SCORED SPECIES EVALUATION TABLES

Background

A comprehensive evaluation of species was undertaken for the purpose of screening and selecting candidates with potential for commercial aquaculture in Hawaii. (See also Chapter II, "Summary of Assessments, Species Selection and Assessment.") The selection procedure can be characterized as a stepwise progression with each step analyzing fewer species in greater detail. The following briefly relates the development and scoring of the evaluation tables. A more detailed account of these procedures is planned for a future technical report.

Species Selection Procedure

Initial listing. A list of 54 candidate species-groups[1] (many of which were made up of single species) was assembled utilizing input from the Aquaculture Planning Program (APP) staff, the State aquaculture community and pertinent literature (e.g., Bardach, et al., 1972; *The Mardella Report*, 1972; *The Pacific Aquaculture Conference*, 1973; Hanson, 1974; Gates, et al., 1974; Bell and Cantebery, 1976; and Glude, 1976). Criteria applied at this time limited selection to species-groups which were distributed geographically by tropical or subtropical region or which would be likely to respond favorably to elevated temperatures. It was assumed that any candidate species not indigenous to Hawaii could be imported.

Phase I: Preliminary Evaluation. The initial list of 54 species-groups was reduced to 20. The following general criteria were used in the evaluation.

---

[1] For ease of tabulation and discussion, general names, e.g., marine shrimp, are used throughout this report, with all species in a group collectively termed the "species-group". The scientific names of the members of each species-group evaluated in the tables can be found in Table 11 of the text.

1. Environmental Considerations

   - Is the natural temperature range and optimum temperature for the growth of the species compatible with Hawaii's climate? (Controlled temperature environments were not considered as options due to the costs involved.)

2. State-of-the-art for Culture Considerations

   - Are larval and adult foods identified and readily available?

   - Can the animals be reared under conditions which make culture on a commercial scale possible?

   - Have the biotechnical steps required for commercial culture been demonstrated to some degree?

   - Do clear definitions of the immediate constraints (biological, social, political and economic) to commercial culture exist?

3. Economic Considerations

   - Does the cultured product have a readily-defined local market or does it have possibilities of being exported in a cost-effective manner?

   - Do present or projected production economics appear promising?

These criteria emphasize three characteristics of a species-group: (1) biology (ease of culture), (2) biotechnology (the existence of techniques for culture), and (3) economics (cost-effective production and marketing of the product). Information used in making these decisions was gathered from the appropriate literature and personal communications with leading researchers and producers.

Phase II: Comprehensive Evaluation. Greater scrutiny of these species-groups was provided through the formation of a Species Subcommittee which was composed of knowledgeable members of the public and private sectors of the State's aquaculture community as well as the APP staff. The members were as follows:

Takuji Fujimura, Chief Biologist, Anuenue Fisheries Research Center, Division of Fish and Game, State Department of Land and Natural Resources.

Philip Helfrich, Associate Dean, Graduate Research, University of Hawaii

Kenneth Kato, President, Pacific Aquaculture Corporation

Robert May, Assistant Marine Biologist, Hawaii Institute of Marine Biology

Colin Nash, Director and Vice President, The Oceanic Institute

Robert Shleser, Coordinator, Aquaculture Planning Program, State Department of Planning and Economic Development

Comprehensive species evaluation tables were formulated through the combined efforts of: (1) the Species Subcommittee, (2) consultants, (3) various specialists in aquaculture from Hawaii, the Mainland and foreign countries, and (4) the APP staff. These tables—although considerably expanded—are similar in structure and function to the bioeconomic selection matrices of Nash (1974).

Necessary information was grouped into six major areas: (1) biological, (2) biotechnical, (3) market, (4) resource, (5) economic, and (6) legal and social. The selection of the key elements under each area was accomplished through debate and consultation. In all, 56 elements were determined.

The committee and APP staff developed a numerical rating system and scored each of the species according to the elements. The scores numbered one to five; with "one" being the lowest and "five," the highest. In some cases, explicit quantitative requirements were attached to the scores. Other cases required a consensus judgment of the Subcommittee. In many instances the degree of resolution obtained with five ratings was not needed, so only three ratings (1, 3 and 5) were used when the scoring of many elements was straightforward, a consensus could be reached easily; while others required much deliberation and/or library research.

Evaluation of the Method

The goal of this procedure was to provide an objective selection of those species-groups whose culture is technically feasible and which offer the greatest potential for economic benefits to Hawaii. Unfortunately, objective cross species-groups comparisons of totaled scores (i.e., ranking according to best species-group) could not be justified with this method. Reasons for this include: there are difficulties in comparing very diverse species-groups—for example, comparing the biology of algae with crabs, oysters with fish, etc.; there are difficulties in comparing freshwater aquaculture with mariculture, the former being considerably more developed than the latter; and there is a wide variability in the availability, quantity and quality of the information used in the scoring. The development of a weighing system to justify comparisons of numerical scores would alleviate some of these problems, however, it was considered beyond the scope of the program. Although the method outlined here did not provide a straightforward objective rank-ordering of species priorities, the methodology accomplished four important objectives:

1. A large amount of information was systematically and efficiently displayed.

2. Specific areas of advanced development for certain species-groups were identified.

3. Problem areas or areas constraining development for certain species-groups were identified.

4. Problem areas that certain species-groups have in common were clearly illustrated.[2]

[2] These areas of commonality can be approached through broad discipline-oriented programs.

The element descriptions and scoring criteria are presented below. They are followed by a complete set of scored grids. These evaluations were used to help prioritize species for State development as described in Section D of Chapter II.

Biological Considerations

Those aspects of the biology of species-groups that are important for aquaculture are presented below. Appropriate consideration was given during the scoring to the applicability of the criteria to the differences in species-groups, e.g., prawns versus aquatic algae—although this may not be reflected in the wording.

Reproduction in Captivity

Large-scale commercial culture of a species will be affected by the achievement of controlled reproduction in captivity.

Score	Description
5	Reproduction in captivity has been demonstrated in Hawaii and does not present a major problem.
3	Reproduction has been achieved in Hawaii with some difficulty or high cost.
1	No successful reproduction in captivity has been achieved in Hawaii; stocking material must be imported.

Broodstock Maintenance

Key components to be considered are survival, fecundity, space requirements, age to maturation, useful reproductive life, dietary requirements and reproductive cycles per year as it relates to the other factors.

Score	Description
5	The broodstock is easy to maintain in relatively high density with good survival, high fecundity and long reproductive life.
3	Broodstock maintenance is complicated by some problems associated with one or two of the following: survival, fecundity, reproductive life, age to maturation, or dietary and/or space requirements.
1	The broodstock is extremely difficult to maintain due to serious problems in more than two of the following: survival, fecundity, space requirements, age to maturation, useful reproductive life, dietary requirements.

Reproductive Cycles

The number of reproductive cycles per year may affect the suitability of the species for aquaculture. For example, the species may reproduce before it achieves market size, or the species may reproduce infrequently over a period of years.

Score	Description
5	The timing and/or frequency of reproduction poses no problems,
3	some problems, which can be managed, or
1	major problems to commercial culture.

Culturing Stocking Material

The time in the hatchery phase of aquaculture may critically affect the feasibility of production. For example, an extended larval period (several months to a year) reduces the suitability of a species for aquaculture.

Score	Description
5	The time in the hatchery phase is two months or less,
3	four months, or
1	six months or more.

Survival to Time of Stocking

The survival rate to time of stocking (larval survival) has a significant influence on the cost of seed stock. The survival rates obtained from the literature or personal communications reflect the rates from the most widely practiced production strategy applicable to Hawaii.

Score	Description
5	The survival rate is greater than 80 percent;
4	between 60 and 80 percent;
3	between 40 and 60 percent;
2	between 20 and 40 percent; or
1	less than 20 percent.

Diseases and Parasites

The susceptibility of a species to disease and parasite problems affects its suitability for culture.

Score	Description
5	The susceptibility to disease and parasites is low,
3	moderate, or
1	high.

Hardiness

Environmental stresses may affect survival. The sensitivity of the species to variations in the salinity, temperature, dissolved oxygen and concentrations of waste products can affect growth rate and survival. The subjectively determined integrated tolerance level of the species to these variations (i.e., hardiness) is considered an important characteristic.

Score	Description
5	The species has high resistance to adverse environmental conditions,
3	moderate resistance to adverse environmental conditions, or
1	low resistance to adverse environmental conditions.

Growout Time

Growout time refers to the time required for a species to grow from initial stocking size to a harvestable size. The data used here are obtained from commonly found commercial practices, as well as preliminary laboratory-derived estimates.

Score	Description
5	The growout time is shorter than six months,
4	between six and nine months,
3	between nine and twelve months,
2	between twelve and fifteen months, or
1	longer than fifteen months.

Survival to Harvest

Average survival to harvest under commonly observed culture conditions affects the suitability of a species for aquaculture.

Score	Description
5	The survival rate is greater than 80,
4	between 60 and 80 percent,
3	between 40 and 60 percent,
2	between 20 and 40 percent, or
1	less than 20 percent.

High Density Culture

The ability to culture a species at high densities is a desirable characteristic because lower cost per unit production can be achieved. Also, feeding and harvesting are often more easily facilitated in a high density system. The utilization of individualized grow-out containers to avoid cannibalism was excluded in evaluating species for this element.

Score	Description
5	The density potential is high,
3	medium, or
1	low.

Feed Conversion Efficiency

Feed conversion efficiency refers to the animal's ability to convert feed into body weight. Efficiencies are calculated as dry weight food to wet weight animal where supplemental or total feeding of prepared rations are used. Animals feeding on phytoplankton, zooplankton or detritus in a pond or intensive culture situation are assumed to be relatively inefficient converters. However, their low scores here are balanced by the high ratings in trophic level evaluations.

Score	Description
5	The feed conversion efficiency is less than 2:1,
4	between 2:1 and 3:1,
3	between 3:1 and 4:1,
2	between 4:1 and 5:1, or
1	greater than 5:1.

Trophic Level

A species' trophic level essentially describes the types of food an animal or plant requires. A high score is given for ability to utilize material such as phytoplankton, zooplankton, or detritus which occurs naturally or can be induced to occur in a growout pond. Low scores are associated with species which need high protein feeds or feed at a high trophic level.

Score	Description
5	The species feeds on naturally occurring nutrients, vegetation, weeds or phytoplankton,
4	feeds on naturally occurring zooplankton,
3	uses combinations of formulated feeds and naturally occurring organisms,

2	requires formulated feeds of less than 15% protein, or
1	requires formulated feeds of more than 15% protein.

Maturation

The time of sexual maturation affects the feasibility of various production strategies.

Score	Description
5	The species reaches sexual maturity at about the time it reaches market size,
3	somewhat before or after reaching market size; may adversely affect amount of marketable product or production of offspring, or
1	long before or after it reaches market size, causing considerable problems in the production of marketable products or offspring.

Cannibalism

Cannibalistic behavior of species influences its suitability for commercial culture.

Score	Description
5	The behavior of the species indicates no cannibalism,
3	moderate cannibalism which poses some problems to culture, or
1	highly cannibalistic which requires individual rearing vessels.

Biotechnical Considerations

The biotechnical evaluations are based on the degree of development of physical systems for aquaculture; i.e., hardware, containers and/or equipment for each of the elements.

First Ten Elements

The initial ten elements to be scored for biotechnical considerations are as follows: Broodstock Maintenance, Mass Rearing of Stocking Source (larval/juvenile), Mass Grow-out, Broodstock Feeding, Larval Feeding, Juvenile Feeding, Adult Feeding, Harvesting, Transporting and Processing/purging. These elements were scored similarly.

Score	Description
5	A commercial level system has been demonstrated or is in use in Hawaii.
4	A prototype system is operational in Hawaii.
3	A commercial system is operational elsewhere, and the probability of direct transfer to Hawaii is very high.

2 A system is operational elsewhere, but the probability of direct transfer to Hawaii is uncertain.

1 No system has been designed.

Larval Nutritional Needs Known, and Juvenile and Adult Nutritional Needs Known

The existence of basic nutritional information (i.e., requirements for amino acids, fatty acids, vitamins, etc.) is deemed an asset in the culture of most species. The same set of criteria were used to score species for both larval Nutritional Needs Known, and Juvenile and Adult Nutritional Needs Known.

Score	Description
5	Most basic nutritional requirements are known.
3	Some basic nutritional requirements are known, others will be investigated.
1	None of the nutritional requirements are known.

Larval Rations Developed, and Juvenile and Adult Rations Developed

The elements Larval Rations Developed and Juvenile and Adult Rations Developed refer to the existence of artificial, compounded or other rations. The same set of criteria were used to score species for both elements.

Score	Description
5	Effective formulated feeds or cultured foods are available to Hawaii.
3	Formulated feeds or cultured foods are available to Hawaii, but methods to effectively present feeds to organisms and feeds that maintain their integrity in water for an adequate period of time are needed.
1	No adequate supply of formulated feeds or cultured foods is available to Hawaii.

Year-round Cultured Stocking and Year-round Cultured Market Supply

An unlimited availability of material for stocking and market are considered important to aquaculture in Hawaii because full advantage can then be taken of the year-round growing season and market. The same set of criteria were used to score species for both year-round cultured stocking and year-round cultured market supply.

Score	Description
5	The culture can be managed to provide material for Hawaii at all times of the year,
3	half a year or more, or

1	two months or less per year.

Market Considerations

The market elements concern established markets based on known volumes of consumption. Basically, the higher the per annum sales for a product, the higher the score.

Identifiable Local Market

The higher the identifiable local market for an aquacultured product, the greater the opportunities for commercial development.

Score	Description
5	Total wholesale market value for a Hawaii-grown product exceeds $5,000,000 per annum,
4	lies between $1,000,000 and $5,000,000 per anum,
3	lies between $500,000 and $1,000,000 per annum,
2	lies between $250,000 and $500,000 per annum, or
1	is less than $250,000 per annum.

Identifiable Mainland Market and
Identifiable International Market

The higher the identifiable Mainland and international markets for an aquacultured product, the greater the opportunities for commercial development. The same set of criteria were used to score species for both elements.

Score	Description
5	Total wholesale market value exceeds $50,000,000 per annum,
4	lies between $10,000,000 and $50,000,000 per annum,
3	lies between $5,000,000 and $10,000,000 per annum,
2	lies between $2,000,000 and $5,000,000 per annum, or
1	is less than $2,500,000 per annum.

Potential Local Market

Potential local market figures utilize current consumption data of a product plus estimates of consumption in five years. These projections assume supply from aquaculture could be increased and some substitution occurs.

Score	Description
5	Potential wholesale market value exceeds $5,000,000 per annum,
4	lies between $1,000,000 and $5,000,000 per annum,
3	lies between $500,000 and $1,000,000 per annum,
2	lies between $250,000 and $500,000 per annum, or
1	is less than $250,000 per annum.

Potential Mainland Market and
Potential International Market

The figures for potential Mainland and international markets utilize current consumption data plus estimates of consumption in five years. These projections assume the supply from aquaculture can be increased and that some substitution can occur. Species were scored for both elements according to the same set of criteria.

Score	Description
5	Potential wholesale market value for Hawaii-grown product exceeds $50,000,000 per annum,
4	lies between $10,000,000 and $50,000,000 per annum,
3	lies between $5,000,000 and $10,000,000 per annum,
2	lies between $2,500,000 and $5,000,000 per annum, or
1	is less than $2,500,000 per annum.

Wholesale Price–Hawaii

The wholesale price of an aquaculture species is of importance in Hawaii. Due to the high cost of inputs (i.e., land, labor, water, feed, etc.), species of relatively high market value may have the most immediate commercial potential because they may allow enough margin for profit. Scoring was as follows:

Score	Description
5	Wholesale price potential per pound exceeds $3.00,
4	lies between $2.00 and $3.00,
3	lies between $1.00 and $2.00,
2	lies between $0.50 and $1.00, or
1	is less than $0.50.

Subcultural Preference

If the appeal of a species to a specific ethnic group is limited, the expansion of that market may be restricted.

Score	Description
5	Species appeals to a variety of ethnic groups,
3	to several ethnic groups, or
1	to a small ethnic group.

Interregional Competition

A candidate for culture in Hawaii will most likely be cultured elsewhere in the world. Interregional competition addresses the estimated extent to which other areas can compete with a Hawaii product in the local seafood market. It must be kept in mind that the form of the imported products may be the same as the Hawaii-grown product.

Score	Description
5	The product is produced only in Hawaii, or other areas cannot compete economically in the local market.
3	There is some competition from elsewhere, but the Hawaii produced product is considered superior.
1	Severe competition from other areas affects the viability of culture in Hawaii.

Recreational Potential ("Pay and Fish")

An aquaculture industry of considerable size has emerged in the southern United States. The culture of channel catfish for recreational fisheries ("Pay and Fish") is rapidly becoming an important outlet for cultured species. A smilar situation for trout exists in France and the United States (Brown, 1977).[3] Species with potential for recreational fishing increase the feasibility for commercial culture.

Score	Description
5	The potential for recreational fishing is high,
3	moderate with some problems, or
1	not foreseen.

---

[3] Such species as oysters, which are not suitable for "Pay and Fish," received lower scores.

Catch Fisheries Competition–Hawaii

The volume of landings from capture fisheries in Hawaii can affect the viability of a given species. The larger the natural fishery, the harder it may be for a cultured product to compete in the marketplace.

Score	Description
5	No natural fisheries exist.
3	There are small fisheries, but these are important to only a small segment of the market.
1	Large natural fisheries exist.

Economic Risk

Economic risk is measured by the stability of the market. The greater the stability, the greater the reliability in marketing estimates. Consequently, fewer risks are involved.

Score	Description
5	The market is large and stable,
3	widely fluctuating, or
1	unidentified and not predictable.

Resources

The physical requirements for the candidate species-groups can be related to certain available State resources. Aquaculture is generally considered "technology extensive" and moderately "labor intensive" (Bardach et al., 1972; Brown, 1977). Key elements considered were availability of sites, water and expertise.

Sites

The availability of appropriate sites for culture is fundamental to development. For example, if a species requires seawater embayment for culture and suitable embayments are not available in Hawaii, then a low score was assigned. Also, competition from alternative uses must be evaluated. If a species requires land which is unsuitable for other uses, it scored highly. If a species requires land or water areas which are in competition for other uses, such as urban development or tourist attractions, it received a lower score.

Score	Description
5	The species can be cultured on available, unused land or water areas,
3	requires land or water areas which are either scarce or in competition with other industries, or
1	requires land or water areas which are not available, or which are highly competitive with other uses or committed to other uses.

Water

Species-groups were evaluated and scored with respect to the availability, quality and quantity of water (fresh water and seawater) necessary for culture. Generally, brackish water and saltwater species would receive a high score.

Score	Description
5	Water of required quality and quantity is available in abundance throughout the State,
3	available regionally, or
1	limited.

Expertise Required

The availability of technically competent personnel familiar with all aspects of the aquaculture of a species-group is deemed an asset for commercial development.

Score	Description
5	Technical requirements are well-known, and knowledgeable managers and technically qualified personnel are available in Hawaii,
3	known, but expertise is not available in the State, or
1	not well-known, and expertise is not available.

Economic Considerations

The economic elements for scoring the species-groups assess: (1) economic feasibility, and (2) the likelihood of obtaining institutional financing for aquaculture ventures.

Past Performance

Past or demonstrated performance is important in financing. Most financial institutions will not approve a loan for an enterprise that has not successfully demonstrated economic feasibility.

Score	Description
5	Production and financial success have been demonstrated in Hawaii.
3	Production and financial success have been demonstrated elsewhere.
1	No financial success has been demonstrated to date.

Likelihood of Institutional Financing

Lending institutions may have differing views as to the potential for success of an aquaculture venture. Lendors with a high degree of understanding of the operation will have greater confidence in its profit potential and will be more favorably inclined to offer loans.

Score	Description
5	Lendors have a high level of confidence in the operation—loans and funding available in Hawaii,
3	some understanding of the operation—loan potential exists in Hawaii, or
1	little or no understanding of the operation—the likelihood of obtaining a loan is not great.

Potential Profitability

Based on the state-of-the-art for culture and the structure of the market, the potential profitability can be estimated.

Score	Description
5	The profit potential is high,
3	marginal, or
1	not profitable or unknown.

Confidence in Profitability Estimate

This element reflects the reliability of information that has been used to estimate profitability.

Score	Description
5	The estimate of profitability is based on well-established practices in situations similar to Hawaii, both physically and economically.
3	Isolated example(s) suggests profitability.
1	Estimates are highly tentative; no commercial production has been demonstrated.

Time to Develop Industry

The estimated time necessary for development of commercial production in Hawaii will affect funding decisions.

Score	Description
5	The time needed is estimated to be less than 2 years—short term,
3	5 years—midterm, or
1	10 or more years—longterm.

Legal and Social Considerations

This table addresses the issues of legal and social barriers to the importation, culture, sale and exportation of aquaculture commodities by Hawaii's aquafarmers. These areas have an important effect on the ability of private interests to begin or invest in aquaculture ventures.

Legal Barriers to Import

Species-groups which require a permit to bring them into the State are deemed less desirable. Similarly, those on the Federal Injurious Species List are deemed less desirable.

Score	Description
5	The species is endemic and already present in Hawaii.
3	must be imported from Mainland or Canada, or
1	must be imported from other countries.

Other Legal and Social Barriers

Legal and social barriers refer to laws or a social consciousness which may impede the development of a species-group. The elements scores were: legal barriers to culture, legal barriers to sale, social barriers to import, social barriers to culture and social barriers to sale. The same set of criteria were used to score species for all five elements.

Score	Description
5	There are no barriers,
3	minor problems, or
1	major barriers.

Table C-1. Species-Group Tables

Biological Considerations	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Reproduction in captivity	3	5	5	5	2	3	5	1	5	1	2	1	4	5	1	5	5	2	5	3
Broodstock maintenance	3	5	5	5	5	5	5	1	5	1	3	3	3	5	3	5	3	3	5	5
Reproductive cycles	3	5	5	5	1	3	5	1	5	1	1	1	1	5	1	5	1	2	1	3
Culturing stocking material	5	5	5	5	5	4	4	1	5	1	5	1	1	5	2	5	1	2	1	5
Survival to time of stocking	4	5	3	4	5	5	2	1	4	4	5	4	3	5	1	4	1	3	4	5
Diseases and parasites	4	4	3	4	3	4	4	3	4	4	3	3	3	4	3	2	5	5	3	3
Hardiness	3	5	5	5	5	5	3	5	3	3	3	5	4	3	3	5	5	2	3	3
Growout time	1	5	5	5	3	3	4	3	2	3	5	3	1	5	4	3	3	3	3	3
Survival to harvest	4	5	4	5	4	5	3	4	3	3	4	5	4	4	2	3	3	2	4	4
High density culture	1	5	5	5	5	5	5	5	3	5	5	5	5	1	5	5	1	5	5	5
Feed conversion efficiency	3	5	4	1	4	1	1	4	3	1	3	1	1	5	2	1	1	1	4	5

Table C-1 (*continued*)

Biological Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Trophic level	1	5	3	5	2	5	5	2	2	5	1	5	4	1	2	5	5	5	3	2
Maturation	5	5	5	5	3	3	5	1	5	3	5	1	1	5	1	5	5	5	5	5
Cannibalism	1	5	3	5	4	5	5	5	3	3	5	5	5	1	3	5	1	5	5	5
Biotechnical Considerations																				
Broodstock maintenenace	3	4	4	5	4	4	5	1	5	2	3	2	4	4	4	5	3	3	4	4
Mass rearing of stocking material	3	4	4	5	4	4	5	1	5	1	3	1	4	2	3	5	3	3	4	4
Mass growout	2	4	4	5	5	4	5	3	5	1	3	3	5	3	3	5	2	3	2	3
Broodstock feeding	2	5	4	5	5	4	5	5	5	1	3	2	2	2	3	5	2	3	4	3
Larval feeding	3	5	4	5	5	4	5	1	5	1	3	1	2	2	3	5	1	2	1	3
Juvenile feeding	3	5	4	5	5	4	5	3	5	1	3	1	5	2	4	5	2	3	2	3

Table C-1 (*continued*)

Biotechnical Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Adult feeding	2	5	4	5	5	4	5	3	5	1	3	3	2	2	4	5	2	3	4	3
Harvesting	3	2	4	4	5	4	5	3	5	5	3	3	5	5	5	5	2	3	4	3
Transporting	5	5	4	4	5	4	5	3	5	5	5	5	5	5	5	5	5	5	5	5
Processing/Purging	5	5	5	5	5	5	4	5	1	5	5	5	5	3	5	5	5	5	5	5
Larval nutritional needs known	3	5	2	1	2	2	3	3	3	1	4	2	2	1	2	3	1	2	2	5
Juvenile and adult nutritional needs known	3	5	2	1	4	2	2	2	3	1	3	1	2	2	2	2	1	1	2	5
Larval rations developed	4	5	3	5	4	5	5	2	2	1	3	2	2	1	2	5	1	3	2	5
Juvenile and adult rations developed	4	5	3	5	4	5	5	2	2	1	3	2	2	1	2	5	1	3	2	5
Year-round cultured stocking supply	2	5	5	5	1	5	5	1	5	1	1	2	2	1	1	5	1	1	3	1
Year-round cultured market supply	1	5	1	5	5	5	1	1	5	1	1	1	1	1	1	5	1	1	1	1

Table C-1 (*continued*)

Market Considerations	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Identifiable local market	4	1	2	1	3	1	3	1	2	2	4	1	2	2	1	4	2	2	1	1
Identifiable mainland market	5	4	1	1	1	1	1	1	2	1	5	1	1	1	2	1	1	1	1	1
Identifiable international market	5	4	1	1	1	1	1	4	1	1	5	1	1	1	3	1	1	1	1	1
Potential local market	4	2	4	2	4	1	4	3	5	3	5	1	3	1	2	4	2	3	3	2
Potential mainland market	5	5	1	4	1	1	1	1	4	1	5	1	1	1	3	2	1	2	1	1
Potential international market	5	5	1	5	1	1	2	4	4	1	5	1	1	1	3	2	1	2	1	1
Wholesale price - Hawaii	5	1	1	5	4	2	1	5	4	3	4	1	4	3	5	3	3	4	3	1
Subcultural preference	5	5	5	5	3	1	5	3	3	1	5	2	3	3	3	4	5	5	3	3
Inter-regional competition	2	3	2	3	1	2	1	4	3	5	2	1	1	1	1	1	1	1	5	1
Recreation potential	1	1	3	1	5	3	3	1	1	1	1	1	3	1	1	3	5	3	5	5
Catch fisheries competition - Hawaii	5	5	3	5	5	5	5	5	5	2	5	3	3	1	3	5	2	5	3	5

Table C-1 (*continued*)

Market Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Economic risk	5	5	5	3	5	1	5	3	4	4	5	3	3	3	3	4	3	5	3	4
Resource Considerations																				
Site	5	2	5	5	5	5	3	5	5	3	3	3	5	3	5	3	3	3	3	2
Water	5	5	5	5	3	3	5	3	3	5	5	5	5	5	5	5	5	5	5	2
Expertise required	4	5	5	4	5	5	5	3	5	2	3	1	5	4	5	5	1	3	4	3
Economic Considerations																				
Past performance	1	3	3	3	4	3	3	3	5	1	3	3	3	1	2	3	1	2	2	3
Likelihood of institutional financing	1	1	1	4	3	1	2	1	5	1	1	1	3	1	1	3	1	1	1	2
Potential profitability	4	3	4	5	3	3	3	4	5	5	5	2	2	3	5	3	3	4	2	3

Table C-1 (*continued*)

Economic Considerations (cont'd)	American Lobster	Aquatic Algae	Baitfish	Brine Shrimp	Catfish	Chinese Carp	Clam	Eel	Freshwater Prawn	Limpet (*Opihi*)	Marine Shrimp	Milkfish	Mullet	Octopus	Ornamental Fish	Oyster	Samoan Crab	Scallop	Threadfin (*Moi*)	Trout
Confidence in profitability estimate	3	3	3	3	5	3	3	3	5	1	4	1	4	1	4	5	1	3	1	5
Time to develop industry	3	3	5	3	5	5	5	1	5	2	2	1	5	1	2	5	1	3	3	3
Legal/Social Considerations																				
Legal barriers to import	5	5	5	5	5	3	5	1	5	5	5	5	5	5	5	3	5	3	5	5
Legal barriers to culture	3	1	5	3	5	5	3	1	5	3	3	3	3	3	3	3	5	3	3	5
Legal barriers to sale	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	3	3	3	5	5
Social barriers to import	5	2	5	5	4	2	3	1	5	5	3	5	5	3	5	3	5	3	5	4
Social barriers to culture	5	5	3	5	5	5	5	1	5	5	5	5	5	3	3	5	5	5	5	5
Social barriers to sale	5	5	3	5	3	3	5	3	5	5	5	3	5	5	5	5	5	5	5	5

APPENDIX D

SPECIES DEVELOPMENT PROJECTS, FY 1977-78

This table describes the State Aquaculture Development Program's species development projects, FY 1977-78. Projects are listed in alphabetical order. Funding appropriate applied research and demonstration projects is one of several on-going development activities being undertaken by the ADP. Projects shown below reflect proposed State funding priorities discussed in Chapter V, Budget and Timetable.

Species and Project Titles	Description	Sources and Amounts of Funding				
		Aquaculture Development Program	Other State	Federal	Private and in-kind	Total Project Funding**
Baitfish Culture of Baitfish	Research aimed at (1) investigating the biology of topminnow, (2) studying the life histories of several species (*P. vittata, P. mexicana, P. latipinna*), (3) producing topminnow for full-scale testing by commercial tuna fishing boats, (4) observing topminnow behavior and its use as baitfish, and (5) conducting economic studies on topminnow culture and use for development of skipjack fisheries.	$16,000	(UH) $35,508	(SG) $20,000	-	$71,508
Baitfish Development and Utilization	Production of 15,000 pounds of the topminnow, *P. vittata*, for use in fishing trials. To determine the suitability of topminnow as baitfish for the skipjack tuna fisheries as compared with the traditional *Nehu*.	$12,000	(MAC) $33,000	-	(MC) $74,000 (NMFS) 4,000 (HIMB) 1,500 (HTP) 500	$45,000
Opihi *Opihi* Research	To complete studies in the biology of *Opihi* with emphasis on laboratory spawning and larval rearing.	$ 8,400	-	-	(UH) $ 2,120	$ 8,400
Oyster Case Study of Oyster Production	The Kahuku Seafood Plantation's oyster facility will be investigated to determine ways to minimize capital and operating costs.	$ 7,600	-	-	(UH) -**	$ 7,600

Appendix D (*continued*)

Species and Project Titles	Descriptions	Sources and Amounts of Funding				
		Aquaculture Development Program	Other State	Federal	Private and in-kind	Total Project Funding**
Freshwater Prawn Hawaiian Prawn Aquaculture Program	For the further development of the State's freshwater prawn industry, a coordinated AFRC-UH program will perform research in the areas of genetics, reproduction, nutrition, behavior, environmental studies, food processing, economics, engineering, and systems analysis.	$136,000	(UH) $17,667	(SG) $146,827	-	$300,494
AFRC/OSG Prawn Program			(DLNR) $45,000	(SG) $ 90,000	-	$135,000
Ecotype Testing	Expansion of genetic stock.	$ 12,500	(DLNR) $16,000 (restricted)	-	-	$ 12,500
Workload Increase	To provide additional support, extension and advisory services, to Hawaii's prawn farmers, whose farmed acreage has nearly tripled in the last year.	$ 74,000	-	-	-	$ 74,000
Seaweed Seaweed Marine Agronomy	To continue research on seaweeds leading to the production of a food for marine organisms, an edible commodity for the local market (*ogo*), and marine colloids for use in industrial chemicals and drugs.	$ 25,620	(UH) $13,982	(SG) $ 40,000	(Brewer) $25,000 (KSP) $25,000 $50,000	$129,602
Marine Shrimp Preliminary Research in Culture of *Penaeid* Shrimp	To identify & compile information on the requirements of achieving maximum grow-out and routine reproduction.	$ 28,000	-	-	(OI) $20,490	$ 48,490

*Abbreviations as used in this section: Brewer=Brewer Chemical; DLNR=State Department of Land and Natural Resources; HIMB=Hawaii Institute of Marine Biology; HTP=Hawaii Tuna Packers; KSP=Kahuku Seafood Plantation; MAC=Office of the Marine Affairs Coordinator; MC=Maui County; NMFS=National Marine Fisheries Service; OI=The Oceanic Institute; SG=Sea Grant; UH=University of Hawaii.

**Does not include in-kind contributions.