East meets West: Hawai'i, a lesson for aquaculture development in the United States. Part I: The early days

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Aquaculture, as defined by the FAO[3] is "the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated." In Hawai'i, aquaculture has been pursued since antiquity as early Polynesian colonists arrived 1,000-1,500 years ago to settle volcanic islands with limited terrestrial fauna (Sidebar). To secure a readily accessible and continuously available supply of fresh fish, crustaceans and other protein-rich foods, fishponds (*loko i`a*) were constructed and managed. An early form of polyculture that utilized a variety of local fishes and often integrated endemic plants and algae was developed. Traditional, sustainable practices employed by indigenous Hawaiians evolved over time and were augmented with advances brought to the islands by new immigrants from Asia and the West. With the advent of contemporary aquaculture, diversification into a wealth of aquaculture options from modest backyard systems through family-run farms to open ocean production has been pursued, consistent with cultural traditions that value ecological integrity. Today, Hawaiian aquaculture embraces both its millennium-old fishponds and the most advanced technologies to ensure a dependable and sustainable supply of high quality fisheries products, while creating jobs and income for the local populace.

Although long a part of the United States, initially as a territory in 1900 and since 1959 as the fiftieth state, Hawai'i's distance from the North American continent makes it unique and in many ways more like a foreign country. Hawai'i is located "2,390 miles from California; 3,850 miles from Japan; 4,900 miles from China; and 5,280 miles from the Philippines."[4] As such, the Hawaiian aquaculture experience, which marries the technologies and traditions of both eastern and western cultures, has developed differently than practices in the East or the West. This two-part survey initially explores the early roots of Hawaiian aquaculture and then examines its evolution into a vibrant, diverse and environmentally benign, contemporary pursuit that can serve as a catalyst and guide for the further development and implementation of sustainable aquaculture in the United States and around the world.

Traditional Pond Culture

Traditional Hawaiian society revolved around the people's relationship with the land. Islands were divided into triangular wedges of land called *ahupua`a*, ruled by *ali`i* or lesser chiefs under control of a single, most senior chief or *mō`i*. The pointed apices of *ahupua`a* were located in the mountains and gradually widened to a base as land and sea merged. Presence, abundance and size of fishponds in an *ahupua`a* contributed to the spiritual, cultural and political life of the community. Fishponds provided not only a reliable source of protein, but also served as a highly visible statement of a community's wealth and power. Fewer than 30 percent of all *ahupua`a* possessed one or more fishponds. Fishponds were managed by a lower level ruler, *konohiki*, and maintained by common people, *maka'āinana*, for the *ali`i* and *mō`i*. *Kapu* (forbidden or taboo activities prohibited by religious sanctions, which, if broken, were often punishable by death or blinding) assisted with fishpond management and had a spiritual, cultural, political and ecological basis. Fish from ponds were shared through barter with community members in distant areas for products, such as taro or pork that were not readily accessible to inhabitants near fishponds.

When Captain James Cook reached the Hawaiian Islands in 1778, as many as 488 fishponds incorporating fresh, brackish and marine waters existed[5] (Kikuchi 1976, Costa-Pierce 1987, Farber 1997). The date of first construction is unknown, but ponds were "probably in use as early as the 14th century"[5] (Kikuchi 1976, Farber 1997) and maybe as early as 1,500 years ago (Costa-Pierce 1987). The last recorded construction was Pukio fishpond on Molokai around 1829 (Farber 1997).

Construction sites were meticulously selected based on geography and geomorphology (Kikuchi 1976). After construction, ponds were stocked with fish obtained from nature and managed to promote survival and growth of the cultured organisms. Fishpond construction, management and harvest were achieved by human labor inasmuch as no beasts of burden other than the dog accompanied Polynesian settlers. The uniqueness of Hawaiian fishponds was recognized and appreciated by Jordan and Evermann (1902): "The system of fencing off arms of the sea for the formation

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Table 1. Hawaiian, English and scientific names of fishes commonly cultured or found in traditional Hawaiian fishponds; "R" indicates the fish was reared in the pond, "A" indicates eels were accidentally introduced and coincidently cultured; opae or shrimp were also grown (Summers 1964; Costa-Pierce 1987; Rosauer undated). FW, UFW, BW and SW indicate freshwater, upland freshwater, brackish water and saltwater, respectively.

Fish Name			Pond Type			
Hawaiian	English	Scientific	*Loko wai* (FW)	*Loko i`a kalo* (UFW)	*Loko pu`uone* (BW)	*Loko kuapā* (SW)
O`opu	gobies	*Eleotris sandwicensis* *E. fusca* *Gnatholepis anjernesis*	R	R	R	R
Awa	milkfish	*Chanos chanos*	R		R	R
`Ama `ama	striped mullet	*Mugil cephalus*	R	R	R	R
Aholehole	Hawaiian flagtail	*Kuhlia xemura* *K. sandvicensis*	R	R		R
Awa` awa	Hawaiian ladyfish	*Elops hawaiensis*				R
Kaku	barracuda	*Sphyraena* sp.				
Puhi	eel	Congridae Muraenidae				A A

of mullet ponds is practically, in American Territory, confined to Hawai'i." Jordan and Evermann provide an early, detailed description of fishponds in Hawai'i, "the most interesting of the fishery resources of the islands."

Freshwater Ponds

Freshwater ponds were natural or excavated (*loko wai*) and those located in upland areas were used in conjunction with taro cultivation (*loko i`a kalo*). Mostly lesser chiefs and common people used the rarely >0.2 ha, ponds. *Loko wai* were frequently supplied with water from ditches or streams and used to grow freshwater shrimp or *opae* (*Atyoida bisulcata*, *Macrobrachium grandimanus*) and a variety of mainly freshwater and occasionally euryhaline fishes, such as gobies (Table 1).

Loko i`a kalo illustrate an early form of integrated aquaculture where "taro was planted in mounds within the fishponds, permitting the fish to feed on the insects infesting the plants and the ripe leaf stems," while the fish provided nutrients to promote growth of taro[5]. Freshwater shrimp and a variety of fishes were grown in those ponds (Table 1).

Brackishwater Ponds

Brackishwater ponds, *loko pu`uone*, were natural static waters or constructed with an embankment. They were located near the sea and connected to it by a ditch or stream that allowed saltwater to enter by tidal action[5] (Costa-Pierce 1987). Small fish brought naturally into *loko pu`uone* or intentionally introduced were grown in the ponds (Table 1).

Saltwater Ponds

Saltwater ponds, *loko kuapā*, are found only in Hawai'i and nowhere else in Polynesia. They were considered by Kikuchi (1976) "an independent Hawaiian innovation." Fishponds were built by the community, but controlled by the local chief (Summers 1964, Costa-Pierce 1987). Pond size ranged from 0.4 to >200 ha. The main structural feature was a seawall (*kuapā*) constructed of volcanic rock and/or coralline limestones that weighed up to a half ton. Walls ranged from a few hundred to a few thousand meters in length and were 1-6 m in width (Figure 1). Wall height was about 1.6 m, sufficient for the top to remain exposed at high tide[6] (tidal range of 0.3-0.8 m). Sea walls were made permeable to permit limited water exchange. Typically 1-4 grated openings called *mākāhā* were incorporated into the sea wall to permit passage of small fish (to stock the pond), removal of sediments and wastes, and maintenance of good water quality as the tide ebbed and flooded. Several species of fish were stocked intentionally into *loko kuapā*, while others naturally entered through the *mākāhā* or porous wall (Table 1).

Pond Management

Given the FAO definition of aquaculture, ancient Hawaiians clearly practiced the technique in fresh, brackish and marine waters. Ponds were constructed in carefully selected and prepared sites, commonly incorporating a means to flush the system passively. Small fish were collected by net from shallow coastal waters, transported in gourds and stocked into ponds or allowed to enter systems passively through *mākāhā* and become trapped (Summers 1964). Ponds were

Side Bar

Significant dates for aquaculture in Hawaii

500-1000	Hawaiian Islands colonized by Polynesians
1555	Hawaiian Islands "discovered" by Spanish navigator Juan Gaetano
1778	Contemporary contact by Captain James Cook, at least 360 ponds existed, by some accounts the number was 488
1790s	"Runaway Chinese sailors" on Hawaiian Islands
1819	Break with traditional religion
1820	Christian missionaries from Boston arrive abroad the *Thaddeus*, written tradition starts
1839	Constitution drafted, fishing regulations codified in Civil Code and replace the Kapu system
1841	Fishing regulations modified, from access restriction to payment, in fish
1845	Fishing regulations further modified, expanded to include punishment for property damage
1848	"Great Mahele", transfer of land to people, and often foreigners
1851	Fishing regulations modified again, to include punishment for malicious injuries and mischief; transferred ownership of fish from government to people, provide for fines and/or prison for noncompliance
1859	Fishing regulations approved by Hawaiian legislature and passed into Civil Code
1868	First "boatload" of Japanese immigrants arrive
1872	Prohibit use of "giant powder" (dynamite) to take fish
1888	Prohibit collection of young fish (mullet and milkfish) from public waters
1892	Civil Code modified to ensure that restrictions imposed by law are applied to and followed by Konohiki
1892	Hawaii becomes Republic on 4 July
1898	Hawaii annexed to US on 12 August
1899	Hawaii ravaged by Bubonic plague brought to island by exotic rats and fleas
1900	Hawaii becomes U.S. Territory on 14 June
1902	Hawaiian fishes and fisheries inventoried by Jordan and Evermann; many fishponds are in disrepair, particularly on Molokai and Hawaii. On Oahu, many were converted to rice cultivation and other purposes. Jordan and Evermann observe that "probably not more than half the number of ponds in use today that there were 30 years ago".
1902	Estimated that >100 fishponds in some form of operation
1903	Estimated that 86 fishponds in operation
1938	Fishponds inventoried, assessed and categorized
1940s	Fishponds explored as potential food source during Second World War
1950s	Limited commercial culture of ornamental fish and live-bait
1959	Hawaii becomes 50th state on 21 August
1965	Takuji Fujimura, considered by many as the father of contemporary Hawaiian aquaculture, introduces freshwater prawn culture
1977	Inventory indicates that 27 fishponds in operation
1978	First formal Aquaculture Development Plan in U.S. assembled in Hawaii
1985	Inventory indicates that 7 fishponds in commercial or subsistence use
1993	Aquaculture Development Plan revisited and updated
1999	Ocean Leasing legislation passed in Hawaii

fertilized with plant or animal material, but not excrement because sewage or pollution of any kind was prohibited by *kapu*[5] (Kikuchi 1976, Harris 1977). Pond substratum was cleaned of algae (*limu*) and associated debris with weighted bamboo rakes. Fish were concentrated by feeding taro leaves or use of tidal flow to facilitate harvest; harvesting employed a variety of net styles (Summers 1964, Costa-Pierce 1987).

Observations reported by Cobb (1902) have been used to estimate harvests and carrying capacity of traditional fish ponds, yielding values between 200-400 kg/ha at harvest (Kikuchi 1976, Costa-Pierce 1987, Farber 1997). Using Cobb's observations we calculate a similar estimated harvest of 235 kg/ha. Those yields are consistent with values commonly realized in low intensity or extensive aquaculture systems that receive minimal inputs of management or supplemental nutrients. They are also based on observations and data for fishpond harvest after exotic Asiatic fishes had been integrated into culture protocols (see below). They do not include production values for all ponds extant at the time and fail to account for the removal of large fish as needed and their subsequent replacement by small fish, a practice called "topping." Computed yields may best be considered as conservative approximations.

While the actual yields in traditional Hawaiian fishponds likely will never be known; it is clear that early Hawaiians were competent and conscientious conservationists that pursued a form of sustainable aquaculture. They possessed knowledge of fish biology that included migration patterns, reproductive requirements, and dietary needs. Water quality issues were addressed by pond location, pond structure,

Fig. 1. He`eia Fishpond, a loko kuapā, was constructed by running a wall across the mouth of a small bay (Image: J. Raymond)

flushing rate and sediment removal. Tidal flux and currents provided for passive flushing twice daily. Pond operators employed various management tools including topping and polyculture, the culture of multiple species of aquatic organisms to maximize conversion of energy into food. They also practiced integrated aquaculture using taro plants and algae, *limu*, to remove and incorporate fish excrement and metabolites. Traditional fishponds were ecologically benign, required little capital investment to manage and provided a reliable supply of quality animal protein for hundreds of years, particularly during the spawning season when capture of wild fish from coastal waters was forbidden by *kapu* (Kikuchi 1976). The basis for aquaculture was defined and, as newer and more effective approaches were developed, a receptivity to evolve became established among Polynesians in Hawai'i prior to European contact.

Post Contact Adjustments

In 1778, Captain James Cook arrived and re-established contact with the Hawaiian Islands, more than 200 years after the Spanish navigator, Juan Gaetano, stumbled upon them around 1555. Within two generations, influences from the East and West had initiated changes that continue today. The new immigrants were highly competitive, with well-developed commercial instincts and limited conservation ethics (Harris 1977). Aquaculture technologies established and refined for over two millennia in China brought new species, production methods and attitudes to Hawaiian aquaculture. From the West, government regulations – as civil codes – and punishment for transgressions – as fines and prison time – replaced traditional cultural and religious *kapu*; capitalism replaced the barter system. By 1900, when Jordan and Evermann (1902) assessed Hawaiian fisheries, traditional aquaculture in fishponds had been transformed.

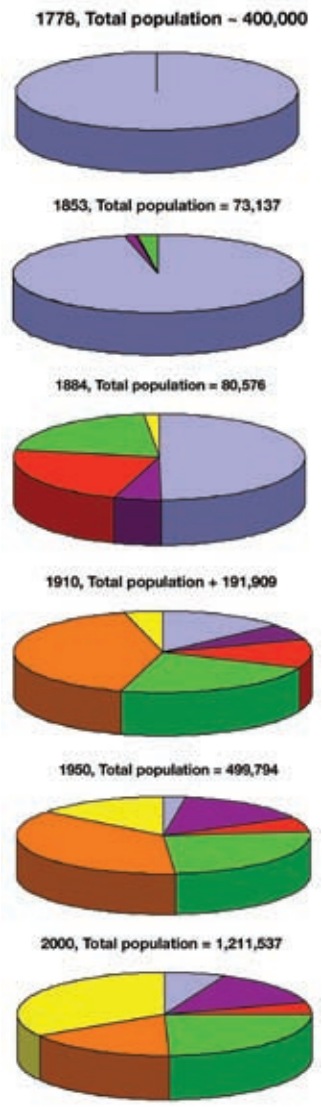

Fig. 2. Demographics of Hawaii obtained from Thrum (1875, 1878, 1886), Schmitt (1973, 1977) and U.S. Census website (www.census.gov/census2000/states/hi.htm; (http://www.census.gov/prod/www/abs/decennial/index.htm). Values for 1778 are estimates, values for 1853 and 1884 are from the Hawaiian government, and all others from U.S. census. Indicated are the proportions of population as Hawaiian, Part Hawaiian, Chinese, Caucasian, Japanese and Other. (Image: J. Buttner)

Eastern Influence

Immigration from Asia to Hawai'i commenced shortly after contact as absent without leave Chinese sailors were observed in Hawai'i in the 1790s and farmers arrived by 1802 (UNMERCP 1975). By the1878 Hawaiian census, Chinese were the dominant non-native ethnic group. The first major influx of Japanese immigrants arrived in 1868 and by 1896 Japanese replaced the Chinese as the most numerous non-native, ethnic group in Hawaii (UNMERCP 1975). As immigrants arrived the native population decreased dramatically; in slightly more than a century Native Hawaiians had become a minority in their homeland (Figure 2).

As Chinese immigrated to Hawai'i, they brought their millennia-old aquaculture traditions and technologies (Costa-Pierce 1987). Those practices were embraced by native Hawaiians and integrated into traditional fishpond culture, just as Chinese aquaculture had influenced Japan, India, Thailand, Malaysia, Singapore and Indonesia (Costa-Pierce 1987, Edwards 2004). Chinese immigrants brought with them and introduced exotic fishes, such as goldfish (*Carassius auratus*), snakeheads (*Ophiocephalus striatus*, now *Channa striatus*), and white spot catfish (*Clarias fuscus*). The goldfish arrived sometime before 1867 and the latter two fishes in the decades immediately proceeding 1900 (Cobb 1902, Jordan and Evermann 1902). Somewhat surprising, Jordan and Evermann (1902) attributed introduction of the common carp (*Cyprinus carpio*) not to the Chinese, but rather the United States. Sometime shortly after 1872, Julius Poppe imported the species to Hawai'i (Cooper 1987).

Cobb (1902) reported on the status of commercial fisheries in Hawai'i, documenting the evolution of traditional aquaculture. In sea ponds, the traditional striped mullet and milkfish were still cultured (Table 1); however, in freshwater and brackish ponds the Chinese

(Continued on page 46)

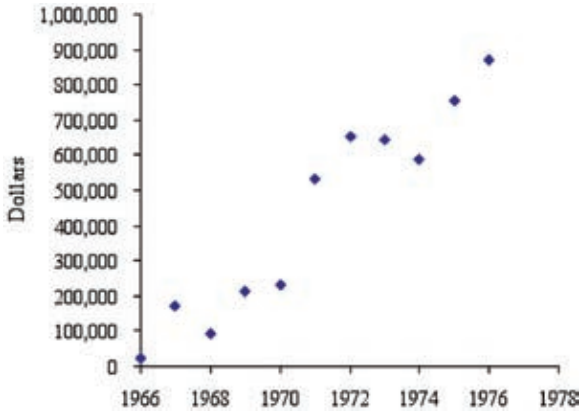

Fig. 3. Funding for aquaculture research between 1962-1976 (Corbin 1976). (image: J. Buttner)

(Continued from page 44)

influence was apparent as exotic goldfish, snakeheads and white spot catfish, as well as carp complimented traditional crops of gobies (*o`opu*), shrimp (*opae*) and Hawaiian flagtail (*aholehole*; Table 1). Asian fish raised in ponds were sold to the Chinese, who also managed most ponds (Cobb 1902, 1905a,b, Jordan and Evermann 1902). Pond design and management were also influenced by Chinese technologies. By 1900, the single-gated, immobile *mākāhā* was replaced with "narrow entrances, protected by sluice gates, which can be opened or closed at will" (Jordan and Evermann 1902) that facilitated concentration and harvest of fish as the tide ebbed and flowed. Diversity of nets employed to harvest fish also expanded to include dip nets, seines, gill nets and scoop nets (Jordan and Evermann 1902).

Western Influence

Concurrent with the arrival and integration of Chinese aquaculture practices, western culture established a presence and impact in Hawai'i. In 1819-1820 a pair of events dramatically transformed Hawaiian culture and aquaculture. The Hawaiian King, Kamehameha II, abandoned the traditional religion, creating a cultural disruption and void. Adding to the confusion was the arrival of American missionaries from Boston aboard the *Thaddeus* (Cobb 1902, Jordan and Evermann 1902). The establishment of a written tradition and a fledgling embrace of western views were among the many legacies of the missionaries.

In 1839, Hawaiians drafted a constitution, which partitioned waters to all people and fisheries management was codified into law. Between 1841 and 1892, fisheries regulations and punishments were incorporated into the civil code, replacing the traditional *kapu*. The *kapu* system, based upon conservation, was replaced with regulations that restricted access, protected spawning and fry/fingerlings, and defined punishment for infractions. Initially, punishment denied access, such as "for two years he shall not fish at all on any fishing ground;" subsequently, punishment evolved into often ecologically questionable restitutions, such as "if he shall take one fish criminally, he shall pay five," which could lead to overexploitation of vulnerable fish populations; and, ultimately, into fines and/or prison for infractions (Jordan and Evermann 1902). By 1892, when Hawai'i formally became a Republic, all waters except fishponds were managed for and by the people. Jordan and Evermann (1902) recognized the uniqueness and ecological soundness of fishponds. They recommended that "the best interests of the fisheries will be served by leaving their (fishpond) present owners in undisturbed possession."

Although not directly affecting fishponds and traditional aquaculture, the Great Mahele (divide) of 1848 effectively ended the *ahupua`a* system and disrupted fishpond maintenance. Land, a shared resource until 1848, was partitioned into private allotments with less than one percent going to the common people (Farber 1997). In essence, land became a commodity and the social structure based upon cooperation, barter and reciprocity that made fishpond construction and management possible, ceased to exist. Over 70 percent of the population found itself abruptly without resources at a time when capitalism with its emphasis on private ownership was embraced. Privatization, based primarily on monetary gain, did not favor fishponds. Cheaper sources of seafood could be obtained elsewhere, specifically from capture fisheries and imports that were often supported by government subsidizes and undervalued or ignored ecological costs associated with capture fisheries.

Effect of Contact

The decades following contact initiated an accelerating cascade of dramatic, often traumatic, changes to Hawaiian culture and aquaculture. Before the arrival of western and eastern influences as many as 488 identifiable fishponds existed and were managed sustainably by native Hawaiians (DHM Planners, Inc. 1989). By 1900, the number of ponds "in some form of operation" had decreased by 70 percent (Cobb 1902) and most were managed by foreigners. Fishponds traditionally constructed and maintained for the common good, employing environmentally sound management practices, were transformed into revenue generating operations. Land originally held by the King and ponds managed by lesser chiefs, but accessible to all, were distributed into private ownership and in many cases sold to outsiders during the Great Mahele in 1848, often at rates of $0.62-1.24 per hectare (Costa-Pierce 1987). The populace suffered a similar fate, inasmuch as the number of native Hawaiians decreased 90 percent during the same period, largely from exotic disease (Figure 2). By 1900, when Hawai'i officially became a U.S. Territory, the resolve and resiliency of Hawaiian aquaculture and culture had been severely tested.

Territory Time

Between 1900 and 1959, Hawai'i was a Territory of the United States. During Territory times, Hawaiian aquaculture and culture managed to survive despite many challenges. The number of fishponds in production continued to decline, but at a reduced rate (Costa-Pierce 1987). Sadly, many ponds were permanently lost because of construction projects, siltation and ecological succession, severe storms, lava flow and general neglect associated with depopulation. Peppered throughout the Territory time were inklings of resurrection as ponds were categorized, inventoried and as-

sessed in 1938, explored as a food source during the Second World War and surveyed for cost of renovation in 1956 (Farber 1997). Collectively, these efforts kept interest alive and precluded total destruction of the ponds.

By the 1950s interest in aquaculture was reawakening with limited culture of ornamental fish (koi and carp), live-bait (nehu, *Encrasicholina purpurea*; tilapia, *Oreochromis mossambicus*) and species grown and released to complement existing fisheries (ta`ape, bluestripe snapper, *Lutjanus kasmira*)[7]. In the 1960s, foundations were seeded for the "Blue Revolution," the birth of contemporary aquaculture and Hawaiian Renaissance, the assertion of indigenous rights and cultural pride. Traditional Hawaiian resiliency had prevailed, providing for a new generation of aquaculture that synthesized western and eastern influences with Hawaiian practices and "ecoethos," literally, ecological ethics or living in a manner respectful of the environment and acknowledging humankind's unique role in ecological processes.

Rebirth

As an early advocate of the Blue Revolution, shortly after becoming our 50th state in 1959, Hawai'i gradually but steadily revisited aquaculture possibilities. A cultural and economic resurgence morphed, as noted by W.W. Paty, Chairperson, Board of Land and Natural Resources, "fish farming has been part of Hawai'i's history for hundreds of years, but the modern thrust began in the 1960s" (ADP 1993). Initial support for aquaculture research was limited and targeted oyster culture, but financial and logistic support grew steadily (Figure 3). Arguably, the most important catalyst for the expanded funding and activity necessary to nurture aquaculture was the introduction of freshwater Malaysian shrimp (*Macrobrachium rosenbergii*) to Hawaii in 1965 by Takuji Fujimura, who is viewed by many as the father of contemporary Hawaiian aquaculture (Corbin 1976).

Building upon its aquaculture tradition and commitment to "ecoethos," several government-requested reports examined the history and potential of commercial aquaculture in Hawai'i (Hawaii 1969, 1974, Trimble 1972), culminating with the first formal state aquaculture development plan in 1978 (APP 1978). The Plan identified constraints to commercial aquaculture. Economic options were expanded, including the first low-interest, state-sponsored loans for commercial aquaculture in 1972 (Corbin 1976). The Department of Agriculture (DOA) ultimately was identified as the lead agency for aquaculture development. Transferred from the Department of Land and Natural Resources to the DOA in 1999, the Aquaculture Development Program (ADP) has been charged with bridging the needs and interests of elected officials, agency people, and commercial aquaculturists to expand the industry (Figure 4). In 1993, the aquaculture development plan was revisited and commitments to sustainability and preservation of Hawai'i's treasured cultural and environmental uniqueness reaffirmed (ADP 1993). The resultant regulatory atmosphere and permitting process rank among the most efficient in the United States.

Beyond the nurturing guidance afforded by State sup-

Fig. 4. ADPMarketing Information Specialist, Dean Toda (l) shares with Dr. Joe Buttner materials developed to inform people about Hawaiian aquaculture. (Photo by J. Buttner)

Fig. 6. Tom Iwai, Aquatic Biologist with the Anuenue Fisheries Research Center examines seaweed destined for release on a local reef as part of restoration effort. (Photo by J. Buttner)

Fig. 7. Jim Szyper, one of four Sea Grant Extension Specialists in Hawaii, flushes accumulated solids from a demonstration recirculating aquaculture system at UH Hilo Panaewa facility. (Photo by J. Buttner)

port, the fledgling aquaculture industry has benefited from expertise and assistance provided by research and extension people as well as a trade association. Included among the many reservoirs of assistance are the Ānuenue Fisheries Research Center, Oceanic Institute, University of Hawaii and Hawaii Sea Grant Program, Natural Energy Laboratory of Hawaii Authority, Center for Tropical and Subtropical Aquaculture, and Hawaii Aquaculture Association, which promotes public awareness of aquaculture and is an advocate of the commercial aquaculture industry (Figure 5).

Aspiring and practicing aquaculturists have been afforded assistance that includes: broodstock, immature fish (fingerlings) and immature shrimp (post-larvae) as well as technical assistance and educational opportunities, both formal and nontraditional (Figures 6, 7, 8). New species for culture, including Pacific threadfin, mullet, yellow tang (*Zebrasoma flavesenes*) and new culture protocols, such as pathogen-free shrimp and net-pens suitable for open ocean aquaculture, have been developed by researchers and transferred to industry (Figure 9). Incubator facilities have been established, particularly at the Natural Energy Laboratory of Hawaii Authority, that nurture start-up companies through their first few years; commonly in aquaculture it takes 3-7 years for a new company to become profitable (Figure 10).

Through long-established traditions and a desire to nurture sustainable aquaculture, a commercial industry valued at $28 million to farmers in 2005 has been established, embraced and expanded in Hawai‘i (USDA and National Agricultural Statistics Service 2006). Methods of production and species cultured are varied, but the industry as a whole is consistently respectful to traditional commitments of conservation and sustainability, initially manifested by *kapu* and currently embodied in contemporary Hawaiian aquaculture. Part II of this survey explores contemporary aquaculture, how it is pursued and accepted.

Notes

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[3]FAO website. Undated. http://www.fao.org/fi/glossary/default.asp, accessed 13 February 2007.

[4]http://www.50states.com/facts/hawaii.htm, accessed 31 Jan 07.

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[6]http://www.freetidetables.com/tides/?tti=2609, Tide Charts, accessed 11 February 2007.

[7]H. Takata, retired S.G. Extension Specialist, personal communication; J Corbin, Aquaculture Development Program, retired, personal communication; T. Iwai, Anuenue Fisheries Research Center, personal communication.

[8]http://www.nelha.org/about/about.html, accessed 15 April 2007.

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Fig. 8. Dr.Kevin Hopkins (right) consults with contractor assembling support for recirculating aquaculture systems being constructed at the UH Hilo new5.0 ha aquaculture research/education/demonstration site. (Photo by J. Buttner)

Fig. 9. Oceanic Institute technician Gary Germano (l) and John Ginoza harvest fingerling Pacific threadfin grown on-site as part of a collaborative arrangement with industry (Cates International). Fingerlings aretransferred to net-pens in the open ocean for growout to market-size. (Photo by J. Buttner)

Fig. 10. Natural Energy Laboratory of Hawaii Authority on Keahole Point,Kona, Hawaii is a state agency leasing sites with dependable energy and water of high quality for aquaculture. NELHA is home to nearly two dozen companies involved in some form of aquaculture (http://www.nelha.org/about/about.html). (Photo by J. Buttner)

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