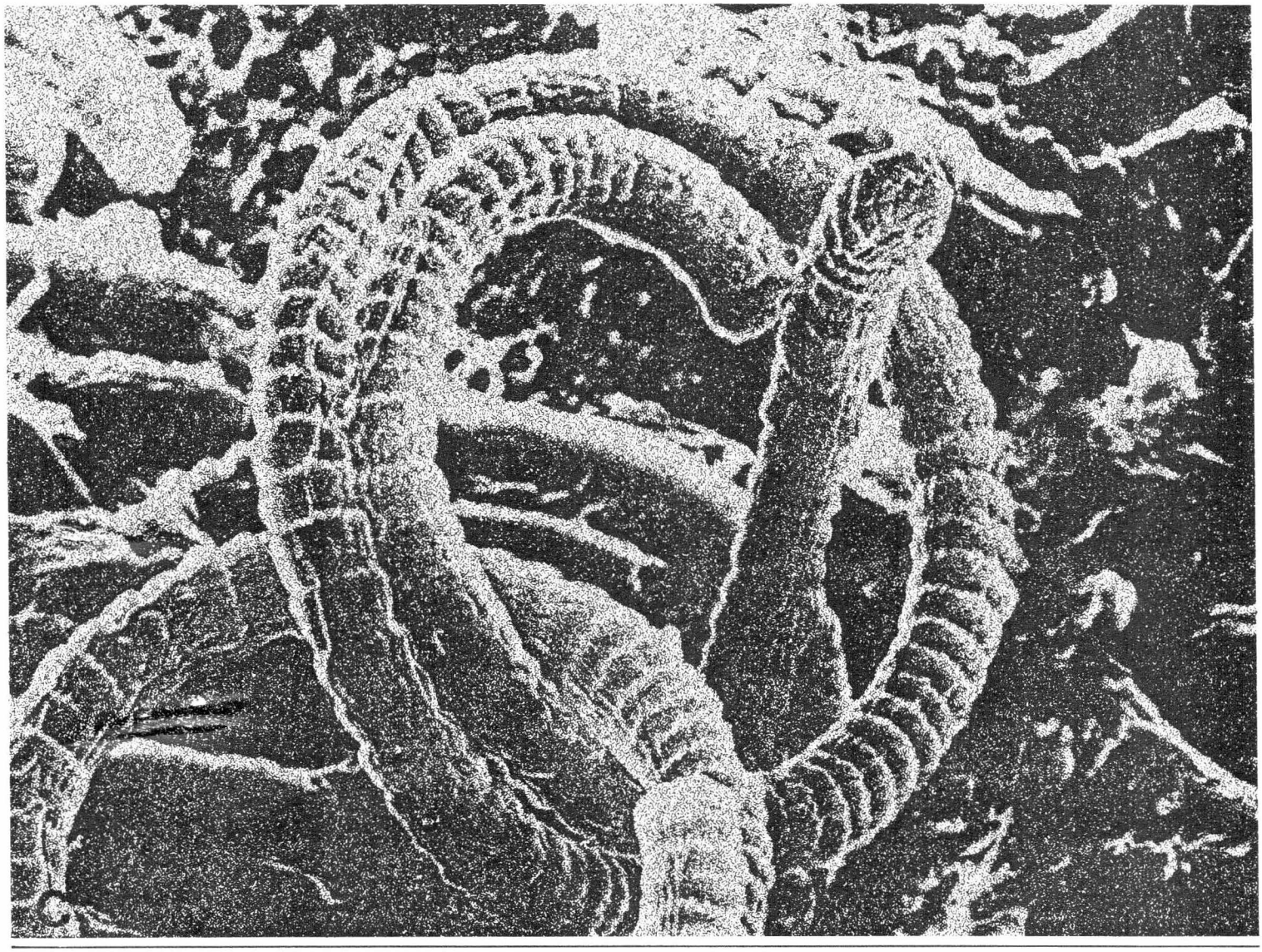
COMMERCIAL AQUACULTURE IN HAWAII, 1986

Kevan L. Main and Robert H. Deupree, Jr.



ACKNOWLEDGMENTS

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OVERVIEW

Results of a 1986 survey of Hawaii's commercial aquaculture industry are reported here. The survey goals were to (1) describe the current status of the aquaculture industry in Hawaii, (2) determine what kinds of support services are needed by commercial aquaculture producers, and (3) determine areas whose further research and development will enable commercial producers to increase their production levels. The first portion of this paper presents data describing the current status of Hawaii's aquaculture industry as a whole. The second portion presents information on individual species groups cultured in Hawaii (e.g., marine shrimp, freshwater fish, etc.), and discusses the problems and needs associated with each group.

In 1986, there were 36 producing aquaculture farms and more than 200 people employed by the industry. Thirty-one owners or managers of these farms were interviewed. A wide variety of species is cultivated in Hawaii, the most common being the freshwater prawn, *Macrobrachium rosenbergii*. Species presently under commercial cultivation include freshwater prawn, marine shrimp, Chinese and channel catfish, tilapia, rainbow trout, grass and silver carp, bighead carp, koi, mullet, aholehole, milkfish, freshwater tropical ornamental fish, bullfrog, abalone, and macro- and microalgae.

Farms were classified by size, primary species cultivated, and level of management intensity. There were three size classifications: cottage, small business, and corporation. Cottage farms are the dominant organizational form in Hawaii; they are small, family-operated businesses with one or two employees. Farms were also classified by six species groups: prawn, shrimp, freshwater fish, algae, ornamental fish, and miscellaneous species. Finally, farms were classified by level of management intensity: extensive, semi-intensive, and intensive.

Marine shrimp and freshwater prawn farms reported the highest production levels for 1985. None of the shrimp farms reported a profit in 1985; however, the majority of these farms were operating at pilot scale. In 1985, 50 percent of the freshwater prawn farms reported a profit. Production costs hinder the ability of a farm to make a profit. Although the major production costs vary among farm size classes and species groups, many farmers reported that labor and feed costs imposed a significant drain on their financial resources.

The limitations on aquaculture production are discussed for the individual species groups cultured in Hawaii. The limitations frequently identified by the farm operators interviewed were lack of capital for expansion, high production costs, disease, predation, and feed costs.

Aquaculture producers reported that the major limitation on production in Hawaii is the inaccessibility of capital for expansion. Hawaii's aquaculture industry is dominated by cottage-industry farms that have limited financial resources. These producers believe that large, short-lived aquaculture businesses have made it virtually impossible to obtain capital for expansion or operating expenses. Although the state administers an Aquaculture Revolving Fund Loan (ARFL) Program, cottage and small business farmers report that they are unable to obtain capital from it. The lack of a financial resource base for these operators may be limiting industry growth in the state. Thus, the loan fund should be increased and the qualification criteria revised to better meet the needs of cottage producers.

Farm operators expressed an interest in forming an aquaculture trade association. This association would serve as a voice for their problems and needs with state administrators and legislators.

The most commonly requested extension/advisory services are access to information on low-interest loan programs, access to technical information, marketing campaigns for certain species groups, an extension service similar to the agriculture extension service, and a reliable source of postlarvae.

Members of the commercial industry said that a central location for aquaculture information was needed in Hawaii. Information on technical problems (primarily aquaculture library services), low-interest loan programs, and market demand, as well as additional extension services, was frequently requested during our survey. A center for aquaculture information could provide many of these services.

With the exception of freshwater prawns, no marketing schemes have been devised for Hawaii's aquacultured products because of their low production levels. Freshwater fish producers in particular report that they restrict

their production levels because of the limited market for their product. Market promotion for several species groups should be considered.

Current policy restricts the state hatchery from guaranteeing postlarval availability for more than one year at a time. This resulted in limited prawn farm expansion in 1986 because producers were concerned that postlarvae would not be available in the future. The state needs to develop a policy that guarantees the availability of prawn postlarvae or to establish a state hatchery revolving fund if cottage-industry farms are expected to continue to operate and expand.

INTRODUCTION

We conducted a USDA-funded survey of the commercial aquaculture facilities in the state of Hawaii from July through November 1986. The only other published survey of Hawaii's aquaculture industry was conducted in 1982 by the West Coast Aquaculture Foundation (Stern and Ure, 1984).

Hawaii has a long history of aquaculture-related activities dating back to the fishponds constructed in the 14th century by early Hawaiians (Kikuchi, 1973). In 1965, the Hawaii State Anuenue Fisheries Research Center began a concentrated research program on the commercial culture of freshwater prawns. Its initial success (Fujimura and Okamoto, 1970; Fujimura, 1974), coupled with a state program offering free stocking material and management advice, provided an incentive for the start-up of several small- and large-scale commercial prawn farms in the mid-1970s.

Hawaii's state administration and legislature have strongly supported growth of the aquaculture industry. In 1976, the Department of Planning and Economic Development indicated that aquaculture had the potential to become a major industry in Hawaii. The legislature subsequently appropriated funding to develop a comprehensive aquaculture plan. Development of this plan was heavily supported by the University of Hawaii Sea Grant College Program. In 1978, Hawaii became the first state in the nation to publish a plan for aquaculture industry development, "Aquaculture Development for Hawaii, Assessments and Recommendations" (State of Hawaii, 1978). This plan detailed Hawaii's aquaculture resources and included guidelines to assist in expansion of the industry.

In 1983, Governor George Ariyoshi appointed a committee of private-sector individuals to examine the status of the aquaculture industry in Hawaii and to make recommendations for integrating aquaculture into the agricultural industry. The committee identified a need for more industry-oriented research to enable the aquaculture industry to reach its full potential (State of Hawaii, 1984).

The goals of our study were to (1) describe the current status of the aquaculture industry in Hawaii (e.g., species cultured, facility sizes, production levels, production techniques), (2) determine the support services (extension/advisory) needed by commercial aquaculture producers, and (3) determine areas requiring further research and development to enable commercial producers to increase their production levels. The first half of this paper describes the current status of Hawaii's aquaculture industry as a whole. The second half presents information on the individual species groups cultured and discusses problems and needs associated with each group.

METHODS

In 1986, 36 commercial aquaculture farms were operating in Hawaii. We conducted personal interviews with 31 of the owners or managers of these farms and with an additional seven prospective farmers. (Five farm operators did not agree to an interview. These farms are small [<2 acres each], however, and information on them would not have contributed significantly to the overall data base. We did include their location, species cultured, and farm area in the survey results.)

We administered a questionnaire adapted from the West Coast Aquaculture Foundation survey (Stern and Ure, 1984). A copy of the questionnaire developed for this study is included in Appendix I.

RESULTS AND DISCUSSION

Commercial Aquaculture in Hawaii: The Overall Picture

The aquatic species cultured commercially in Hawaii are presented in Table 1. Forty-three percent of the producers culture more than one species at their farm. In addition, 17 percent of the farms plan to diversify their operation and cultivate new species during 1987. Most aquatic farms maintain monocultures in their ponds. Only 26 percent of the farms are polyculturing several species within the same pond. Of the seven prospective farmers who were interviewed, four planned to polyculture prawns and fish (e.g., tilapia); one planned to culture marine shrimp; one planned to culture giant clams (*Tridacna* sp.); and one planned to culture microalgae (*Spirulina* sp.).

Table 1. Species commercially cultured in Hawaii

Common name	Scientific name
Freshwater prawn	*Macrobrachium rosenbergii*
Marine shrimp	*Penaeus vannamei, P. monodon, P. stylirostris*
Tilapia	*Sarotherodon* spp.
Channel catfish	*Ictalurus punctatus*
Chinese catfish	*Clarius* spp.
Rainbow trout	*Salmo gairdneri*
Grass carp	*Ctenopharyngodon idellus*
Silver carp	*Hypophthalmichthys molitrix*
Bighead carp	*Aristhichthys nobilis*
Koi	*Cyprinus carpio*
Mullet	*Mugil cephalus*
Aholehole	*Kuhlia sandvicensis*
Milkfish or awa	*Chanos chanos*
Jack or papio*	*Caranx* spp.
Bonefish or 'o'io*	*Albula vulpes*
Freshwater tropical ornamental fish	
Bullfrog	*Rana catesbeiana*
Samoan crab*	*Scylla serrata*
Pink and red abalone	*Haliotis refuscens, H. corrugata*
Nori	*Porphyra* spp.
Limu manauea	*Gracilaria* spp.
Microalgae	*Spirulina* spp., *Dunaliella* spp.

*Cultured at only one Hawaiian fishpond.

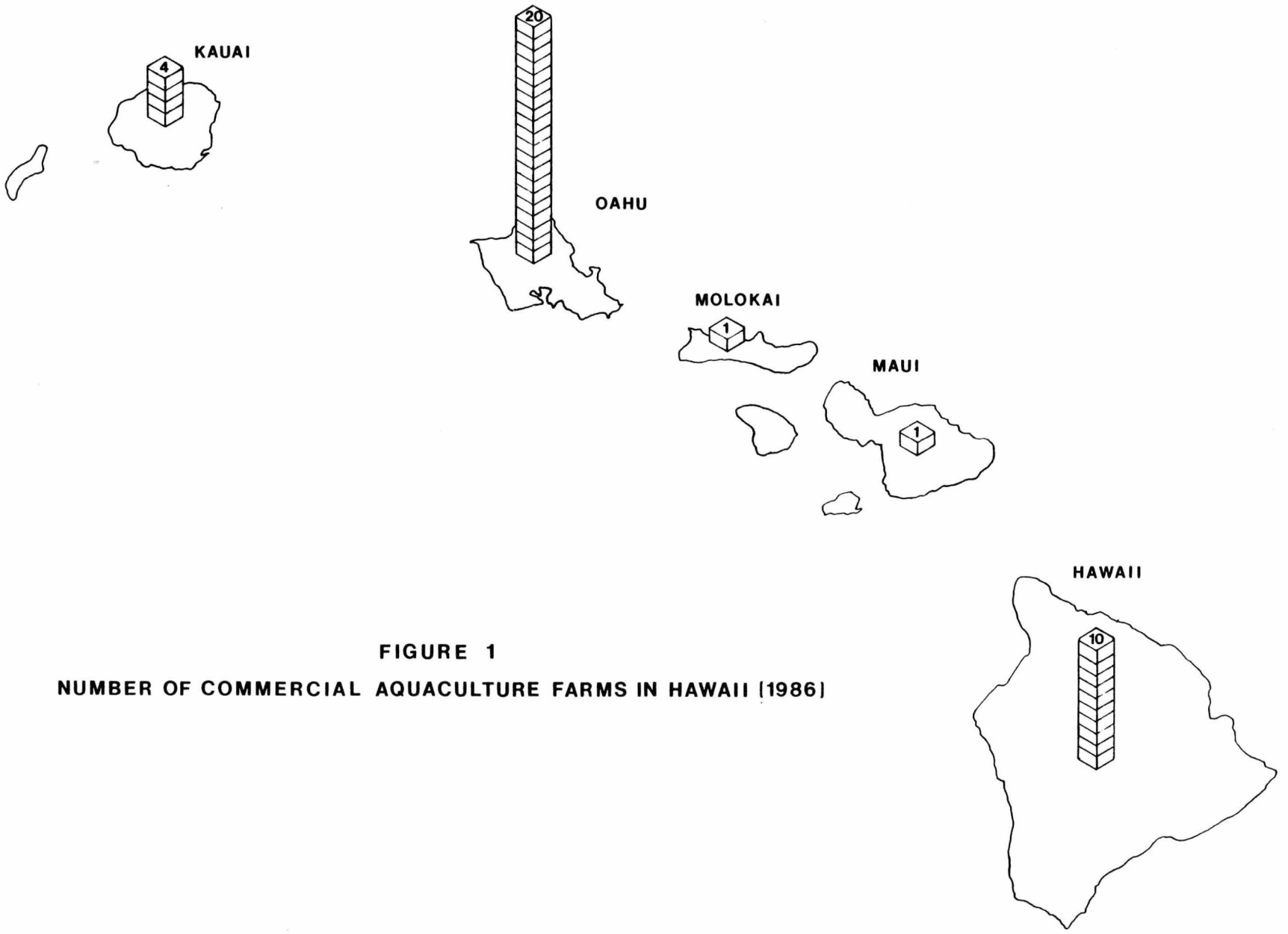


FIGURE 1

NUMBER OF COMMERCIAL AQUACULTURE FARMS IN HAWAII (1986)

The distribution of aquaculture farms in the Hawaiian Islands is illustrated in Figure 1. Farms were classified by size, primary species cultivated, and level of management intensity.

Farms were divided into three size classifications—cottage, small business, and corporation—based on the number of employees and the company structure (e.g., incorporated, limited partnership). Cottage farms are the dominant organizational form in Hawaii; 63 percent of the farms are cottage farms.

Figure 2 presents the mean number of employees in cottage, small business, and corporation farms. Cottage-industry farms are small, family-operated businesses that have one or two full- or part-time employees. Small businesses are intermediate in size and include partnerships that frequently have seven or more full-time employees. Corporation farms are large operations that are organized as incorporated businesses, having many employees.

Cottage farms as a whole have operated longer than corporation or small business farms. Cottage farms have been in business an average of 8.5 years, whereas corporations averaged 6.0 years and small businesses 1.9 years (Figure 3). Small businesses tend to operate fewer years than corporation and cottage farms because they depend on product sales for operating income. Corporations have a larger financial resource base and frequently operate for many years without turning a profit. Cottage farms are not dependent on product sales as their sole income source, and frequently use resources from other businesses to maintain their farms during low-income periods.

Farms were divided into six species groups based on the dominant species cultured. These groups are prawn, shrimp, freshwater fish, algae, ornamental fish, and miscellaneous species (abalone, bullfrog, tilapia, and other saltwater fish). All freshwater and ornamental fish farms and 66 percent of prawn farms were in the cottage size class (Figure 4). Algae and marine shrimp farms were equally divided between the small business and the corporation size classes. Prawn, freshwater fish, and ornamental fish farms have been in commercial business the longest (Figure 5).

Farms were also classified by level of management intensity: extensive, semi-intensive, and intensive. Extensive farms involve seminatural systems entailing little daily management, low stocking densities, limited feed input, and limited water exchange. Semi-intensive farms involve low-level management of physical and biological parameters, moderate stocking densities, and intermediate levels of feeding and water exchange rates. Intensive farms involve small ponds or raceways designed for maximum control of physical and biological parameters, high stocking densities, high water exchange rates, and feeding levels that are carefully monitored.

Small businesses most commonly use intensive management techniques, while cottage-industry businesses primarily use extensive management techniques (Figure 6). One hundred percent of the algae farms, 75 percent of the ornamental fish and miscellaneous farms, and 40 percent of the freshwater fish farms use intensive management techniques. Most marine shrimp farms use semi-intensive techniques. Prawn farmers use both extensive and semi-intensive management techniques equally (Figure 7).

One of the costs involved in operating a farm is land lease fees. Many of the cottage farms own their own land, but all of the large corporate-owned farms lease their land (Figure 8). Operators of ornamental fish, freshwater fish, and prawn farms often own their farmland (Figure 9). These three groups make up a large portion of cottage farms; avoiding lease fees is one way they have been able to keep their operating costs low.

The mean acreage underwater was greatest on marine shrimp farms ($\bar{x} = 12.22 \pm 4.77$ SE) (Figure 10). About 35 percent of all the aquatic farms planned to increase their underwater acreage in 1987, although most farms (65 percent) planned to stay the same size. Water resources vary from farm to farm. Most freshwater farms obtain their water from streams (70 percent) or wells (26 percent), and saltwater farms either have wells (44 percent) or get their water directly from the ocean (56 percent). Water availability was a problem for about 30 percent of the aquatic farms.

The amount of dissolved oxygen (DO) present in aquatic systems can significantly affect animal growth rates. Limited DO has caused 45 percent of the aquaculture operations to aerate their ponds to increase the oxygen level.

The cost of feed can determine whether a farm is able to turn a profit. The mean feed cost for freshwater and ornamental fish farms was more than twice that of prawn farms (Figure 11). Feed costs have a much greater impact on cottage and small business farms than on corporations (Figure 12). Because large operations are able to purchase larger quantities of feed at bulk-rate prices, their feed costs are significantly lower than those of cottage and small business farms. The mean price per pound of feed for cottage and

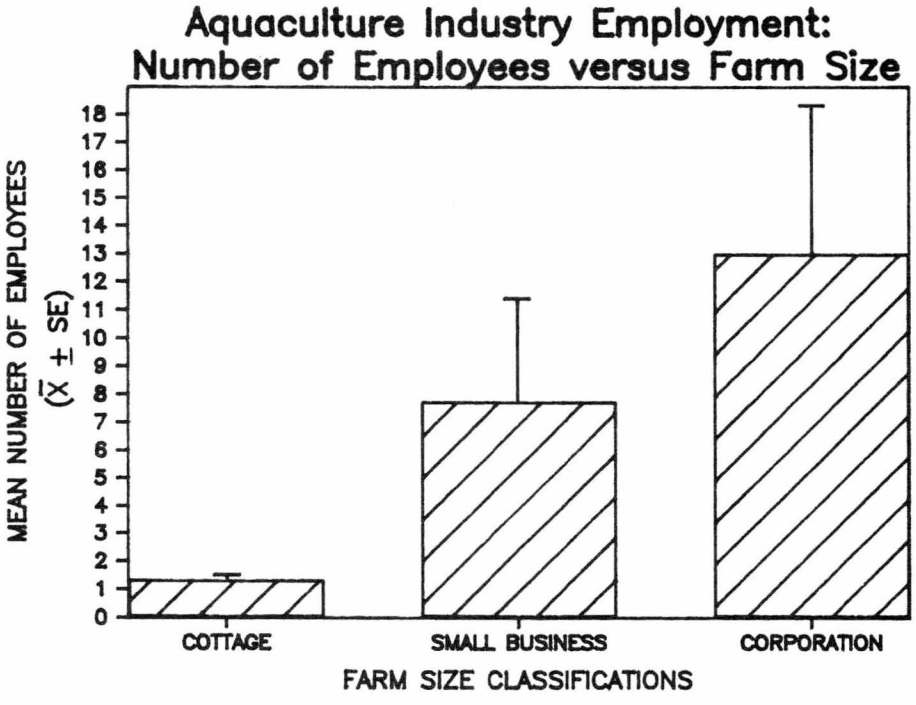
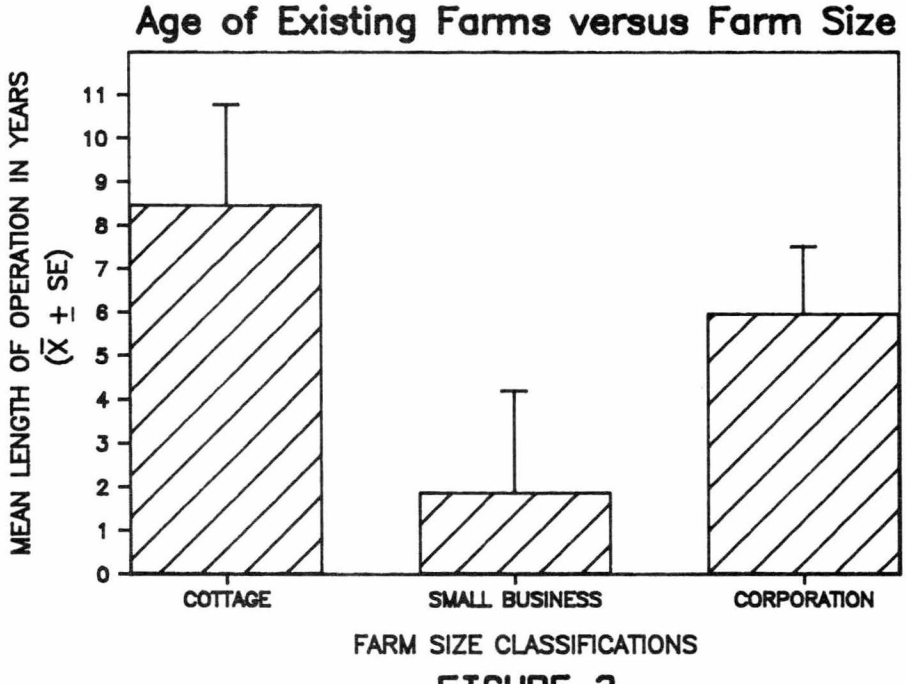


FIGURE 2



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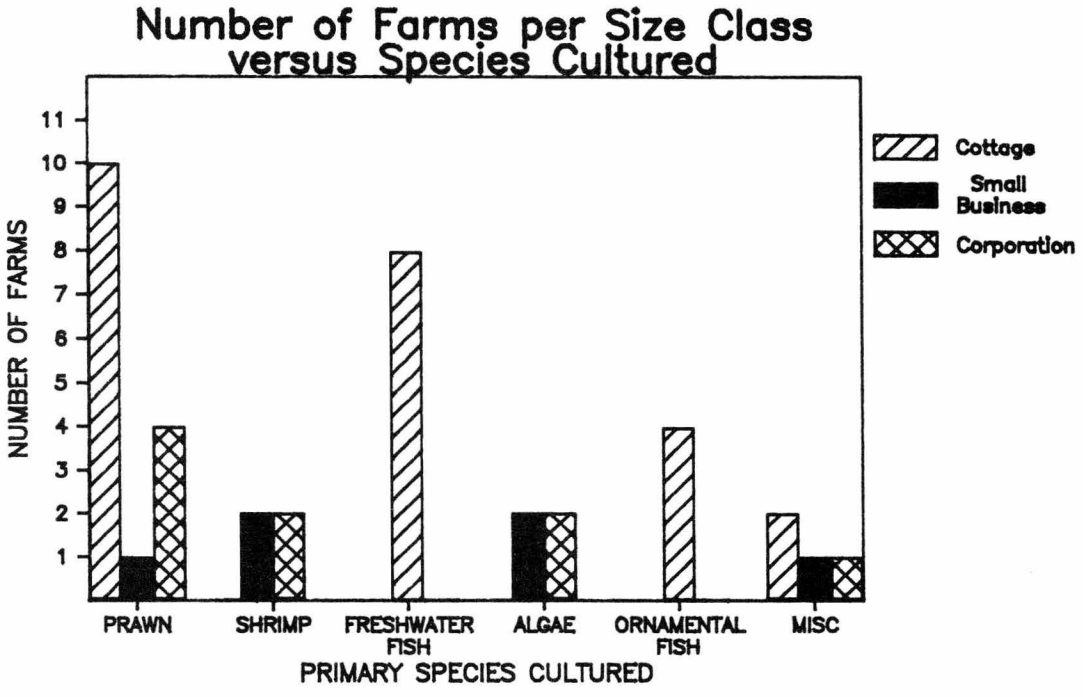

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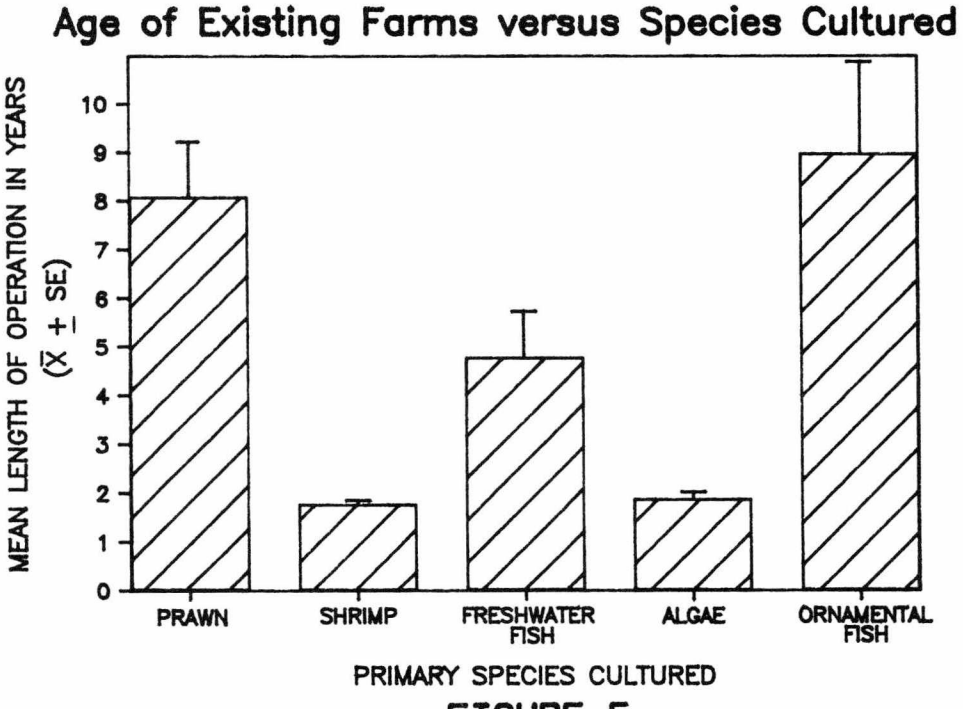

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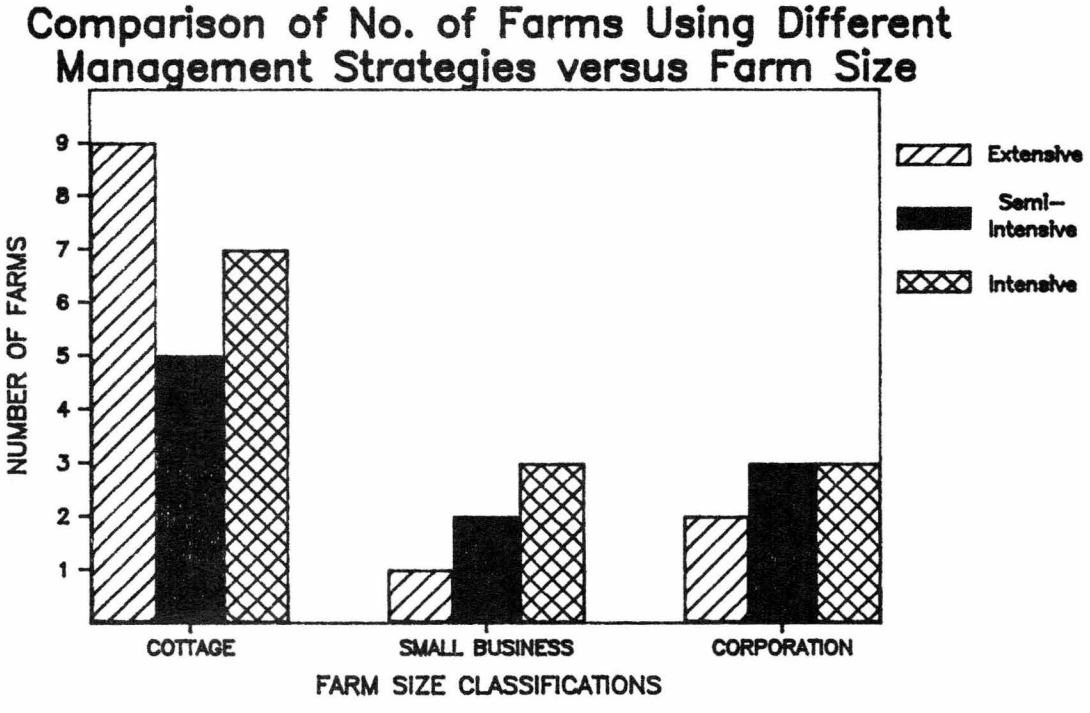

Comparison of No. of Farms Using Different Management Strategies versus Farm Size
NUMBER OF FARMS
9
8
7
6
5
4
3
2
1
COTTAGE
SMALL BUSINESS
CORPORATION
FARM SIZE CLASSIFICATIONS
Extensive
Semi–Intensive
Intensive

FIGURE 6

Comparison of Levels of Management Intensity with Species Cultured

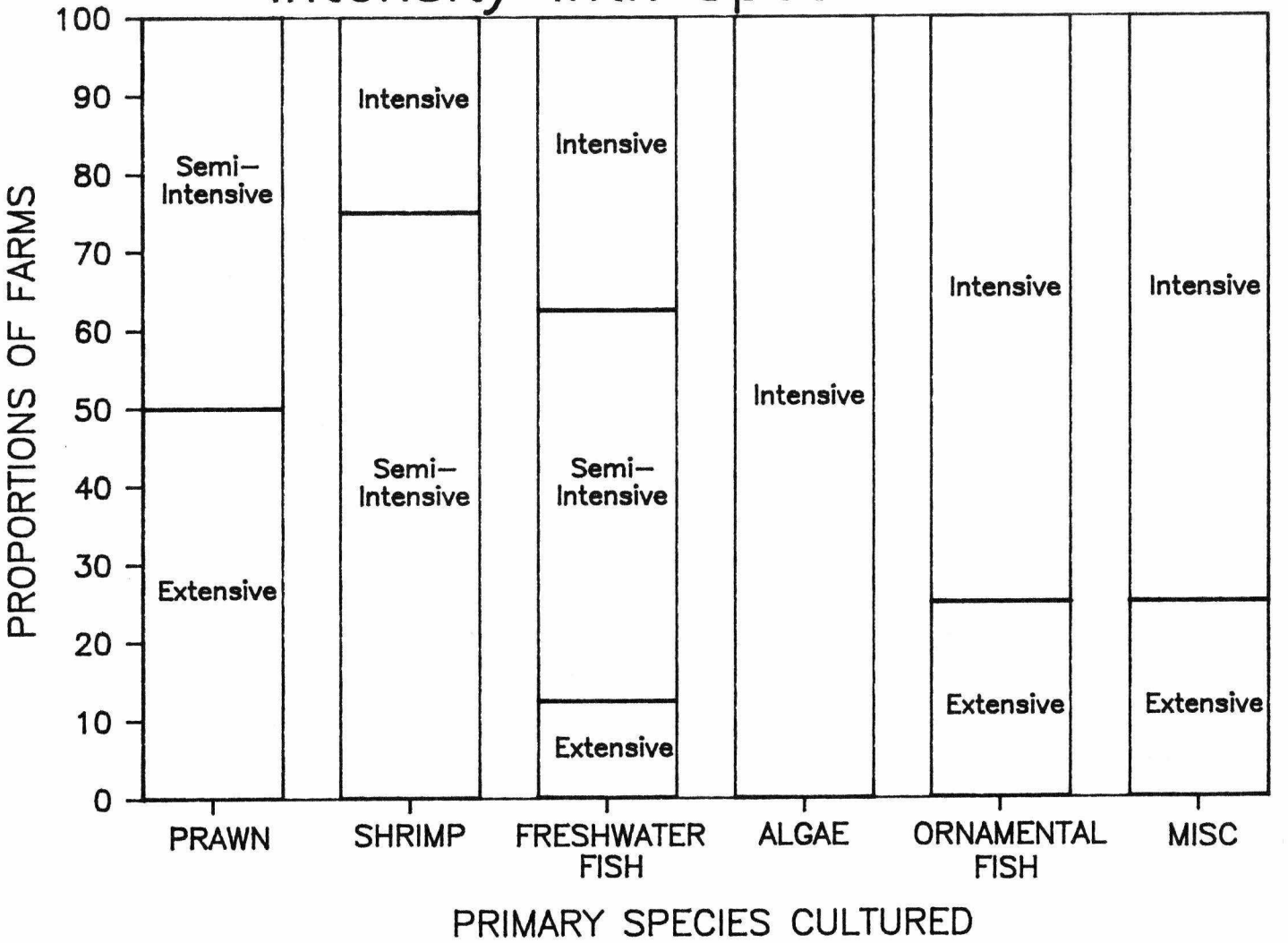


FIGURE 7

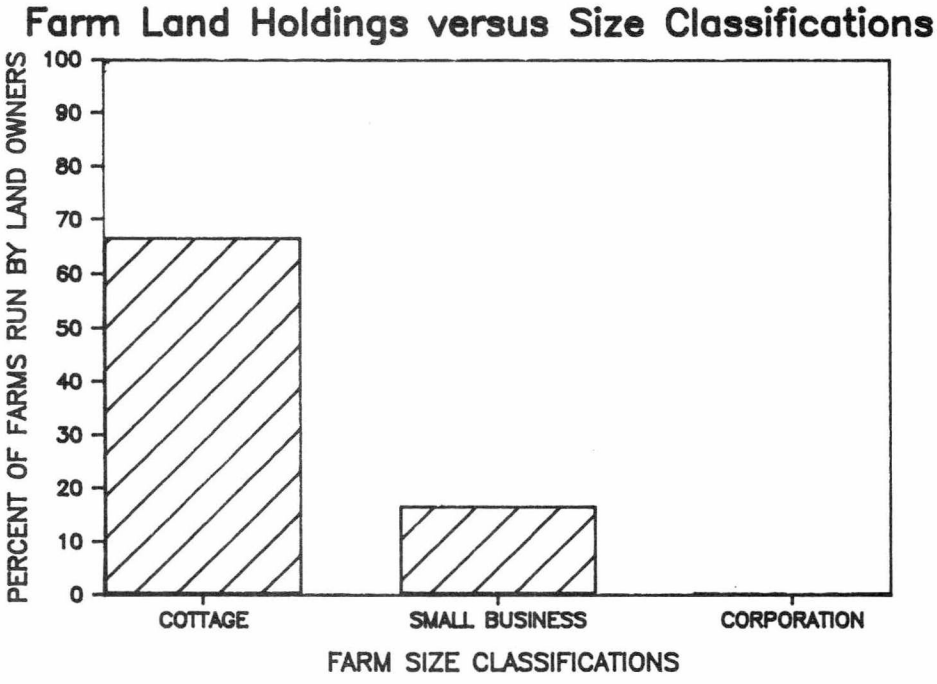


FIGURE 8

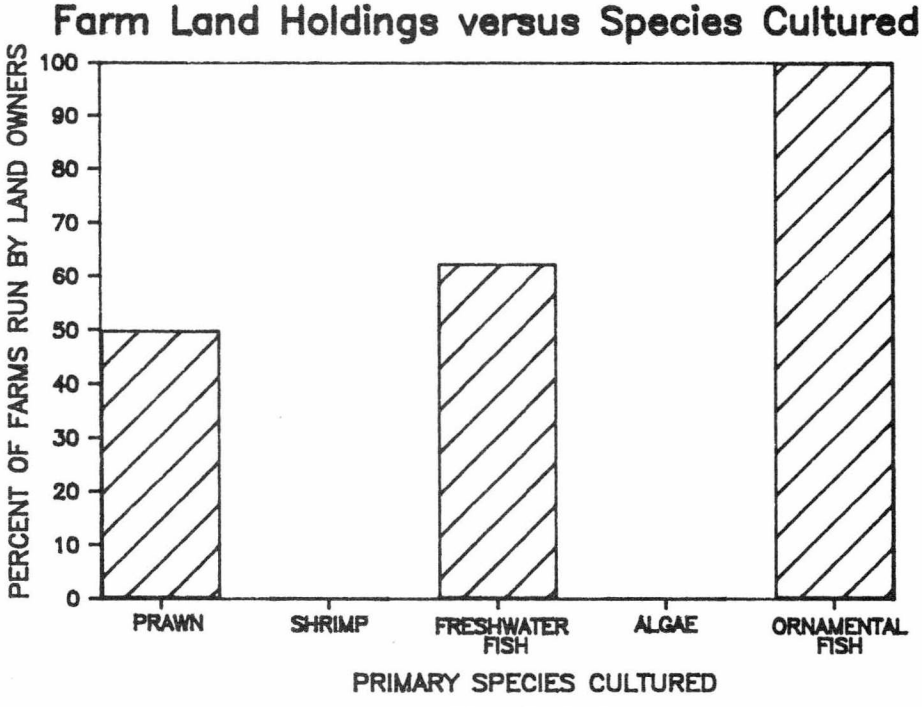


FIGURE 9

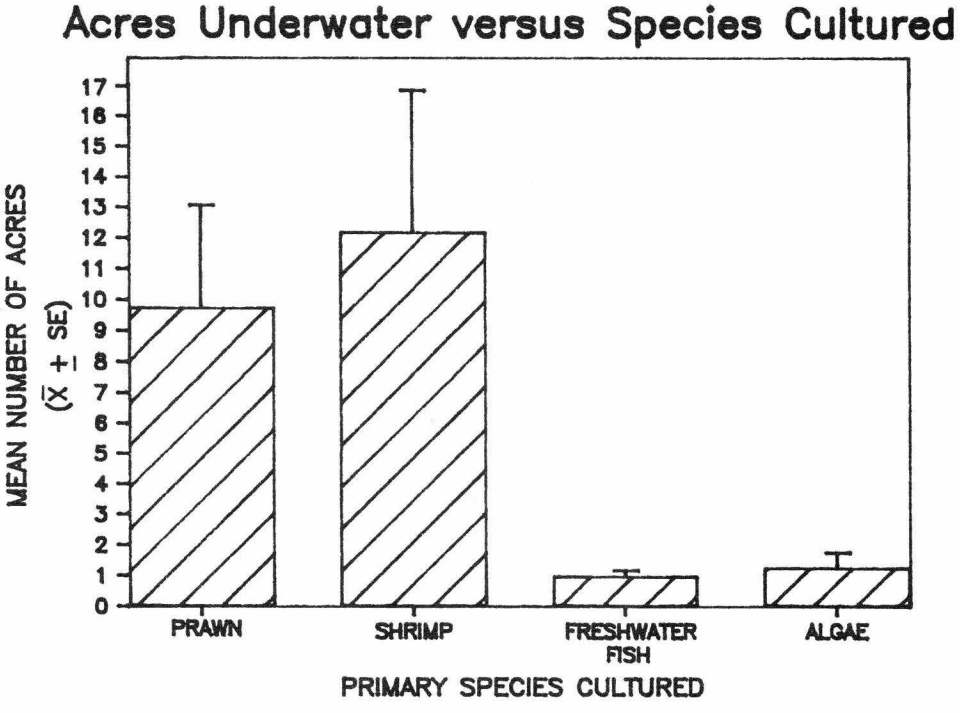
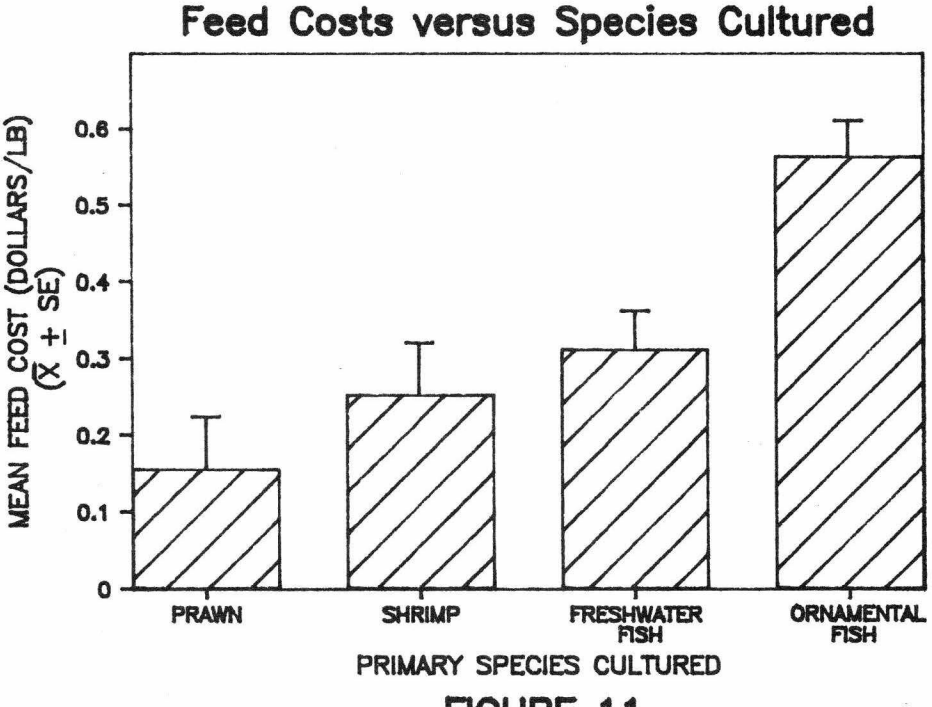


FIGURE 10



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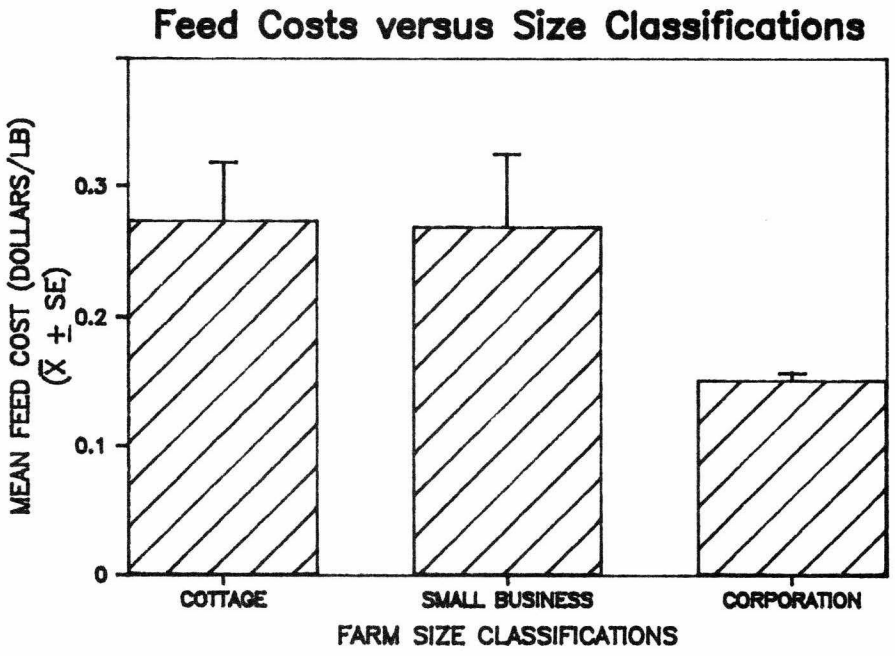

FIGURE 12

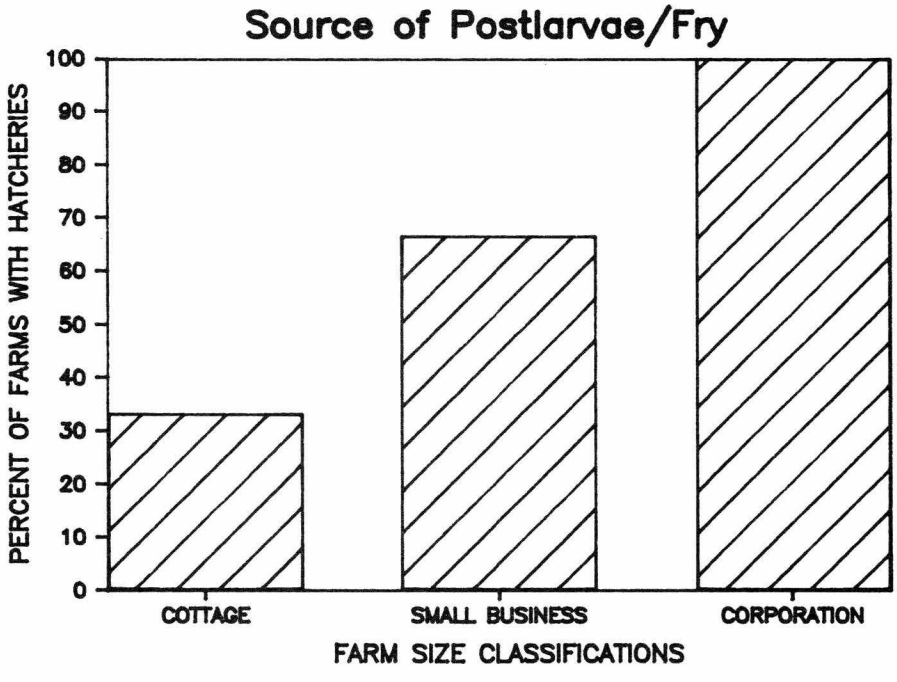

FIGURE 13

small business farms is $.27, whereas corporations spend about $.15 per pound.

Most cottage farms depend on outside suppliers for prawn and shrimp postlarvae or fish fry (Figure 13). For example, most commercial prawn farmers obtain postlarvae from the state of Hawaii. Smaller farms are unable to produce their own fry or postlarvae because of the high cost of setting up and the technical skill required to run a hatchery.

In 1985, the highest reported production levels (total pounds produced) were those for marine shrimp (184,600 lb) and prawn (165,228 lb) farms. Micro- and macroalgae producers ranked third (18,276 lb), and freshwater fish farmers ranked fourth (14,935 lb).

Seventy-five percent of the ornamental fish farms and 50 percent of the freshwater prawn farms made a profit in 1985 (Figure 14); both are predominantly cottage-industry farms (Figure 4). In contrast, none of the marine shrimp farms, which are corporations and small businesses, made a profit in 1985. However, the majority of shrimp farms were operating at pilot scale during that year.

Cottage-industry operations differ from small businesses and corporations in four ways: (1) they usually own the land that is used for cultivation; (2) they do not include the cost of labor when calculating the profitability of the operation; (3) they primarily raise agriculture products and only supplement their income with aquaculture crops; and (4) they tend to culture more than one species.

A number of factors contribute to the costs of operating a commercial aquaculture farm. During this survey we asked farmers to state their highest production cost component. Although the major production costs vary among farm size classes and species groups, many farms reported that labor and feed imposed a significant drain on their financial resources. The majority of corporations and small businesses said that labor was their highest cost (Figure 15). The next highest production cost commonly reported by corporations and small businesses was feed. The majority of cottage farms said that feed was their greatest cost.

All the freshwater fish farmers and 58 percent of prawn farmers said feed was their major cost (Figure 16). These groups make up the majority of cottage farms and reflect the responses of that size classification. The majority of shrimp farmers said that labor was their highest production cost.

With few exceptions, the majority of cultured products produced in Hawaii are locally marketed directly by the producer. The high cost of shipping and government regulations were cited as limitations to mainland or international marketing. Algae farmers and ornamental fish farmers market their products on the U.S. mainland and in international markets, as well as directly in Hawaii.

With the exception of freshwater fish producers, commercial aquaculture farmers in Hawaii are able to sell everything they produce. In fact, most farmers are convinced that they are unable to meet the demand for their product. Freshwater fish producers, on the other hand, felt that, although there is a strong market established for saltwater fish in Hawaii, the market for freshwater fish is limited. These farmers voiced the need for a marketing campaign to educate the local consumer and encourage consumption of freshwater fish.

The reported limitations on aquaculture production include (in order of importance[1]) lack of capital for expansion, high production costs, disease, predation, and feed costs.

Aquaculture producers report that the major limitation on production in Hawaii is the inaccessibility of capital for expansion. Hawaii's aquaculture industry is dominated by cottage-industry farms that have limited financial resources. These producers believe that the example of large, short-lived aquaculture businesses has made it virtually impossible to obtain expansion or operating capital from lenders. Larger businesses have the resources to get capital from banks, investors, and state and federal loan programs. They tend to operate for two or three years and then declare bankruptcy. The limited success rate of the large operations affects the availability of capital for the entire aquaculture industry. A few producers have received USDA Farmers Home Administration loans, Small Business Innovative Research Grants, or State Department of Agriculture Aquaculture Revolving Fund loans. Most cottage and small business farmers report that it is extremely difficult to obtain capital for expansion from these sources, however. The lack of a financial resource base for these operators may be limiting industry growth in Hawaii.

Farm operators expressed an interest in forming an aquaculture trade association that could voice their problems and needs to the state administration and legislators. Seventy-five percent of the operators said they would be willing to join this association.

[1]Order of importance reflects the number of times that an item was cited.

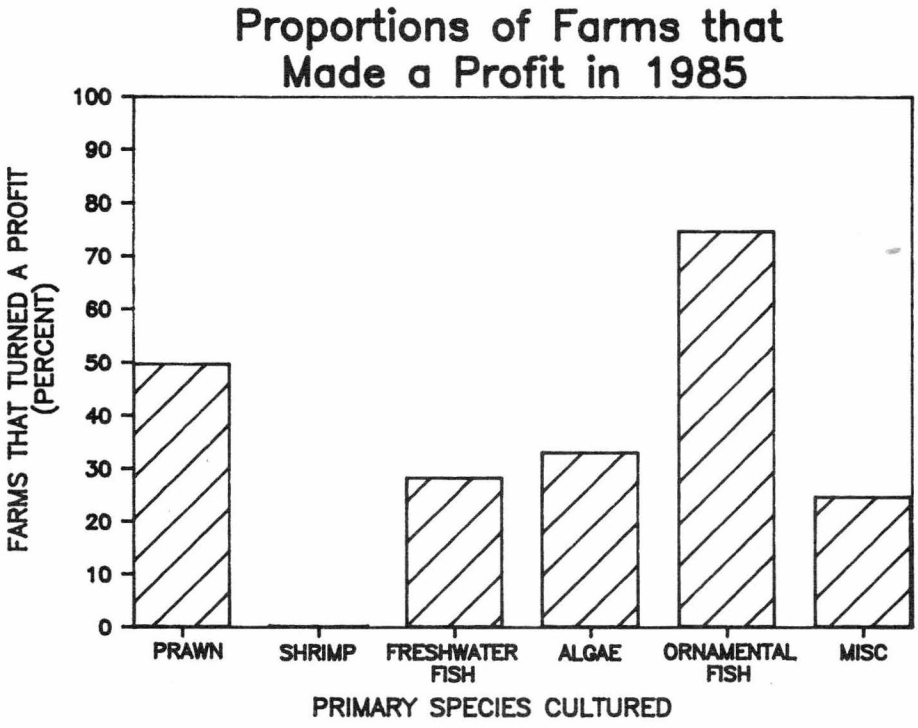

FIGURE 14

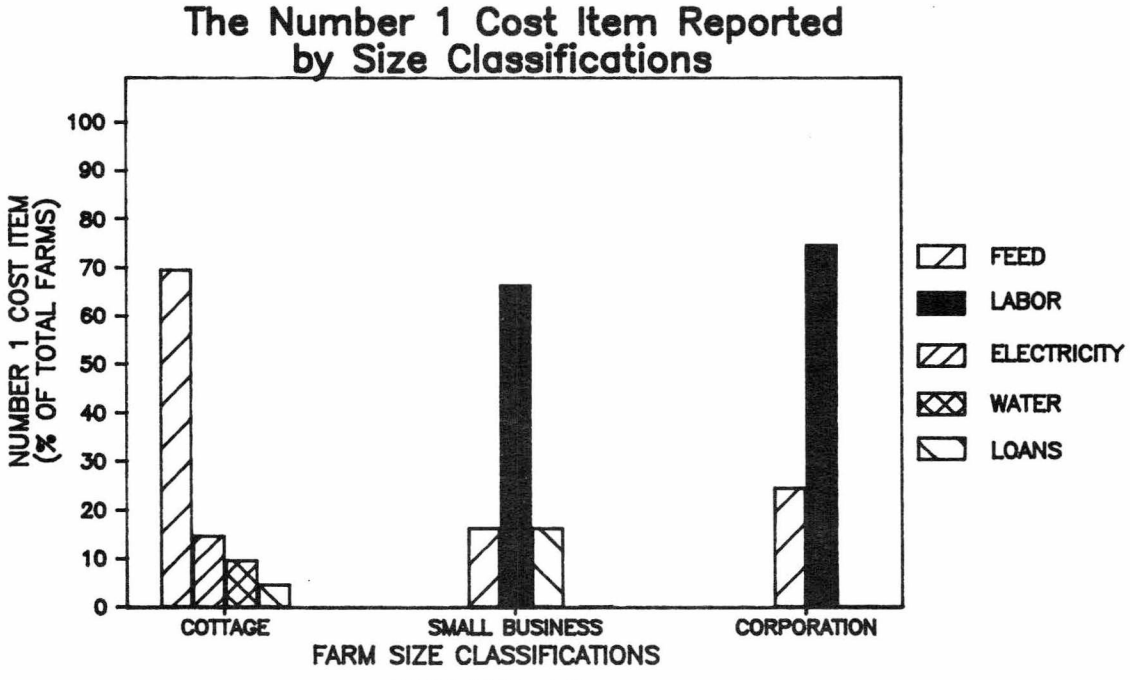

FIGURE 15

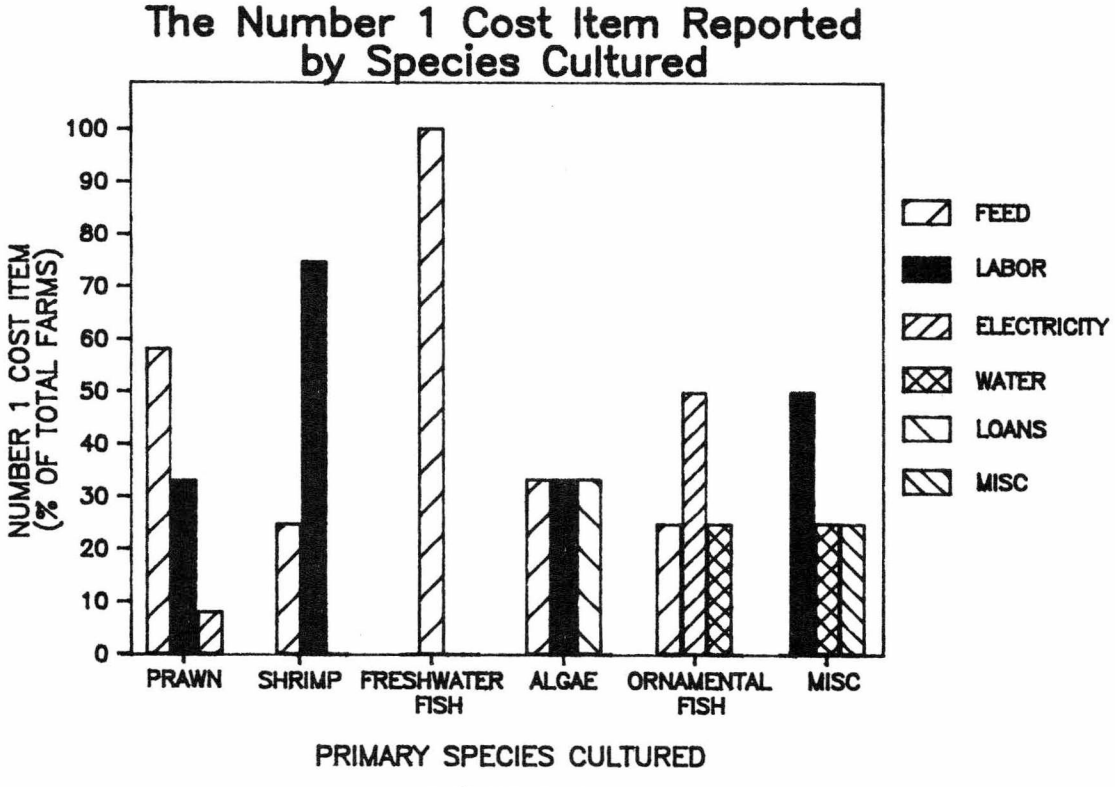
The Number 1 Cost Item Reported by Species Cultured
NUMBER 1 COST ITEM (% OF TOTAL FARMS)
100
90
80
70
60
50
40
30
20
10
0
PRAWN
SHRIMP
FRESHWATER FISH
ALGAE
ORNAMENTAL FISH
MISC
PRIMARY SPECIES CULTURED
FEED
LABOR
ELECTRICITY
WATER
LOANS
MISC

FIGURE 16

Shrimp, algae, and ornamental fish farmers claim that current technological methods for culturing their product result in high operating costs. Labor requirements, feed, and electricity costs must be reduced in order to economically increase production of these products in Hawaii.

The most commonly requested extension/advisory services are (in order of importance) access to information on low-interest loan programs, access to technical information, marketing campaigns for certain species groups, an extension service similar to the agriculture extension service, and a reliable source of postlarvae.

Individual Species Groups Cultured in Hawaii

The rest of this paper will concentrate on the individual species groups. We will discuss the general approach to production, limitations on production, extension/advisory service needs, and research needs of each species group.

Prawn farming. The most common crop on aquaculture farms in Hawaii is the freshwater prawn, *Macrobrachium rosenbergii.* This is a direct result of the state's program in the mid-1970s to encourage farmers to culture prawns. During this period, the state supplied postlarvae, started an association of prawn farmers, and provided extension services to new farmers. In 1986, there were 15 freshwater prawn farms operating in Hawaii. Twelve of the 15 farm operators were interviewed; the location, species cultured, and farm area of all 15 farms were included in the survey results.

Many prawn farms are small (eight of 15 have less than 1 acre underwater), own their own land (Figure 9), and have been in business for eight or more years (Figure 5). Water is most commonly diverted from freshwater streams (67 percent), although a few farms use well water.

Prawns are cultured in earthen ponds in Hawaii, and both extensive and semi-intensive management techniques are practiced (Figure 7). The primary production cost is feed (Figure 16), even though the price per pound for prawn feed is lower than the feed costs for other species (Figure 11).

Farm owners claim that the major limitations on prawn production are (in order of importance) availability of postlarvae, predation, and lack of capital for expansion.

The majority of prawn farmers report that the greatest limitation on production is the availability of postlarvae (PLs). Only three of the 15 prawn farmers produce their own PLs; the rest depend on the state hatchery, the Anuenue Fisheries Research Center (AFRC). The production of prawn PLs by AFRC was phased out in December 1985. Private hatcheries had committed themselves to providing prawn postlarvae to commercial producers, and the state did not want to compete with the private sector. Unfortunately, the private hatcheries either ceased operations or stopped supplying postlarvae less than one month after the state hatchery was scheduled to stop producing PLs. Prawn farmers are now completely dependent on the state hatchery. Current policy restricts the state hatchery from guaranteeing postlarvae availability for more than one year at a time.

In 1986, prawn farmers did not expand their production capabilities, even though 50 percent of the prawn farms turned a profit in 1985 (Figure 14). Without assurance of PL availability, cottage-industry prawn farmers, who dominate this group (Figure 4), are unwilling to expand their production capabilities. The state needs either to develop a policy that guarantees the availability of prawn postlarvae or to establish a state hatchery revolving fund to enable cottage-industry prawn farms to operate and expand.

Bird predation has also limited production on several prawn farms in Hawaii. Farmers frequently mentioned that the night heron population had increased on their farms and was consuming large numbers of prawns. Some farmers also mentioned that tilapia, tadpoles, and human poachers were preying on postlarvae and adult prawns.

Finally, many cottage farmers have been unable to obtain capital for expansion from either state or federal loan programs or from private lending institutions. Cottage-industry prawn farmers believe that large aquaculture businesses have given the industry a bad name. "They bring in large amounts of investment capital, operate for a year or two, and then they leave town." This practice has made it virtually impossible for small aquaculture farm owners to get capital for expansion from lending institutions. Bankers have been unwilling to lend money to expand aquaculture farms because of the high risk associated with this industry.

Farmers expressed the need for the following extension/advisory services (in order of importance): an extension service similar to that provided for agriculture, a guaranteed supply of postlarvae, better communication between farmers and wholesalers, and access to technical and loan availability information (e.g., an information service).

Commercial operators report that extension services for prawn farmers are not as common

as they were in previous years, particularly on the neighbor islands. Several farmers suggested that an extension service program similar to the USDA agriculture extension service was needed. At harvest time, larger farm owners need to know who is looking for prawns, and buyers must be able to make their needs known. Many prawn farmers requested greater access to technical information and an advisory service on loan availability.

Many farmers said that they had interacted with extension agents from AFRC and had found them to be very helpful. Dr. James Brock (state aquaculture veterinarian, Aquaculture Development Program) was often cited as being extremely helpful to farmers in diagnosing and treating diseases in prawn stocks.

Prawn farm operators requested that future research funds be directed toward more applied problems. Research is needed in production (e.g., effects of density variations, feed quantities, and aeration on yields), the effect of temperature on growth rate, and improved harvesting methods.

Marine shrimp farming. In 1986, there were four marine shrimp farms operating in Hawaii (three commercial and one pilot) and two planning to start operations in 1987 or 1988. All producers were interviewed. Commercial shrimp farming is relatively new to the Hawaiian Islands, with the majority of farms having operated two years or less (Figure 5). Three species are cultured commercially: *Penaeus vannamei, P. monodon,* and *P. stylirostris.* Most of the farms are large ($\bar{x}$ = 12.22 acres $\pm$ 4.77; Figure 10) and are owned by corporations or limited partnerships (Figure 4). All of the shrimp farms in Hawaii lease their land (Figure 9) and use water pumped from brackish-water wells.

In Hawaii, shrimp are cultured both in earthen ponds, using a semi-intensive management strategy, and in raceways, using a highly intensive management strategy. Three of the four farms operate their own hatcheries. Ponds are presently stocked two to three times a year.

Marine shrimp producers listed the following factors as limiting production (in order of importance): production costs (e.g., labor rates, feed, electricity), lack of capital for expansion, inability to produce a consistent supply of postlarvae, and disease (i.e., IHHN virus).

Although shrimp farms reported one of the highest annual production rates, none of the farms made a profit in 1985 (Figure 14). The majority of these farms, however, were operating at pilot scale during that year. High operating costs, mainly for labor and feed, limited production and depressed revenues below a profitable margin.

Shrimp farmers also felt that lack of available capital for expansion limited their ability to increase production levels and achieve economies of scale. In addition, some of the farms operating hatcheries reported difficulty in producing a consistent supply of postlarvae to stock growout ponds. Finally, the effects of IHHN, particularly in *P. stylirostris* stocks, and the precautions necessary to ensure disease-free stock, limited production on shrimp farms.

Shrimp producers requested a variety of extension/advisory services (because of the limited number of responses, these are not listed in order of importance): assistance in developing a more simplified permitting process, information on low-interest loan programs, a marketing campaign for marine shrimp, pesticide and water-quality analytical services, and a reliable source of postlarvae (e.g., a state hatchery).

All of the shrimp producers have interacted extensively with Dr. James Brock regarding disease problems in marine shrimp stocks. Most farmers also mentioned that the Aquaculture Development Program (Department of Land and Natural Resources) had been helpful in providing information.

Marine shrimp producers requested that future research funds be directed toward the following activities (because of the limited number of responses, these are not listed in order of importance): developing a better locally produced feed, developing genetically superior stock, disease control, and increasing production in extensive systems.

Freshwater fish farming. The freshwater fish that are cultured in Hawaii include rainbow trout (*Salmo gairdneri*), channel and Chinese catfish (*Ictalurus punctatus, Clarius* spp.), and grass, silver, and bighead carp (*Ctenopharyngodon idellus, Hypophthalmichthys molithrix,* and *Aristhichthys nobilis*).

Tilapia were included in the miscellaneous species group because commercial operators culturing tilapia use brackish or saltwater sources. In 1986, there were eight freshwater fish farms operating in Hawaii. Seven of the eight farm operators were interviewed; the location, species cultured, and area of all eight farms were included in survey results.

All of the Hawaiian freshwater fish farms are classified as cottage-industry farms (Figure 4). The majority (75 percent) have less than one acre underwater (Figure 10), own their land (Figure 9), and have been in operation for five or more years. Freshwater fish are cultured in

earthen ponds, rock-bottom ponds, large circular tanks, concrete tanks, and floating pens or cages. All of these farms obtain their water from freshwater streams or springs. In the Hilo area on the island of Hawaii, several farmers culture trout in brackish-water, rock-bottom ponds. These ponds are tidally connected to the saltwater table and receive a constant flow of freshwater from springs.

Freshwater fish farmers listed the following factors as limiting production (in order of importance): feed costs, disease, predation, and a lack of capital for expansion.

The majority of freshwater fish farmers expressed the need for a high-quality, low-cost feed that is produced locally. All operators said that feed was their number one cost item (Figure 16). Disease is a major problem for freshwater fish farmers, especially in catfish culture. Some farms are losing up to 50 lb of fish each week to disease. The exact cause of the disease is unknown, but bacterial infections appear to be responsible. Other limitations on production include predation by birds (e.g., night herons) and inaccessibility of capital for expansion. Fish farmers echoed prawn farmers in stating that the instability of large aquaculture businesses had made it impossible for small farm owners to obtain financing for facility expansion.

The following extension/advisory services were requested (in order of importance): a marketing campaign for freshwater fish; greater access to loans and to technical, marketing, and processing information; and information on fish diseases and treatments.

One problem that nearly all farm owners mentioned was the limited market for freshwater fish. The tourist industry has promoted saltwater fish (e.g., mahimahi) for restaurant use and, as a result, has established a strong market for these fish. Both the local market and the tourist industry are uninformed regarding the freshwater fish cultured in this state. The result has been a limited market, in spite of the availability of high-quality, locally grown fish. In particular, trout farmers are affected both by the limited market and by competition from lower-priced frozen trout shipped from the U.S. mainland. A marketing campaign is needed to inform consumers that locally grown, high-quality fresh fish are available in Hawaii.

Most fish farmers frequently interact with Dr. James Brock. Although Dr. Brock has been extremely helpful with the disease problem, producers requested future research in this area.

Freshwater fish farmers requested that future research funds be directed toward the following activities (because of the limited number of responses, these are not listed in order of importance): the causes and treatments of fish disease, developing a better locally produced feed, and applied research to lower production costs.

Algae farming. The following algal species are cultured commercially in Hawaii: macroalgae– *Porphyra* spp. and *Gracilaria* spp.; microalgae– *Spirulina* spp. and *Dunaliella* spp.

In 1986, there were four algae farms operating. Three of the four farm operators were interviewed; however, the location, species cultured, and area of all four farms were included in survey results. In Hawaii, macroalgae are cultured in tanks and microalgae are cultured in raceways. All farmers use an intensive management strategy. This strategy involves careful monitoring of water quality and addition of nutrients and carbon dioxide. Most farms are small (Figure 10), are owned by corporations or limited partnerships, and have been in business for two years or less (Figure 5). All algae producers planned to expand their underwater acreage in 1987.

Algae farmers listed the following factors as limiting production (in order of importance): a lack of capital for expansion, and production costs.

The initial financial investment involved in setting up or expanding a raceway or tank culture system is large. As a result, the limited capital available from state and federal loan programs has restricted the production capabilities of these producers. High operating costs, primarily for nutrients and labor, limit production on algal farms.

Algae farmers expressed the need for the following extension/advisory services (because of the limited number of responses, these are not listed in order of importance): information on low-interest loan programs and bank loans for facility expansion, a marketing campaign for macroalgae, and technical information (especially on the neighbor islands).

Most algae farmers said that they had not interacted with the state's aquaculture extension/advisory groups. One producer reported that the Aquaculture Development Program had been very helpful in obtaining permits.

Some farmers indicated that a more applied approach to production-related problems was needed in aquaculture research on algae.

Ornamental fish farming. In 1986, there were four ornamental fish farms in Hawaii. All producers were interviewed. The ornamental fish cultured in Hawaii include koi (*Cyprinus carpio*) and a variety of freshwater tropicals.

The clientele for this species group includes collectors of prize-winning koi for exhibition at ornamental fish shows, hotels and shopping centers with garden pools for ornamentals, pet or tropical fish stores, and individuals who have public or private garden pools. Ornamental fish farms in Hawaii are cottage-industry farms (Figure 4). The operators own the land (Figure 9) and have less than one acre underwater (Figure 10). Ornamentals are cultured in concrete tanks or glass aquariums and require intensive management techniques. Many of these farms have been in business for nine or more years, and 75 percent reported that they turned a profit in 1985.

The major limitations on production (in order of importance) of ornamental fish are feed costs and production costs.

Ornamental fish farmers expressed the need for a high-quality, low-cost feed that is produced locally. Production costs were a major expense for this group. Electricity to pump water and air to tanks was the highest cost for most producers (Figure 16).

The following extension/advisory services were requested: information on low-interest loan programs and bank loans for expansion, information on fish diseases and nutrition, and more sites for aquaculture development, such as aquaculture parks.

Most ornamental fish producers have interacted with Dr. James Brock regarding diseases associated with ornamental fish. However, growers rely primarily on Japanese expertise to control diseases in their fish stocks.

Ornamental fish producers requested that future research funds be directed toward the following activities (because of the limited number of responses, these are not listed in order of importance): the causes and treatments of fish diseases, developing a better locally produced feed, and nutritional requirements of ornamental fish.

Culture of miscellaneous species. There are a few species that are cultured only at a single farm in Hawaii. We will briefly mention the limitations on their production, the extension/advisory services requested, and research needs of these farmers.

– Bullfrog (*Rana catesbeiana*). Bullfrogs are cultured in covered raceways and concrete tanks on one farm. The limitations on production are disease, a lack of capital for expansion, and an inability to obtain a reliable source of live food. The extension/advisory services requested were information on low-interest loan programs and bank loans for expansion, and technical information on feeding and reproduction. This farmer requested that future research funds be directed toward disease control, nutrition and food sources, and reproduction.

– Tilapia (*Sarotherodon* spp.). One operator is currently culturing tilapia at high densities in a raceway system. The farm owner reported that the following factors were limiting his production levels: a lack of automation in the production system, and government regulations (e.g., a lack of tax incentives).

– Saltwater fish. A variety of saltwater fish are cultured in an ancient Hawaiian fishpond on the island of Oahu. The owner selectively stocks his pond, removes predators, and occasionally adds food to the pond. The limitations on production are a lack of accessible markets and a reliable source of fry. The owner requested that research efforts be directed toward developing culture techniques for Samoan crabs.

– Abalone (*Haliotis* spp.). The major limitation on production of abalone is the length of time to maturity. This farmer conducts his own research and did not have any requests for assistance in this area.

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APPENDIX I: OCEANIC INSTITUTE COMMERCIAL INDUSTRY QUESTIONNAIRE

July 17, 1986

INFORMATION FROM INDIVIDUAL FARMS WILL BE KEPT CONFIDENTIAL, AND ONLY SUMMARY INFORMATION WILL BE REPORTED TO USDA.

A. Name of facility
B. Location
C. Species cultured
D. Are you planning to change the species you are culturing or start culturing additional species?
E. Facility size
   1. Ponds
      a. Nursery # _____ size _____
      b. Growout # _____ size _____
   2. Raceways # _____ size _____
   3. Tanks/troughs
      a. # _____ size _____
      # _____ size _____
      b. Hatchery # _____ size _____
      c. Growout # _____ size _____
      Total farm area _____
F. State of development
   1. R & D _____
      Pilot _____
      Commercial _____
   2. Years in business _____
G. Employment

	Full-time	Part-time	Seasonal
1. No. employees	_____	_____	_____

   2. Types of positions
      a. Technicians _____
      b. Managers _____
      c. Other _____
H. Ownership
   1. Business
      a. Family/individual _____
      b. Limited partnership _____
      c. Corporate _____
   2. Land
      a. Rent _____
      b. Lease _____ How long? _____
      c. Own _____
I. Fry/postlarvae supplier
   Are you dependent on a fry supplier? Yes _____ No _____
J. Hatchery
   1. Do you operate a hatchery? _____
   2. Monthly PL production? _____
   3. How many PLs do you sell a year? _____
   4. Price _____/1000
K. Operating system
   1. Extensive _____ (e.g., ponds are large, seminatural systems with little daily management required—low stocking densities and little to no feeding or water exchange)
   Semi-intensive _____ (e.g., ponds are designed to allow predator control, harvest, and low-level management of oxygen level and plankton density—moderate stocking densities, feeding, and water exchange)

Intensive _____ (e.g., ponds or raceways are small and designed for maximum control of water quality and oxygen levels– high stocking densities, nutritionally complete diets, high water circulation or exchange)

2. Open/flow-through _____
   Recycle _____
   Closed/semiclosed _____
3. Monoculture _____
   Polyculture _____
   Varies seasonally _____
4. Aeration _____ hours/day _____

L. Water resource

1. Stream _____
2. Well _____ # _____ size _____
3. Direct ocean intake _____
4. Salinity (in pond) _____ at inflow _____
5. Is water readily available? Yes _____ No _____
   If no, why (e.g., cost or regulations)? _____
6. Volume pumped/day _____

M. Effluent discharge

1. Injection well _____
2. Oxidation/settling pond _____
3. Direct discharge _____
   Stream _____ Ocean _____
4. Discharge/day _____

N. Feeds

1. Local supply _____
2. Imported _____
3. Average price/lb in 1986 _____

O. Production

1. Did you make money in 1985? Yes _____ No _____

2. 1985 production

	What units?	Gross market value $	1986 estimate
Postlarvae	_____	_____	_____
Market-sized adults	_____	_____	_____
Broodstock	_____		_____
Other products	_____	_____	_____
Total	_____	_____	_____

3. Production per acre for each species
4. How do these production figures compare with those of your competitors?
5. In what form do you sell your product?
   a. Whole _____
      Filleted _____
      Shucked _____
      Peeled _____
      Other _____
   b. Live _____
      Fresh _____
      Frozen _____
      IQF _____
6. What are the current limitations on production?
   a. Facility size _____
   b. Expansion capital _____
   c. Lack of hands-on experience _____
   d. Lack of technical information _____
   e. Costs of production (what is your major cost?) _____

f. Lack of profitable, accessible markets _____
g. Available feeds or cost of feed _____
h. Disease _____
i. Predators _____
j. Other _____

7. Are you interested in joining an aquaculture association, which will serve as (1) a collective voice to present industry concerns to the administration and legislature, and (2) a forum for exchange of ideas and information?
8. What (if any) outside extension/advisory services would help improve your production levels?
9. What types of research would help improve your production levels? (e.g., reproduction, culture methods, disease, nutrition, farm management, product handling, etc.)
10. What interaction have you had with the research institutions in Hawaii in conducting your aquaculture business? What role should these institutions play in aquaculture development?

P. Marketing

1. Major markets served (%)
   a. Local _____
   b. In state _____
   c. Western region _____
   d. National _____
   e. International _____
2. Sales channel
   a. Broker _____
   b. Wholesaler _____
   c. Direct _____
   d. Other _____
3. Who decides the selling price?
4. What factors influence price variations?
5. Do you sell everything you produce?
6. Does the supply satisfy the demand for your product?
7. What are the major marketing problems you face? (barriers to increased sales)
   a. Locating customers _____
   b. Market saturation _____
   c. Low prices _____
   d. Coordinating peak production and demand _____
   e. Supplying product consistently year-round _____
   f. Foreign competition _____
   g. Other competition _____
   h. Customer unfamiliar with product _____
   i. Insufficient funds for marketing campaign _____
   j. Quality control _____
   k. Packaging _____
   l. Processing _____
   m. Handling/distribution techniques of customer _____
   n. Government regulations _____
   o. Other _____
8. Ideas to solve marketing problems/improve and expand sales?
9. What (if any) outside extension/advisory services would help improve your marketing techniques and increase sales?

DISCLAIMER

Reference to a company or product name does not imply approval or recommendation of the product by the College of Tropical Agriculture and Human Resources, University of Hawaii, or the United States Department of Agriculture to the exclusion of others that may be suitable.

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