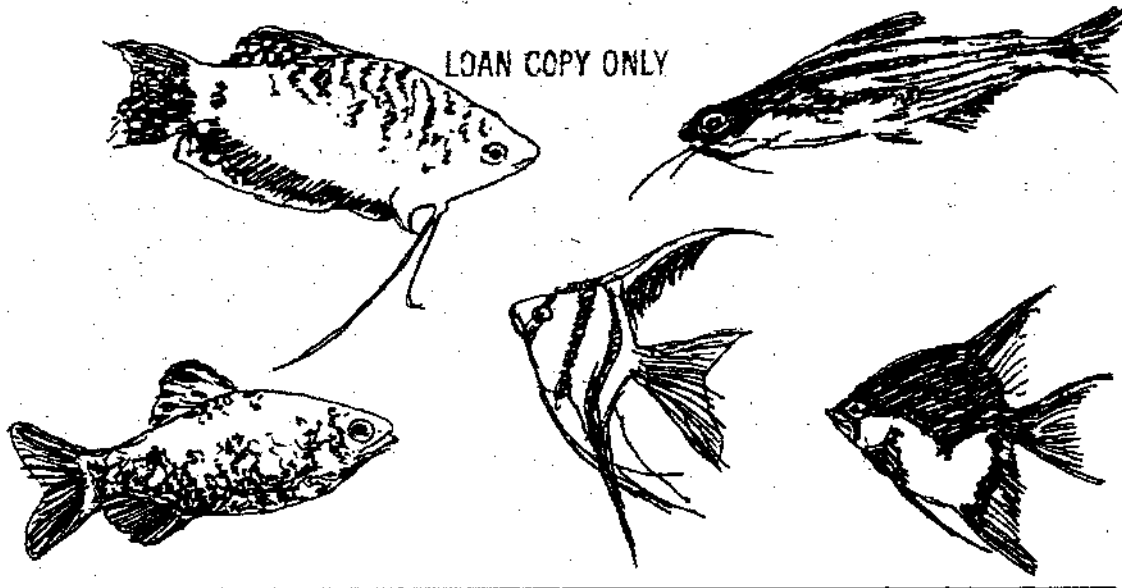


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An Ornamental Aquaculture Research Program for Hawaii



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Aquaculture Development Program

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Preface

The following document describes a multidisciplinary approach to a research and development program for an ornamental aquaculture industry in Hawaii. The proposed program will establish a scientific basis for an economically rewarding industry in Hawaii, Guam, and American Samoa. A strong research program in Hawaii, in cooperation with ongoing programs in Florida and other states, could transform the United States into a strong competitor in the expanding aquarium trade.

The University of Hawaii Sea Grant College Program and the State of Hawaii's Aquaculture Development Program have a long history of supporting research in aquaculture and strongly support the objectives of this initiative. With the financial support of these programs, the state has established the necessary infrastructure and has a keenly interested core of researchers required to develop a successful ornamental aquaculture research program. The purpose of this document is to present an outstanding economic development opportunity for Hawaii and the nation and the research agenda to pursue it. We urge your support.

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Summary

Hawaii is in an excellent position to assume a highly competitive international role in the breeding, rearing, and marketing of freshwater and marine tropical fish and plants. Substantial expertise already exists in Hawaii in aquacultural engineering, marketing, fish biology, and intensive aquaculture. This expertise, in combination with Hawaii's good water quality, geographic location, ideal climate, and economical shipping costs provides important advantages for the establishment of a new industry producing ornamental fish, plants and ancillary products. Hawaii is not susceptible to winter freezes, such as the one that decimated ornamental fish farms in Florida in 1989.

The production of ornamental fish, plants, invertebrates, and hardware is an expanding industry well suited for tropical and sub-tropical climates. In general, the aquarium trade continues to grow even in times of economic distress. The production of ornamental fish has grown to a \$30 million per annum industry in Florida, although this represents only a small fraction of the domestic market and does not significantly impact the vast export market. The annual world market for aquarium fish, plants, invertebrates, and supplies has been estimated at over \$4 billion.

The development of a tropical ornamental aquaculture industry in Hawaii could lead to the production of valuable cash crops and could reduce and perhaps eventually eliminate pressure on wild fish populations. A tropical ornamental aquaculture industry could significantly enhance the economic viability of rural Hawaii in much the same fashion as the tropical flower business already has. Intensive tropical ornamental aquaculture production can be carried out successfully in small land areas and can be automated to a large extent. The industry will therefore be relatively impervious to high real estate and labor costs, which in the past have constrained the growth of agriculture in Hawaii.

The tropical fish industry depends on several hundred species. By specializing in different species, an ornamental aquaculture industry in Hawaii and the U.S.-affiliated insular Pacific territories could complement the existing industry in Florida. It could also provide a domestic alternative to foreign producers as a source of the broodstock that are needed to replace mortalities and to maintain genetic diversity.

A strong ornamental aquaculture research program in Hawaii, in cooperation with Florida, the Gulf and western states, and the U.S.-affiliated Pacific islands, could lead to the establishment of a national program. This would allow the United States to actively compete in the expanding multi-billion dollar world market. The following document outlines a plan for research needed to establish an ornamental aquaculture industry in Hawaii. It is not intended as a specific research proposal, but rather an overview of research and development projects needed to lay the foundation for the industry. With sufficient state and federal funding for the various component parts of the project, and active coordination within the University of Hawaii, a profitable, new industry can be brought to the U.S.-affiliated Pacific Islands.

Introduction

Trading, cultivation, and exhibition of aquatic ornamental fish, invertebrates, and plants is an expanding, multi-billion dollar industry. The World Wildlife Fund estimated 350 million ornamental fish were sold in the 1988 world market. Of that number, the U.S. imported 125 million fishes. The U.S. Department of Agriculture's Economic Research Service reported that in 1990, U.S. imports of ornamental fish rose 16 percent from 1989. Also, the export of U.S.-produced ornamental fish, primarily to Canada, Mexico, Hong Kong, Japan, and Taiwan, increased 36 percent between 1989 and 1990. For the most part, this figure represents the growth of the ornamental aquaculture industry in Florida; we believe similar growth is possible in Hawaii and elsewhere in the Pacific.

The aquarium hobby ranks among the favorite pastimes in the United States. Between 10 and 20 million American aquarium enthusiasts keep approximately 95 million tropical fish. The purchase of ornamental fish contributes to our balance-of-trade deficit, since about 80 percent of these fish are imported. It therefore makes good economic sense to promote the domestic production of tropical fish for import substitution as well as export. Also, since livestock accounts for only about 25 percent of the value of the aquarium trade, it is a sound idea to develop the domestic aquarium supplies and equipment industry.

In this document, we present a research agenda for establishing an active ornamental aquaculture industry in Hawaii. It is important to note the need for careful attention to the environmental risks of scaling up the ornamental aquaculture industry in Hawaii. The introduction of exotic fish species and pathogens must be controlled through sensible and carefully planned industry growth. Well-engineered culture systems which minimize the risk of escape are essential. Effective fish health monitoring processes must be established. The regulatory procedures must provide the necessary controls to prevent unwanted introductions, but at the same time be flexible enough to allow the industry to expand.

In general, the farming of tropical fish represents a sound environmental and economic alternative to the collection of wild fish. At present, the vast majority of saltwater and rare freshwater tropical fish marketed are wild-caught. Overcollection, in combination with habitat destruction, has contributed to sharp declines in wild populations of ornamental fish worldwide. Collection methods range from acceptable (careful hand netting by trained divers) to abominable (the use of poisons or explosives which inflict gross environmental damage for each live fish collected).

The establishment of an ornamental aquaculture industry in Hawaii requires technical and marketing expertise, as well as an atmosphere conducive to growth. State cooperation and a well-organized growers' association have helped to transform a cottage industry into a significant commercial activity. In southeast Asia, specialized research programs at the National University of Singapore on the genetics and reproductive biology of ornamental fish have helped to spark a thriving ornamental aquaculture industry. A progressive fish-breeders association has also been a key to industry growth in Singapore and Malaysia.

Hawaii has a well-established aquaculture community in which government, academic, private, and commercial interests cooperate on industry development. Ornamental aquaculture is viewed by many Hawaiian aquaculturists as the wave of the future. A few culturists are already producing and

marketing ornamental species but the widespread perception is that expansion is possible. However, a sudden, major expansion of an ornamental aquaculture industry in Hawaii is not likely to happen spontaneously, despite the high level of interest and the entrepreneurial spirit that are present. A variety of technical obstacles must first be overcome. These are discussed in detail below. We believe a coordinated research effort by scientists representing several departments at the University of Hawaii could help overcome these obstacles and lead the way to an economically viable new industry here. This could also establish the basis for similar industries in Guam and Samoa.

Hawaii, with its tropical climate and unpolluted water resources for ornamental aquaculture, should develop a strong, supportive research and development program. As the basis for development of an ornamental industry for Hawaii we propose coordinated research in four areas: (1) ornamental fish farming technology, (2) ornamental aquaculture systems, (3) ornamental aquatic plant production, and (4) technology transfer and industry development.

1. Ornamental fish farming technology

Research in ornamental aquatic animal production will provide the foundation for the growth of an aquarium industry in Hawaii. A targeted research program should emphasize production technology and nutrition.

Fish and invertebrate culture

The development of cultural methods for ornamental animals suitable for Hawaii requires the establishment of reliable techniques for maturation and spawning of adults, culture of the larval stages, and efficient growout methods for post-larval and juvenile stages. The selection of appropriate species should follow the established protocols for commercial-scale production and transshipment of fish. Both freshwater and marine organisms have strong potential for commercial culture in Hawaii. Endemic Hawaiian species will make up the bulk of marine fish studied. Virtually all of the industry-standard freshwater fish could be produced in Hawaii. Since these include a wide variety of Asian, Latin American, and African fishes, it will be necessary to use effective quarantine and containment methods.

Our growing understanding of the reproductive physiology of fish has made artificially induced spawning feasible for an increasing number of species. It is now possible to obtain fertilized eggs and larvae for many fishes previously considered difficult or impossible to breed in captivity. It is also possible to produce eggs at times other than the normal spawning season. This could lead to the cultivation of many Hawaiian reef fishes currently supplied to hobbyists at the expense of wild populations.

Larval fish have complex nutritional and physiological requirements which must be identified and understood to enhance their growth and survival. Mass production and grow-out of these larvae are the final objectives of fish production. Achieving this objective requires information on optimal densities, tank design, water quality, and feeds.

Invertebrates are another group of organisms which have commercial potential in Hawaii. Some invertebrates such as rotifers, *Daphnia*, and copepods, are sold as food for ornamental fish. Others, such as the intensely colorful reef shrimps and anemones, are grown to a limited extent as aquarium species.

Feed Development

Nutrition plays a vital role in reproduction, growth, and health of captive ornamental fish and invertebrates. Currently, the industry relies largely on live feeds or the combination of live and artificial feeds. Reliable and economical production systems are needed for various live feed organisms to ensure a consistent supply of nutritious food. Nutritionally balanced artificial diets will improve the profitability of commercial-scale ornamental fish culture and should be developed. Research in artificial feeds should concentrate on nutritional balance, palatability, and effects on water quality. The presence of commercial- and research-scale aquaculture feed mills in Hawaii suggests that the local production of pelleted ornamental fish feeds could reduce the need to import specialty feeds as the industry grows.

Fish Health

Specialized expertise must be developed in the identification and treatment of pathogens, which could threaten both cultured crops and wild populations. New pharmaceuticals developed here and elsewhere must be screened for their effectiveness and appropriateness for use with endemic and non-endemic species.

The aquaculture industry is increasingly being regulated in its use of chemicals and drugs for reproduction, disease management, and regulation of growth. Investigation into these areas is necessary to develop a database for making responsible decisions on the safety and efficacy of different treatments. In addition, prevention represents an excellent alternative means of dealing with disease. Stress management is an important component of a successful ornamental aquaculture industry, and this concept should be incorporated into new culture systems. Mass-culture methods using balanced nutrition and stress management can reduce the dependence on drugs for disease control and should be studied. Genetic improvements for disease resistance can be made either through selective breeding or genetic engineering. Experimentation in ornamental fish genetics can also lead to the development of new varieties distinguished by color, finage, etc.

2. Ornamental aquaculture systems

Water Quality Engineering

Automated water quality management systems have been developed for the aquaculture industry and could be refined and applied to the aquarium trade. Computers processing information from environmental sensors can be adapted for use both in commercial farming of ornamental fish and in management of home aquaria. We envision a new generation of automated, reasonably priced, reliable aquarium management systems. Such systems do not necessarily require a high degree of precision; the combination of readings over time can establish a general trend that would trigger a diagnostic procedure. The system would then take whatever corrective action is required. This theoretical approach ("fuzzy-logic") is making inroads into the world of automated control and management, but has not yet been applied to the water quality in aquarium systems. The development of a new generation of "expert systems" can move Hawaii to the forefront of high-technology aquarium system design.

Aquarium automation

The costs of aquarium systems, equipment, feeds, medications, etc. account for more than half of the total aquarium trade. The development of simple, reliable, cost-competitive aquarium technology could be an integral part of an ornamental aquaculture industry in Hawaii. Locally produced parts and products would serve the industry and could be exported. By developing instrumentation and equipment specifically for ornamental aquaculture water quality sensing and control, the industry will be free from using equipment originally designed for other applications. Husbandry systems must be developed for ornamental aquaculture to provide superior water quality during maturation, larval rearing, and grow-out of ornamental fish species. Fully automated aquaria could reduce costs for hobbyists and could prevent some of the failure and frustration experienced by beginners, who are just learning to manage the miniature ecosystem within the aquarium. Automated aquarium systems will also help improve production on the commercial side, by minimizing the labor required in hatchery and growout operations.

Both the decorative and hobbyist markets require reliable aquarium systems that can be operated without the attention of technical personnel. Current aquarium systems rely heavily on mechanical and biological filters to maintain water quality without the use of sensing and control devices. The ability of these systems to perform satisfactorily under varying loads is extremely limited and their reliability must be improved. In addition, diets should be developed with ingredients that can be utilized more fully and hence cause less load on filtration systems.

Aquarium display and design

The design of aquatic display systems as an art form is a relatively new concept. Interior decorators rarely, if ever, include indoor aquatic systems in their work, in part because of the challenges of concealing hoses, pumps, wires, multiple electrical outlets, etc. These components can be designed together into visually appealing units that require little work to manage and which do not detract from the aquascape. Unobtrusive information panels integrated into the system could provide a continuous readout of water quality status from the sensors. To develop the market beyond hobbyists' interest, aquarium display, coupled with new aquarium technology, should be systematically studied.

With the use of modern materials, attractive display units requiring minimal maintenance can be developed. The development of off-the-shelf reliable sensors, controllers, water management devices, and automated feeders that can operate alone for weeks would allow the production of custom systems with varying levels of sophistication and cost. These systems could be tailored to a variety of specialized applications. The engineer/designer team should be encouraged to increase the appeal and practical desirability of ornamental aquatic systems in home, office, restaurant, or commercial ornamental fish production environments.

3. Ornamental aquatic plant production

Freshwater aquatic plants and marine algae are important elements in the aquarium trade, particularly as components for decorative display systems design. They are not only aesthetically important, but also help to maintain water quality. Recent data from Florida indicate that aquatic

plants accounted for 17.5 percent of the wholesale ornamental aquaculture trade in 1989; \$7 million out of a total of \$40 million.

Increasingly stringent regulatory requirements are making the importation of foreign aquatic plants difficult and costly. Plant propagation by conventional breeding and vegetative means will be coupled with more sophisticated biotechnical methods such as the tissue culture approach. A broad-based aquatic plant industry in Hawaii could be developed along the lines of the present orchid and cut-flower industry, which uses cloning and other advanced culture technology in the cultivation of tropical flowers. Specialized propagators distribute stocks to small and part-time farmers, who grow them to market size and then pool their products cooperatively for export. Research is needed to select appropriate freshwater plant species for propagation here, and to establish optimal production methods.

The marine aquarium hobby consumes large amounts of "live-rock" (rocks with discrete invertebrate and algal community assemblages), which could be produced commercially. Because of the environmental damage caused by the collection of wild corals and other organisms for sale as live-rock, the collection of these materials is illegal in Hawaii and is being increasingly prohibited elsewhere. Consequently, the economic potential for farmed live-rock for export to the mainland has increased substantially. We propose a program for development of efficient live-rock culture methods, which would combine selection of lightweight and attractive substrate materials, controlled settlement, and cultivation of desirable species of invertebrates and algae.

4. Technology transfer and industry development

Establishing the means of producing fish, plants, invertebrates, and hardware for the aquarium trade is an important first step toward creating an ornamental aquaculture industry. Extension and demonstration programs will be needed to effectively transfer new technology to industry members. Coordinated extension programs could involve not only the Hawaii-based researchers and producers, but also interested members of the aquaculture communities of Florida and the U.S.-affiliated Pacific island nations. These technology transfer programs should involve representatives of selected government agencies that oversee aquaculture development in their respective areas.

Shipping and Transportation

Efficient, cost effective transport of aquatic animals and plants is essential to the development of a competitive ornamental aquaculture industry. Transportation costs account for about half of the wholesale price of ornamental fish, and Hawaii could capitalize on the relatively inexpensive air shipping rates (back haul rates) available. Bulk shipments reduce shipping costs, and it is important that small producers band together to create enough volume to economically export their products.

Shipping technology is a distinct area for improvement. At present, fish and invertebrates are usually packed in oxygenated plastic bags sealed into styrofoam-lined cardboard boxes. Mortalities due to shock and thermal stress are quite common. Better shipping containers, in combination with innovative treatments such as mild anesthetics, chemical oxygen generators and possibly nitrifying bacteria, could help to minimize losses.

Marketing

Products grown in Hawaii have a special marketing allure and the state is associated with good health, environmental quality, and high value — a reputation that already carries over into the export of Hawaiian reef fish. If an emphasis is placed on quality control and assurance for quality from the outset, the Hawaiian aquarium industry can build a reputation as a source of prime stock for the aquarium trade. This could give Hawaii crucial economic advantages over many foreign fish suppliers who emphasize quality and low price, but who tolerate high levels of mortality and disease in their products.

Next Steps

Potential business development opportunities exist for Hawaii and the American Pacific Basin in the freshwater and marine aquarium industry trade. There are many Hawaii individuals and businesses in this area already producing and/or transshipping livestock. With additional development attention and infrastructural support, increased growth of revenue can occur. We recommend a cooperative approach to integrate the strengths of the U.H. Sea Grant College Program, University of Hawaii at Manoa, and the Aquaculture Development Program, Department of Land and Natural Resources. Further, we must encourage inclusion of interested private parties at the industry planning and public policy setting levels.

We need to develop a strategic industry development plan, in concert with a targeted research agenda. What are the bottlenecks to production? What are the research problems for the business? How can Hawaii be competitive? What is the market and what does it want? How does the market operate? Is a cooperative essential for industry expansion? Where and what is the level of demand for products? What are the market projections for the next five to 10 years? These are just some of the issues.

We should develop a research program that fills the technical needs of business development. Farmers and manufacturers should be encouraged to identify problems so the research team can address them. We should encourage innovation and practical solutions that can be transferred to small and medium-sized farms.

In summary, this generalized research agenda for aquarium industry development should be followed by: (1) a meeting of research interests and persons (retailers, farmers, manufacturers, suppliers, distribution jobbers, and researchers) in the aquatic and marine ornamental trade to identify needs, opportunities, problems, and potential solutions; (2) a comprehensive, multi-year research and extension program with required funding needs; and, (3) a strategic plan for industry development, which is prepared in close cooperation with the industry. Together these actions could provide the impetus for "cutting edge" research and the establishment of a new growth sector in Hawaii's aquaculture industry.