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Aquaculture in Hawaii : past, present and future

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Abstract — *Hawaii's aquaculture industry has a long and colorful history. When Cook arrived in Hawaii in 1778, over 350 fishponds were in operation. Native Hawaiians had practised aquaculture for 400 years before Western contact. In 1903, the Hawaiian ponds produced 310,000 kg of fish from over 2,000 ha of ponds. Today, less than a handful are in use.*

Modern aquaculture in Hawaii began in the early 1960's, with studies of mullet culture at Oceanic Institute and mass rearing of freshwater prawns at the State's Anuenue Research Center. State sponsored industry development efforts focused on the freshwater prawn, Macrobrachium rosenbergii. By 1976, 14 prawn farms produced 19,500 kg of product worth $152,000. In the 1980's, industry effort has turned to marine species including shrimp, abalone, and seaweeds. In 1986, crop value reached $3.6 million with the majority contributed by marine shrimp. The largest shrimp farm in Hawaii, Amorient Aquafarm, Inc. produced 259,000 kg of shrimp from 56 ha of ponds in 1987.

In addition to commercial production, several international consulting companies operate out of Hawaii with annual revenues exceeding $2 million. Both University of Hawaii and Oceanic Institute conduct aquaculture research which brings over $7 million per year into the State.

Future prospects for Hawaii's industry are bright. Expanded R + D activities have the greatest growth potential with technology transfer through international consulting and training likely. Commercial activities will focus on intensive culture of shrimp, finfish and seaweeds.

INTRODUCTION

From prehistoric times (before 1778), when Hawaiian fishponds produced fish for the kings, to present marine shrimp farms, the Hawaii aquaculture industry has gone through many transformations. This paper reviews the highlights of that colorful history. It is divided into three sections : Past (14th century to mid 1960's); Present (mid 1960's to 1988); and Future, and describes the key elements and characteristics of the industry during those periods.

THE PAST

When Capt. James Cook discovered the Hawaiian Islands in 1778, he found a self-sufficient Polynesian society of 300,000 people with sophisticated resource management and food production practises. It has been estimated that perhaps 360 fishponds were actively managed for production of a variety of aquatic species of plants and animals for food (Kikuchi, 1976).

Kikuchi (1973) documented that fishponds were commonly mentioned in oral histories attributed to the 14th through the 19th centuries and concluded that fishponds appeared in Hawaiian Islands sometime prior to the 14th century. He further documented in surveys throughout Oceania. That prehistoric fishponds were unique to Hawaii, not seen in other cultural areas of Oceania. He proposed that coastal fishponds in Hawaii evolved from irrigated agricultural plots and that the fishpond was an independent Hawaiian innovation.

Apparently, Hawaiians utilized practically all sizeable bodies of water for construction of fishponds. From inland freshwater taro ponds where fish were secondary crops, to large coastal ponds where rock walls enclosed reef flats, fishponds were common throughout the islands. Fishponds were symbols of the chiefly right to conspicuous consumption and to ownership of the land and its resources. They symbolized the chief's political power and the extent of his resources. The ponds were not managed to maximize production, but provided food for the chiefs when they travelled from district to district, surveying their holdings and collecting taxes. Most of the fish from the ponds were forbidden (kapu) to commoners to be consumed only by the ruling class.

Kikuchi estimated that of the 360 ponds, area is known for 304 ponds totalling 2,240 ha (7.4 ha/pond). therefore total fishpond area in precontact times could have been 7.4 x 360 = 2,652 ha.

By the turn of the 20th century, Western influences had radically changed Hawaiian culture and fishponds had become commercial fish farms selling their products in the local seafood market. Total fish and shrimp production from ponds was documented in 1900 and 1903 by J.N. Cobb who was a fisheries biologist from the United States Fish Commission studying the commercial fisheries in the islands. A summary of his detailed reports are listed in Table 1. It should be remembered that these data represent commercial pond production for fish that was sold in the market place. The relative consistency in production comparing the two years indicates that the commercial aquaculture industry in Hawaii was well established and significant in size and value. Using current wholesale value of $6.60/kg for pond-raised mullet and milkfish in Hawaii, the fishpond industry at the turn of century was worth more than $2 million (current $) in annual production.

While previous authors writing about Hawaiian ponds have attempted to use Cobb's data to estimate pond production in Hawaiian times, it is unlikely that pond production in Hawaiian times was similar to that at the turn of the century. Most of the ponds at the turn of the century were operated by Chinese immigrants. Because of their commer-

cial interests, fertilization of ponds with animal manures was probably common, a practise that was forbidden by religious sanctions in Hawaiian times (Kikuchi, 1976). Therefore, pond production in prehistoric times was probably substantially lower than at the time of Cobb's studies.

Tab. 1. — Total fish production and value in Hawaiian fishponds in 1900 and 1903

Species	1900		1903	
	Amount (kg)	Value ($)	Amount (kg)	Value ($)
Mullet	220,696	119,902	195,507	87,706
Milkfish	88,260	47,526	101,964	22,662
Other	1,255	313	8,417	953
TOTAL	310,211	167,741	305,888	111,321

THE PRESENT

Modern aquaculture in Hawaii began in the mid-1960's at two institutions. Oceanic Institute began studies of mullet reproduction and larval rearing in 1964. Substantial basic information about mullet reproduction was developed during the 60's and 70's (reviewed in Nash and Shehadeh, 1980). In 1965, the State's Anuenue Fisheries Research Center (AFRC) began efforts to develop mass culture techniques for larvae and juveniles of the freshwater prawn (*Macrobrachium rosenbergii*). By the mid-1970's, AFRC had developed mass rearing techniques and was distributing prawn postlarvae to prawn farmers (Fujimura and Okamoto, 1970). Farmers were given free stocking material and extension services for a three-year period in exchange for production and water quality data.

By 1976, 14 prawn farms were operating and the modern commercial industry had begun. The methods used at the farms have come to be called the Anuenue method and have been described by Corbin et al (1983) and Malecha (1983). The technology was a semi-continuous system using modest stocking densities, an inexpensive feed, 0.4 ha earthen ponds, and monthly cull-harvesting. While the market in Hawaii paid a premium price for large prawns, low production levels (1000-1500 kg/ha/year) could not offset high production costs. Today, only a few prawn farms remain in operation. Recent efforts to intensify prawn production using higher stocking densities, improved feeds and mechanical aeration have resulted in production up to 4,500 kg/ha/yr on a small farm.

By the late 1970's, several large investment projects in aquaculture were started. In time, most of these failed. Analysis of the cause of these failures was compiled by an advisory committee (GAIDC, 1985). These projects failed due to a combination of poor management, poor initial citing, inappropriate marketing strategy, weak financial commitment and uneconomical production technology.

The largest farm in Hawaii is Amorient Aquafarm, Inc. Founded in 1978 as a freshwater prawn farm, the privately owned farm now raises

shrimp, prawns and a variety of fishes in 143 0.4-ha earthen ponds, 34 0.1-ha square ponds, and a shrimp/prawn hatchery. About 50 ha are devoted to marine shrimp culture (*P. vannamei* and *P.monodon*) using semi-intensive methods and about 15 ha use freshwater to produce prawns and fish polyculture (Chinese catfish, *Clarius sp.*, channel catfish and tilapia). In 1987, Amorient produced about 259,000 kg of shrimp which were mostly marketed fresh chilled whole in the local ethnic markets or as shrimp cocktail in their roadside stand (Rosenberry, 1988).

Tab. 2. — Growth of the Commercial Production Sector of the Aquaculture Industry in Hawaii 1976-1982.

	1976	1977	1978	1979	1980	1981	1982	1983	1985	1986	1987	1988
Total Area(ha)	94	98	128	197	230	219	257	203	175	175		
Prawns	10	13	43	110	124	104	122	102				
Other	84	85	85	87	87	115	135	101				
Total Production (1,000 kg)	43	56	82	112	145	154	250	192				
Prawns	20	25	50	93	136	109	144	122				
Other	23	31	32	19	9	45	106	70				
Total Value ($ 1,000)	210	281	525	1,531	1,655	1,868	2,625	1,614	2,700	3,600	6,300	5,500
Prawns	152	206	420	787	1,125	1,031	1,553	1,390	1,600	800		
Other	58	75	105	745	530	837	1,072	224	1,100	2,800		

Four or five other shrimp farms are in various stages of start-up but to date are severely limited by lack of available shrimp seed. Kahuku Prawn Co. is the largest freshwater prawn farm in the state. They produced about 16,000 kg of prawns in their 8.8 ha of ponds in 1987. Total statewide freshwater prawn production in 1988 was about 45,000 kg.

In 1981, Grace and Co. moved its superintensive shrimp company, Marine Culture Enterprises to Hawaii. Utilizing a greenhouse raceway controlled environment culture system, MCE had achieved harvests up to 100,000 kg/ha/yr in their pilot system. In 1986, MCE opened its phase I production facility consisting of 26 greenhouses with total production area of 1 ha. In 1987, when shrimp production had reached 4000 kg/wk, disaster struck. An outbreak of IHHN virus caused mass-mortality in the sensitive *P. stylirostris* and the facility had to be depopulated. The company was subsequently sold to a Norwegian firm and has still not resumed commercial activities by the end of 1988.

In 1986, an extensive survey of the commercial aquaculture industry was conducted (Main and Deupree, 1987a). They found 36 producing farms mostly located on Oahu and more than 200 people employed by the industry. Limitations on production often identified by producers were lack of capital for expansion, high production costs, disease, predation, and feed costs. Limited capital, though, was reported to be the major limiting factor. The industry was dominated by cottage-industry farms with limited financial resources. The authors recommended that the State loan programme be expanded to increase capital resources needed for industy expansion.

On the Big Island of Hawaii, several high tech aquaculture ventures have made major investments in the 1980's. Hawaii Abalone Farms pumps deep ocean water on land to produce kelp which is fed to abalone. Cyantech is a marine biotechnology company specializing in culture of microalgae, Spirulina and Dunaliella. Cyanotech uşes algal raceway technology to produce their high priced algal products.

The information sector of Hawaii's aquaculture industry significantly exceeds the production sector in total revenues. This sector involves research, training and technology transfer and generates about $10 million in revenues each year (Table 3). Major contributors to this sector include Federal research grants (about 50 %), State research (about 10 %), private research companies and consulting companies (40 %). A bibliography of aquaculture research in Hawaii was compiled in 1987 (Main and Deupree, 1987b). It is anticipated that the information sector could expand to over $20 million annual revenues in the next few years. A national applied aquaculture center is being planned for construction at Oceanic Institute in 1989.

Tab. 3. — Growth of Research, Training and Technology Transfer Sector of the Aquaculture Industry in Hawaii 1980-1986.

Year	*Project Value (millions)*
1980	$ 2.4
1981	$ 3.8
1982	$ 3.6
1983	$ 5.6
1985	$ 10.0
1986	$ 9.7
1988	$ 13.0

Aquatic Farms, Ltd. is the largest international consulting firm in Hawaii and reported 1988 revenues at about $2.2 million. Most of their projects focus on tropical shrimp culture with an emphasis on *P. monodon* hatchery technology in Southeast Asia. Other consulting groups include Aquaculture Concepts, Hawaii Aquaculture Company, Inc., and OI Consultants. Each of these companies have consulting projects throughout the tropics with an emphasis on penaeid shrimp technology.

The Hawaii aquaculture industry had a combined total value of $13.3 million in 1986 and reached $18.8 million in 1988. Total full-time and part-time employment was approximately 423 persons.

THE FUTURE

The future of Hawaii's aquaculture industry will continue to be a mixture of activities. Economic analyses predict that for commercial production to be profitable, systems will have to be intensive (Wyban et al., 1987). Since marine shrimp is one of the highest priced, highest demand seafood items in the world, it is likely that commercial shrimp production

in Hawaii will be the cornerstone of the production sector as well as the focus of the information sector.

Recent work at the Oceanic Institute has developed an intensive round pond production system suited to Hawaii's rigorous financial requirements. Capable of reliably producing 45 MT/ha/year of high quality shrimp, this system has the best chance of commercial success of systems that are currently being tested or considered.

The system was first developed in 1985 and consists of a round, self-cleaning pond with paddlewheel aeration and uses disease-free seed and high quality feed. Work at both experimental (0.03 ha) and commercial (0.2 ha) scale over the last several years have demonstrated the production capacity of the system (Wyban and Sweeney, 1988; Wyban et al., 1988).

Recently, three grow-out trials were completed in the commercial scale pond. A total of 9,000 kg of premium quality *P.vannamei* were sent to market from the 0.2 ha pond in 46 weeks from stocking of trial 1 to harvest of trial three (Table 4). Ongoing work in the round pond focuses on producing larger shrimp to capitalize on the premium created by world market conditions.

Tab. 4. — Mean shrimp production and growth in Oceanic Institute. Commercial scale (0.2 ha) round pond in three 1988 trials.

Parameter	*Mean*
Stocking weight (g)	.62
Density (shrimp/m^2)	107
Harvest weight (g)	15.7
Harvest size (count/kg)	64
Duration (d)	94
Survival (%)	90
Feed conversion	2.15
Weekly biomass (g/m^2/wk)	110
Growth (g/wk)	1.15
Mean production (kg/ha)	14,971
Total production (kg/ha/yr)	44,913

Another area in commercial development with interesting potential in the future is revitalization of Hawaiian fishponds. Ideal resources for fish and crustacean culture, a number of Hawaiian ponds will likely be restored for commercial culture of mullet, milkfish, threadfin and seaweeds. Fish production in these ponds could be integrated with visitor activities such as fee fishing or visitor centers.

The information sector probably has the greatest growth potential. Because of its tropical locale, Hawaii will expand on its leadership role as an international center of tropical and subtropical aquaculture research and development and training. By the turn of the 21st century, annual revenues from aquaculture research, training and international consulting could reach $ 25 million in 1988 dollars.

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