

APPENDIX D

DRAFT

KANE'OHE FISHPOND MASTER PLAN

prepared for the  
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and  
Kane'ohe Bay Regional Council

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February 1992

## SUMMARY

This Master Plan is intended to identify goals, directions, and measures to restore remaining fishponds for uses consistent with their historic function and integrity: fish production, historic preservation, wildlife conservation, education, and other compatible cultural and recreational uses.

Attempts were made to contact all fishpond owners/controllers, as part of the development of the Kane'ohe Fishpond Master Plan. Each fishpond was visited and reevaluated and a number of important references consulted. The status and proposed direction for each pond is summarized in Table 1.

Six of the 14 ponds are along the shoreline of Kane'ohe Bay. Excluding one (Mikoli'i), which is a waterbird refuge in Kualoa Regional Park, the remaining 5 ponds are privately owned and capable of remaining in maricultural use (Moli'i), or returning to mariculture (Kahouna, He'eia, Kanohulu'iwi, and Waikalua).

The remaining 8 ponds are located within the *ahupua'a* of Kane'ohe at Mokapu Peninsula and are presently under the jurisdiction of the Marine Corps Air Station, Kaneohe Bay. Three of the ponds serve as a waterbird refuge (Nu'upia 'Eha, Kahulupuhi, and Pa'akai), and should remain as such. The other 5 are in inactive military use (Nu'upia 'Ekahi, Nu'upia Elua, Haleloa, Halekou, and Nu'upia Ekolu), but 3 are capable of restoration for mariculture production and demonstration. The remaining two are recommended for wildlife conservation (Heleloa, Nu'upia and Ekolu).

Table 1. Status and Master Plan Recommendations for surviving Kane'ohe Fishponds. Ponds are listed from north to south. \*KMCAS=Marine Corps Air Station, Kane'ohe Bay.

NAME OF FISHPOND	OWNERSHIP/ CONTROL	SIZE (acres)	EXISTING USE	PREFERRED USE	RECOMMENDED REPAIRS
Mokoli'i (Pahalona)	City & County Parks Dept.	5	wildlife sanctuary	same	none
Moli'i	Kualoa Ranch	124	mariculture production	same	none
Kahalu'u (Kahouna)	Linda Wong	39	mariculture (temporarily suspended)	mariculture	none
He'eia	Bishop Estate	97	restoration for mariculture	mariculture	repair breach in wall, clear and repair <i>makaha</i>
Kanohulu'iwi	Dr. Pacpaco	3	none	mariculture	none
Waikalua	Pacific Atlas	12	none (proposed silt basin)	mariculture demo and education	clean and repair <i>makaha</i>
Nu'upia 'Ekahi	*KMCAS	58	military	mariculture prod. and demonstration	rebuild <i>makaha</i>
Nu'upia Elua	*KMCAS	21	military	mariculture	clear culverts and <i>makaha</i> and repair/rebuild walls and <i>makaha</i>
Nu'upia Ekolu	*KMCAS	92	military	wildlife	clear culverts and <i>makaha</i>
Nu'upia 'Eha	*KMCAS	6	wildlife sanctuary	same	clear and repair culverts
Kaluapuhi	*KMCAS	16	wildlife sanctuary	same	clear culvert
Pa'akai	*KMCAS	20	wildlife sanctuary	same	periodically clear Kailua Channel and install control structure
Heleloa	*KMCAS	2.5	military	recreational fishing or wildlife sanctuary	improve habitat
Halekou	*KMCAS	25	military	mariculture	repair broken fill, clear culvert, heighten wall and clear/repair <i>makaha</i>

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## INTRODUCTION

This report fulfills the recommendations of the Kane'ohe Bay Task Force to prepare a Master Plan for the fishponds of Kane'ohe Bay. The planning area includes all the fishponds in the Kane'ohe region within the *ahupua'a* of Kualoa to Kane'ohe. Of more than 35 Hawaiian fishponds that once lined much of the Kane'ohe shoreline between Kualoa and Mokapu, only 14 now remain. Some of the remainder have been modified by dredging and filling for federal roads and airfields, while others have fallen into disrepair. This Plan gives a pond-by-pond analysis of existing problems and potential benefits, and offers direction on the most feasible future for each pond, consistent with maintaining their historical integrity and functional purpose. The plan focuses on pond restoration for mariculture, education, cultural preservation, and wildlife protection - all consistent with traditional Hawaiian values. In contrast, this plan rejects the notion of using ponds for "alternative" purposes, such as silting basins, marinas, fills for house lots, and additional roads. These latter uses are inconsistent with the original functions of the pond and are construed as disrespectful to the Hawaiian culture. We believe the views and recommendations in this Fishpond Master Plan are consistent with the recommendations of the Kane'ohe Bay Task Force in its Master Plan (1992), but do not represent the official position of the Task Force.

## METHODS

Several important studies have concentrated on Hawaiian fishponds, including those in Kane'ohe Bay. The reference section includes a listing of all known reports. In general, we agree with essentially all of the recent recommendations with specific reference to Kane'ohe Bay fishponds, and have incorporated these recommendations as part of this Plan (DHM, Inc., 1989; Aecos, 1983; Oceanic Institute, 1977; HFRP, 1991). In addition, we visited each of the ponds, and consulted the landowners to determine their views and interests regarding the ponds (Table 2). We also met, and otherwise communicated as a group to discuss the possible restoration and use of the fishponds, and to update their status and potential for fulfilling desirable functions. A draft of this plan was provided to the landowners/managers of the ponds for their views and comments. The final version of this plan will address the concerns and suggestions of the reviewers.

The ponds fall into two groups: the six ponds occurring along or near the shoreline of Kane'ohe Bay proper, and the remaining eight ponds at Mokapu presently under the control of the Marine Corps Air Station, Kaneohe Bay. (KMCAS). These two groups of ponds are treated separately because of

differences in jurisdiction and control. All but one of the six Bay ponds are in private ownership, while all eight of the Mokapu ponds are under federal government control.

Table 2. 1992 Survey Questions and Results: Kane'ohē Fishpond owners or managers.

Questions

1. Would you consider restoring your Hawaiian fishpond to production if:
  - a. State of Hawai'i ADP to permit building
  - b. you could acquire low cost *awa*, mullet juveniles
  - c. creation of fishpond subzone conservation
  - d. tax incentives, income and property
  - e. use of educational and cultural groups with liability insurance

Answers

Kualoa Ranch - John Morgan

- a. not applicable, already in operation
- b. not applicable
- c. yes, like to see the language
- d. yes
- e. yes, definitely

He'eia - Bishop Estate, ~~message to Rep. Peters, Sun Press~~ *request to B.E Trustee Henry, referred to Bassett, requested Brooks to comment*

Kahalu'u Ponds - Linda Wong

- a. yes, should support
- b. yes
- c. against new zoning
- d. yes
- e. not right now

Waikalu - Hugh Brown

- a. yes
- b. yes
- c. no
- d. yes
- e. no comment, but possibly if golf course is allowed

He'eia Pond - Jim Bassett (said to refer to <sup>lessee</sup> Mark Brooks for comment)

Kanohulu'iwi - Dr. Papco (unable to reach for interview)

Nu'upia/Mokapu Ponds - at the request of the Commander, a questionnaire was dropped off at KMCAS for possible written response.

## HISTORY OF THE FISHPONDS IN KANE'OHE

Most of what follows was taken from Devaney et. al. (1976, 1982), courtesy of Marion Kelly, one of the lead authors of this most important historical evaluation of Kane'ohe's fishponds.

Kane'ohe Bay is one of several large estuary systems in the Hawaiian Islands. These areas contained lagoons and productive fisheries protected by broad fringing reefs, and met all the natural requirements as suitable sites for walled fishponds, which the ancient Hawaiians built in large numbers. On O'ahu, all such areas have suffered losses in fishery resources and most of their Hawaiian built walled fishponds.

The first systematic study of fishery resources in the Hawaiian Islands was done in 1901 by John N. Cobb, U.S. Fish Commission agent (Cobb, 1902). At that time, Cobb listed 16 fishponds that were being commercially operated in Kane'ohe Bay, which he called Ko'olau Bay. Cobb estimated that the number of ponds still in existence in 1901 was probably only half that of the ponds there thirty years earlier.

The next systematic survey was done in 1930 by McAllister (1933). He collected information on 97 ponds on O'ahu, many of which no longer existed at that time (McAllister 1933:38). In Kane'ohe Bay, from Kualoa to Mokapu, McAllister found evidence of 23 fishponds, but only a few of them were being worked at the time of his survey.

Today on O'ahu, there are only about 25 sites that can still be recognized as fishponds (only 14 ponds at 7 sites in the Kane'ohe Bay area), and fewer still that are productive. When one considers that for the whole island of O'ahu there were about 100 fishponds in 1900, about 70 remaining in 1930, and now only about 25, these last few become quite important. A list of all known ponds in Kane'ohe Bay was compiled by Devaney, et. al., 1976 (Table 3).

For the year 1900, Cobb estimated the value of the Ko'olaupoko fishponds, with their nets and boats, to be \$33,546. The 16 ponds were valued at \$32,920, five rowboats at \$180, and 39 nets and seines at \$446 (Cobb 1902:431). The yield on this investment for the year 1900 alone was 320, 159 pounds of fish, valued at \$80,029 (ibid. :431-32), or 241.5% of the capital invested. The value of the yield was based on a price of 25¢ per pound.

✓ Shoreline fishing is highly susceptible to the vagaries of weather and surf conditions. With walled fishponds, Hawaiians provided for themselves a



regular supply of fish when other types of fishing were not possible or yielded an insufficient supply. The fringing reefs along the shoreline of Kane'ohe Bay were ideal for the type of walled fishponds that extended out from the land.

Mullet, one of the world's most important food fishes, was the most common species raised; *awa* (milkfish) followed a close second. Unfortunately, both fish are being depleted in Hawai'i because of the destruction of their sanctuaries and habitats. This is also true of the mullet fry. There has been a general neglect of Hawai'i's shoreline fishery resources, particularly those of O'ahu (J. Kelly, pers. comm. to M. Kelly).

One very important aspect of Hawaiian pond-fish farming is that of natural or autarchic feeding. The fish protein provided by mullet and *awa* was produced with natural algae, without utilizing other foods that could have been used directly for human consumption. Mullet and *awa*, being herbivorous, feed on algae that grow at the bottom of a pond, and graze on the roots of certain plants growing around the edges of a pond. The algae grow when sunlight, salt, and fresh water are available in the necessary amounts. For the right amount of sunlight, a depth of no more than about two feet must be maintained, if the algae are to obtain prime growing conditions. The correct relative amounts of fresh and salt water depend on local conditions and the size of the fishpond. Ponds with a large surface area, such as He'eia Fishpond, tend to have high evaporation rates. The salt content of the water in such ponds will rise unless additional fresh water is allowed to enter the pond in the proper proportions.

Hiatt (1947) made an important contribution to the science of fish farming when he analyzed "The food and feeding habits of the three most important market fish in Hawaiian ponds". Hiatt discussed the unique feeding ability of Hawaiian mullet:

"It is apparent that Hawaiian mullet are almost entirely herbivorous ...Moreover, this species digresses from the expected... (fish size to food ratio) and telescopes the food chain because of its elaborate, pharyngeal sieving mechanism. This sieve-like apparatus apparently enables the fish to select a sufficient quantity of minute plant types and organic detritus for its sustenance..."

"...it is safe to assume that they also browse on algal plants and exposed roots of band vegetation. Larger plant fragments are filtered out, permitting only the diatoms and other minute algae to enter the esophagus." [ibid.:256].

In general, the production of fish protein is transferred up the food chain, thus requiring:

"...10,000 pounds of algae to make 1,000 pounds of tiny crustaceans to make 100 pounds of small fish to make 10 pounds of large fish, and 10 pounds of large fish to make one pound of man. These proportions are different in Hawaiian ponds in that the most abundant small and large fish consume algae and its resultant detritus directly, thereby telescoping the usual food-chain relationships. The weight ratios are probably closer to the following: 10,000 pounds of algae and detritus make 1,000 pounds of herbivorous fish, 1,000 pounds of herbivorous fish make about 100 pounds of carnivorous fish or man."

Hiatt's observations and estimates show that the Hawai'ians, by selecting for fishpond development the key herbivorous food-chain link (mullet and milkfish), has raised the natural system efficiency by one hundred times, or 10,000 percent. (Fig 1). There is no doubt that the greatest yield in pounds of fish, and therefore in dollars, can be harvested from the herbivorous link of the food chain.

## EARLY OWNERSHIP OF FISHPONDS

It has often been stated that fishponds were the private property of Hawaiian chiefs, or of royalty, or of the king. Such statements refer to recent historic times when the private property system had made in-roads into the undivided and use rights of the Hawaiian subsistence economy. Fishpond wall building required a large number of people working together. As Kamakau (1976) expressed it:

- The making of walls (*kuapa*) of the shore ponds was heavy work, and required
- the labor of more than ten thousand men...

"Many *loko kuapa* were made on O'ahu, Moloka'i, and Kauai, and a few on Hawai'i and Maui. This shows how numerous the population must have been in the old days, and how they must have kept the peace, for how could they have worked together in unity and make these walls if they had frequently been at war...? If they did not eat the fruit of their efforts how could they have let the *awa* fish grow to a fathom in length; the *'anae* to an *iwilei*, yard ...?" [Kamakau 1976:47].

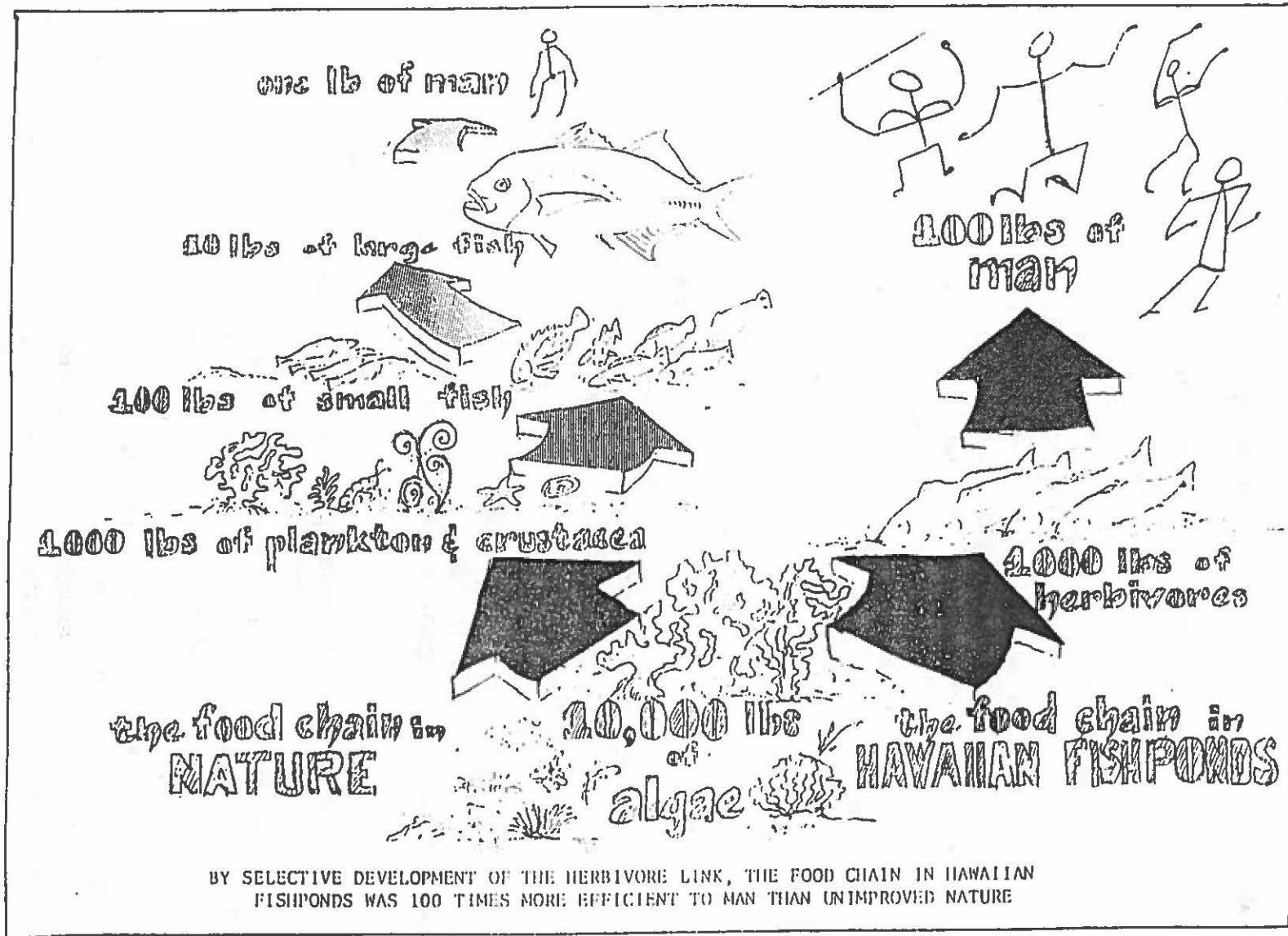


Fig. 1 . GRAPHIC ILLUSTRATION OF THE NATURAL FOOD CHAIN AND THE SELECTED HERBIVORE FOOD CHAIN OF HAWAIIAN FISHPONDS. (Prepared by J. Kelly.)

The chiefs, as the engineers and administrators, planned and then were the overseers of the construction of the fishponds. They called together the community to do the work of constructing the wall. Sometimes a large portion of the population of an island may have provided the labor for a project (Summers 1971:137). Once constructed, it is assumed that the ponds were community property, with the various social and occupational groups, particularly those who aided in its construction, sharing in the productivity. While there are no accounts of that early period of Hawaiian history, our knowledge of the social structure, work methods, and food distribution techniques of pre-European Polynesian and Hawaiian culture, and our understanding of the changes that came about in post-European times, provide a substantial body of knowledge on which to base certain assumptions.

Kamakau provides an example of food distribution when discussing the ceremonial apportionment of *kala* (*Naso lituratus*):

"The first *kala*, those taken on the landholder's day (*la haku*), went to the chief of the land, but the fishermen got a share from the fish set apart for the *akua*, perhaps five *kala* from each basket -- or perhaps three or four. A chief who looked to the welfare of the land, however, gave twenty to forty fish from each trap to the *akua*, and from these the fishermen got a share. The chief's day was the first day the *hina'i* [basket traps] were lowered ..."

"The second day the take was for the *kama'aina* of the land and for the fisherman, and that day his kinsmen and relatives gathered. The first *hina'i* full of *kala* fish was for the fishing *'aumakua* to release their restrictions .... The head fisherman acted as the *kahuna* who prayed to the *'aumakua* and offered the food, and when the tabu of the prayers was over, the fishermen ate ... When all had eaten then the fishermen went to pull up the remaining *hina'i* ... the canoes would be full of *kala*. When the fish were brought ashore there would be a pile as big as a house; a *lau* upon *lau* ("four hundred times four hundred"); a *mano* ("four thousand"); a *kini* ("forty thousand") -- most of them still alive." [Kamakau 1976:85].

It was the fish gathered on the second day that were for the people of the community (ibid.). There is no reason to believe that in Hawaiian times (pre-European times) the products of most fishponds were treated any differently.

In the process of adopting the Western private property concept of land ownership, and for the same reasons, fishponds were declared to be part of

the land sections (*ahupua'a*) to which they were attached. In 1848 the *ahupua'a*, including the fishponds, were claimed by, and in most cases awarded to, the king, the government, and a few powerful chiefs, most of whom were relatives or supporters of the Kamehameha line. It is this introduced private property system of the recent past that has been inherited today and is still in effect.

Once fishponds were declared private property, they were taxed by the government along with the rest of the real property. When commercial agriculture brought promises of high profits, few large landowners paid much attention to the fishponds attached to their land holdings. They were satisfied to lease them to Hawaiians or Chinese who had the technical knowledge necessary to properly manage fishponds. Yet, when disaster struck, such as a break in the fishpond wall, few lessees could afford the capital required to undertake repairs. As a result, many fishponds deteriorated with the passage of time, and the practice of aquaculture among the people, for all practical purposes, ceased.

#### PRESENT STATUS OF KANE'OHE FISHPONDS

Many of the fishponds of Kane'ohe Bay were filled shortly after World War II. Most others continued to deteriorate from neglect. Today, only five walled fishpond sites in Ko'olaupoko have been judged to meet the criteria outlined by the National Register to warrant nomination as historic places (Apple and Kikuchi 1975).

Two of these are the large ponds of Moli'i and He'eia. He'eia Fishpond has some interesting and unusual features. Its wall was one of the longest, extending for nearly a mile, and it completely encircled the pond (McAllister, 1933, Kelly, 1975). There is evidence in early photographs that the portion of the wall along the stream has undergone some changes in historic times. The original wall of the pond along the stream was considerably closer to the land than the present wall. The probability is high that changes in the wall were necessitated by changes in land use *mauka* of the pond (Kelly, 1975).

Other aspects of He'eia Fishpond are the *makaha* gates on the *mauka* wall, which were put there to control the amount of fresh water that flowed into the pond. A pond with a large surface area, such as He'eia (97 acres), is subject to considerable evaporation, and fresh water must be added from time to time to reduce the salinity of the pond's water.

On the *makai* wall at the *makaha* next to the only remaining guard house there are several cut bluestone (basalt) rocks in which grooves were carved to

secure the gates that controlled the ebb and flow of seawater into and out of the pond. According to Yee Hee (pers. comm. to M. Kelly, 1973), these stones were there before his family took over the lease of the pond.

Table 3. Walled Fishponds in 19th Century Kane'ohe Bay

NO	POPULAR NAME	OLDER VARIANT	ACRES*	COMMENTS	SURVIVING PONDS 1992
1	Mokoli'i	Pahalona	4.6	Not Koholalele. Accretion has widened S. wall.	X
2	Moli'i		124.5	Originally single pond; divided early 1900's.	X
3	<i>Kioeaa**</i>		1.5	S. of Hakipuu Stream, destroyed after 1882.	
4	Kahalu'u	Kahouna	26.6	Wall broken & repaired in 1960's; well preserved.	X
5	<i>Fong's**</i>	unknown	0.6	Small pond now altered & part of a residence.	
6	Pokole		4.0	Filled for housing 1946-48 (Miomio Loop).	
7	He'eia		89.2	NW wall alignment altered early 1900's; large break in SE wall 1965; mangrove invading wall.	X
8	<i>Nauka**</i>		1.0	Filled early 1900's (natural?); assumed destroyed.	
9	<i>Mahi**</i>		1.5	Filled for housing 1961-64 (Nana Place).	
10	Oohohe		4.5	Filled for housing 1964-69 (Na Kao Place).	
11	Kaea		0.3	Tiny pond destroyed in early 1900's.	
12	Kalokohanahou	unknown	14.1	Filled for housing 1947 (Ka-hanahou Circle).	
13	Kanohului'wi		2.7	Unaltered except for adjoining marina.	X
14	Waikapoki		6.7	Wall broken 1920's; converted to marina 1950's.	
15	<i>Kaheau**</i>		2.0	Partly destroyed 1920's; artificially filled 1946-48.	
16	Punaluu		12.5	Filled for housing 1946-48 (Mahalani Circle).	
17	Waikalua	Waikalualoko	13.4	Stream delta 1928; rebuilt in early 1930's.	X
18	Waikaluwaho	Waikalaa	3.5	Once part of Keana; remnant at Kawa estuary.	

(continued on next page)

\*Acreage is approximate and from numerous sources, including Cobb (1902), and estimates based on planimeter measurement of maps and aerial photographs. Earliest and largest figures are cited.

\*\*Italicized fishpond names are substitutes for unnamed ponds. The first five are names of landowners adjacent to the ponds; Panaha'a is a small land division in Kane'ohe ahupua'a.

Table 3. Walled Fishponds in 19th Century Kane'ohe Bay (continued)

NO	POPULAR NAME	OLDER VARIANT	ACRES*	COMMENTS	SURVIVING PONDS 1992
19	Keana	Loko Keana	2.0	Once included 18; artificially filled in 1950's.	
20	Mikiola		11.0	Filled for housing 1946-48 (Mikiola Drive).	
21	Kapuu	Kaluoa	3.2	Filled for housing 1946-48 (Mikiola Drive).	
22	Mahinui		7.4	Artificially filled 1946-48.	
23	Keaalau		2.1	Filled for housing 1946-48 (Nohokai Place).	
24	Hanalua		1.6	Artificially filled 1946-48? (Kane'ohe Yacht Club).	
25	Papaa		2.0	Wall cut 1940's; vegetation covers remnant.	
26	<i>Panahaha 1</i> **		2.0	Wall remnant 1940's; since filled (accretion).	
27	<i>Panahaha 2</i> **		215.0	Filled by natural accretion since early 1900's.	
28	Nu'upia Ponds	(Kaluapuhi)	92.0	Modified 1940's and recently; total now 180 acres.	X
29	Halekou		92.0	Extensively filled 1940's; 36 acres in parts.	X
30	Kaluapuhi		24.0	Originally included in N'upia with 297 acres; now 14 acres. u <sup>^</sup>	X

\*Acreage is approximate and from numerous sources, including Cobb (1902), and estimates based on planimeter measurement of maps and aerial photographs. Earliest and largest figures are cited.

\*\*Italicized fishpond names are substitutes for unnamed ponds. The first five are names of landowners adjacent to the ponds; Panahaha is a small land division in Kane'ohe *ahupua'a*.

\*\*\*Nu'upia can be further subdivided into 6 separate ponds as described elsewhere in this report.



## EVALUATION OF EXISTING FISHPONDS

Recently, the State government sponsored a comprehensive evaluation of all remaining fishponds in the State of Hawai'i (DHM, Inc, 1989), including classification and recommendations for each pond (see Appendix for excerpts covering Kane'ohe ponds). For the most part, we follow the recommendations listed for the Kane'ohe Bay ponds evaluated, with a couple of exceptions.

### Mangroves

Mangroves, introduced to Hawai'i at the turn of the century, have invaded many fishponds, slowly converting open water habitat into vegetated marine swamps. Although true that mangrove growth has undermined or modified the structure of walls and choked off water circulation through the gates of many fishponds, mangroves also afford pond walls protection from natural hazards such as shoreline erosion and wave action. In addition, mangroves improve habitat for shellfish such as mangrove crab (called Samoan crab in Hawai'i). The leaf fall and litter are food for other shellfish and finfish. Mangroves provide hiding places for juvenile fish and roosting areas for waterbirds and seabirds, whose guano deposits serve as natural fertilizers for fishponds. Contrary to popular opinion, the spread of mangroves can be easily controlled through periodic cutting. The existence of healthy mangroves elsewhere in a pond are construed as assets - not liabilities in promoting mariculture and wildlife use. Therefore, we do not perceive mangroves as a nuisance, other than the need to clear them from *makaha* and other openings. Except for the clearing of fishpond gates and channels, mangrove removal is not advocated for any of the fishponds addressed in this plan.

### Sediments

Some past studies consider sedimentation or sediment accumulation in ponds a hindrance to viable mariculture potential. Our review and discussion with existing pond managers indicate that the impact of sedimentation has been exaggerated with respect to the Kane'ohe fishponds. Although sediment has accumulated in some ponds, tidal fluctuations and the maintenance of clear openings through gates generally prevents sediment buildup above the low tide level. The active working of a pond for maricultural use tends to resuspend and remove excess fine sediments. George Uyemura (pers. comm.) estimates up to 10 inches of sediment can be removed from a fully operational pond due to the movement of fish, nets, wading and walking, and the restoration of circulation. None of the Kane'ohe ponds need to have sediments removed via mechanical means except for perhaps some small scale excavation near gates. Therefore, neither removal of sediments nor

mangroves is considered an obstacle to immediate pond mariculture restoration and operations.

### **Kane'ohe Bay Fishponds**

The six remaining fishponds inside Kane'ohe Bay (excluding Mokapu) from north to south are: Mokoli'i, Moli'i, Kahouna (Kahalu'u), He'eia, Kanohulu'iwi, and Waikalua.

#### Mokoli'i

Mokoli'i, previously a shoreline pond, is now inland from the shoreline in Kualoa Regional Park. Years of beach erosion along the eastern face of the park, and sand accretion along parts of the southern face have essentially blocked off Mokoli'i, and converted it into wetland habitat, now important for endangered Hawaiian waterbirds. It is presently fenced off and managed as a wildlife refuge in the Regional Park, and is no longer suitable for mariculture. We recommend no further restoration to the pond, or changes to its existing uses for wildlife protection and public education.

#### Moli'i

Moli'i is the only functioning Hawaiian fishpond still in commercial operation in Kane'ohe Bay. Consultations with the long term operator of the pond indicate that no restoration work is needed. Although subject to mangrove colonization and sedimentation over the years, the present operator considers these processes beneficial to the ongoing mariculture operation. We recommend no further restoration or changes to its existing use for mariculture production.

#### Kahouna (Kahalu'u)

Until recently, Kahouna was in active use for fish production. The pond remains in excellent condition, and the owner is still interested in resuming maricultural use. Thus, we make no further recommendations, except to help restore fish production in the pond.

#### He'eia

He'eia has been used on and off in recent years for *limu* growing and shellfish harvesting. Mangroves have colonized the innermost portions of the pond and protect the pond walls. However, during a major flood in 1965, He'eia stream overflowed its banks, causing a breach in the outermost section of the wall. Tidal flow through the breach has scoured out a channel up to 10 feet deep. The wall will need to be rebuilt over the breach to close off the pond and allow resumption of mariculture and fish production. The pond's large size and variable habitat, including mangroves and mudflats, suggest excellent

potential for restoration and mariculture operation. Heavy equipment, however, may be needed to restore the wall. The present lessee, Mark Brooks, is actively planning the restoration and use of the pond for mariculture. We support these efforts and recommend restoration of the wall and gates (*makaha*).

#### Kanohulu'iwi

Kanohulu'iwi is in excellent condition and capable of supporting fish production. At present, there are no mariculture operations. We have not been able to contact the new owner. We recommend the pond be retained for mariculture, and economic incentives provided to stimulate resumption of these operations. Water quality analyses of its sediments is warranted to determine pollution levels and potential for fish/shellfish contamination, since this pond is located in the more urbanized and polluted section of the Bay.

#### Waikalua

Also in excellent condition, Waikalua is capable of supporting mariculture but has fallen into disrepair. The present owner earlier proposed that the pond serve as a sedimentation basin, but recently expressed interest in maricultural use. The gates need to be restored. The Land Use Committee of the Kane'ohe Bay Task Force (1992) prepared a park plan for the fishpond and surrounding lands at the "Bayview" confluence of Kane'ohe and Kawa streams (see Map 5 of the Kane'ohe Bay Master Plan). We support the multiple, cultural, and park uses proposed in that Plan and further recommend water quality and tissue sampling to determine pollution and contamination levels in fish and shellfish.

#### **Mokapu Fishponds**

On August 29, 1991, the Kane'ohe Bay Task Force passed two resolutions recommending action to be taken with regard to the Nu'upia fishponds, currently located within the boundary of the Marine Corps Air Station, Kane'ohe Bay (KMCAS). The purpose of this meeting was to make decisions regarding fishing within Kane'ohe Bay and there was much public interest and input in the proceedings. Many fishermen were upset with a possible ban on gill net fishing, and some Hawaiians were concerned with loss of ancestral fishing grounds. The State Division of Aquatic Resources presented much information, including evidence of an apparent decline in fish catches. A previous report (DHM, Inc. 1989) on Hawaiian fishponds demonstrated the productive potential of the few ponds remaining, and indicated growing community support in restoring such valuable cultural treasures. After much

discussion, and a presentation by the representative from KMCAS, both resolutions passed unanimously.

The first recommendation was to restock Kane'ohe Bay with mullet, *moi*, and *awa*, using a combination of the small, State owned ponds at Hakipuu and Coconut Island, and Nu'upia 'Ekahi Hawaiian fishpond for nurseries, broodstock, and a community project involving fishermen and youth to restore Nu'upia to production and benefit future generations. One participant was heard to say that this was the only action taken by the Task Force that would actually put food on the table. This measure appeared to have overwhelming support from all concerned, and was passed unanimously. The recommendations are also compatible with the Aecos 1983 report (p. 78), prepared for the U.S. Fish and Wildlife Service. Information was given regarding a stock enhancement program of the Oceanic Institute, which is already restocking smaller amounts of juvenile mullet in Hilo Bay, and several spots in east O'ahu. Legislation supported by the Institute, fishpond owners, operators, the Hawai'i Institute of Marine Biology (HIMB), the Office of Hawaiian Affairs (OHA), Hawaiian community groups, and the State Aquaculture Development Program would promote maricultural use of some Mokapu fishponds (Senate Bill 1666 and House Bill 1848).

The second recommendation was to ask the federal government to return the Nu'upia ponds to the Hawaiian people, care of OHA, as they are ceded lands. Two recurring problems expressed to the Kane'ohe Bay Task Force which probably contributed to this recommendation were: 1) the lack of public access and the use of the shoreline at Mokapu and Kane'ohe Bay, and 2) lack of accessible Hawaiian sites in such a historically important region. Much of the shoreline along Kane'ohe Bay belongs to private interest, denying public access to the Bay. With so much discussion over tourism and commercial recreation elsewhere in Hawai'i and Kane'ohe Bay, many local people feel squeezed out. The disappearance of the unique Hawaiian fishponds is especially damaging to the Hawaiian culture, which prides itself on *aloha aina* and the sharing of food. Some people consider the KMCAS use of ponds as a training and maneuver area to be inappropriate. Use of some ponds as a bird sanctuary is entirely compatible with Hawaiian mariculture management, and the endangered Hawaiian stilt would probably flourish if their major food supply (small fish) are allowed to be reintroduced. This is an appropriate time for the federal government to rectify some of the problems of the Hawaiian people caused by annexation and subsequent U.S. military takeover of many culturally important areas (including Mokapu). The transfer of the Nu'upia Ponds to Hawaiian jurisdiction could be a tremendous step in rectifying some of the previous injustices of the federal government.

Next year is the 100th anniversary of the overthrow of Queen Liliuokalani, and pond transfer would be symbolic, timely and significant.

The most recent information on the Nu'upia ponds is contained in the 1983 and 1985 reports by Aecos, Inc. These reports evaluate the hydrological patterns and water quality, and include several important observations and recommendations, referring both to mariculture and wildlife habitat. Quoting directly from the Aecos, 1983 report:

"The best area to cultivate baitfish would be Nu'upia 'Ekahi Pond, as it has the best access and a readily available source of seawater.

... The utilization of some portion of the Nu'upia Ponds for a recreational fishery has greater potential for benefits than does aquaculture. The establishment of a recreational fishery is not predicated upon the control of either the mangrove or tilapia populations, or on major alterations in the pond structures. Indeed, the fishery could be adapted to or moved at will to any desired location. Fishes of potential interest to fishermen, known to occur in the ponds, include barracuda (Sphyraena barracuda), mullet (Mugil cephalus), *awa'awa* (Elops hawaiiensis), and milkfish (Chanos chanos). A few other species found in Kane'ohe Bay probably occur also in Nu'upia 'Ekahi Pond. *Aholehole* (Kuhlia sandvicensis) were reported [Division of Aquatic Resources]. Exceptionally large barracuda can be observed on a flooding tide around the culverts connecting Nu'upia 'Ekahi and Kane'ohe Bay, although the numbers of those fish are probably not large.

... At present, the best area for a recreational fishery would be Nu'upia 'Ekahi Pond. This pond appears to be infrequently utilized by any of the waterbirds common to the Nu'upia Complex. The close proximity of H-3 freeway may be a source of disturbance inhibiting utilization by waterbirds of this area. Thus, use of Nu'upia 'Ekahi for recreational purposes should not reduce nesting or feeding capacity of the wildlife management area, particularly if fishing activity were restricted to the western margin of the pond. Access to this area could be readily facilitated without impinging on sensitive areas of the refuge by providing foot access (essentially by adding a gate) from the KMCAS Main Gate area. Restricting access to other parts of the refuge could be achieved by minor additions to the existing fence system. Heleloa Pond could also be included in the fishing area, although practically, a pier or footbridge would have to be constructed to provide access through the mangroves.

... Inasmuch as stilt (as well as other important waterbirds) feed on small minnows, the presence of tilapia has been viewed as a benign development by avian biologists, assuming that the fish constituted a potential food source. However, the possibility that tilapia are serious competitors with endangered waterbirds for other food items in the aquatic habitat is a possibility if their availability as prey is overestimated. The smaller tilapia are probably the best food source for the Hawaiian stilt. However, the smallest fish (i.e., less than one gram) are probably not utilized as a food source because tilapia are mouthbrooders, a behavior which protects the fry from predation. Juveniles larger than 25 to 50 grams are probably too large to be consumed by most of the endangered waterbirds, but would attract numbers of herons. Thus, probably only tilapia in the range of 1 to 25 grams weight are utilized by stilt as a food item. Either the indigenous fishes once common in Hawaiian brackish water environments (such as *nehu*, milkfish, and fry), or exotic top minnows are probably better food items for endangered waterbirds, but their existence in estuarine and hyperhaline environments is threatened by the tilapia populations. The presence of large tilapia populations in Hawaiian wetlands may result in the shunting of energy inputs into fish that cannot be utilized by the waterfowl.

Management plans for the Nu'upia Ponds might well include the elimination of tilapia and/or all fish from some of the ponds so as to help assess the impact of the tilapia populations. A thorough study of the food web utilized by the endangered Hawaiian waterbirds would be useful in future management of all Hawaiian waterbird sanctuaries.

#### Demonstration and Observation

There is always some interest on the part of the public and educational institutions in access to wildlife areas. Existing access to some parts of the wildlife management area is presently good for military personnel, and arrangements are regularly scheduled for non-military groups. Consideration might be given to opening the mangrove areas of Nu'upia 'Ekahi and/or Heleloa ponds for educational purposes, should this area also become open to fishing.

#### WILDLIFE MANAGEMENT

At the present time, the Nu'upia wildlife management area is intended to benefit primarily the endangered Hawaiian stilt (*Himantopus mexicanus knudseni*), and is one of the major nesting and feeding areas on O'ahu for this species. Considering size alone, the Nu'upia Ponds should provide substantial habitat to support large populations of

waterbirds. Although attempts have been made to increase the suitability of nesting and feeding habitats for endangered waterbirds, population increases have not occurred (Ahuimanu Productions, 1977). A 1970 management plan for the pond complex is presently being updated by USFWS for KMCAS. The suggestions provided herein are intended to indicate the range of options open to managers of the wildlife management area. Although emphasis is placed on maintaining an environment of benefit to the Hawaiian stilt, other potential uses of the ponds (including sewage effluent disposal, aquaculture, recreational fishing, scientific research, and demonstration and observation) are discussed.

... The earliest counts of avian species at Nu'upia in 1947 recorded more than 400 Hawaiian stilt. The numbers of stilt have fluctuated radically over the years, but have not since reached even the [smaller] Hawai'i Audubon Society count of 127 stilt recorded in 1947. Counts taken during the last 30 years indicate that the stilt population at Nu'upia averages 45 to 50 birds, which would be about 3% of the estimated populations of the subspecies (Hawaiian Waterbird Recovery Plan, 1977). Hawaiian coot (Fulica americana alai), and the Hawaiian gallinule (Gallinula chloropus sandvicensis) were recorded from the ponds prior to 1957, but have not been seen there since. Migratory Pintail ducks, at one time abundant in the ponds, disappeared the same year as the coot and gallinule (Ahuimanu Productions, 1977)."

The eight Nu'upia Ponds consist of: the western ponds of 'Ekahi, Elua, Heleloa, and Halekou, the eastern ponds of 'Eha, Kaluapuhi, and Pa'akai, and the largest pond Nu'upia Ekolu in the center. These three groups have similarities created by both manmade and natural factors.

The eastern group is primary habitat for the Hawaiian stilt, an endangered species. Efforts to create artificial nesting areas have centered in these three ponds. The large, long *makaha* leading to Kailua Bay is slowly falling into disrepair, and its channel needs to be dug out periodically. The lack of tidal flow is the primary cause of the high salinity of these ponds as evidenced by the name Pa'akai (salt). Repair of the well-engineered, ancient *makaha* is relatively simple, and could be accomplished by a volunteer Hawaiian working weekends in conjunction with the Marines. Restoration of the canal and installation of a control structure would allow water and salinity levels in the ponds to be manipulated for the benefit of the wildlife. However, because this is the main home for the Hawaiian stilt, any restoration in this area should come later, after further analysis and advice from Hawaiian *kupuna*, the State DLNR, and the USFWS. The increase in the

Hawaiian stilt's natural food source should stimulate a corresponding increase in their population. Access to this area should be generally off limits during nesting season, and well supervised at all times.

### Nu'upia 'Ekahi

As recommended by the Kane'ohe Bay Task Force, Nu'upia 'Ekahi should be the starting point towards revitalization of the whole pond complex. After coordinating work schedules and satisfying security arrangements with the KMCAS, the next step should be to install gates in the *makaha* recently built into the culverts emptying into Kane'ohe Bay. The *makaha* into Halekou and Elua, along with any breaks in the walls, should be screened off with small mesh wire. Once the perimeter of 'Ekahi is relatively secure, the tilapia and barracuda should be harvested with a series of large to small eye nets, using the traditional Hawaiian *pai* method.

The installation of portable net pens, perhaps provided by Oceanic Institute, in the south end of 'Ekahi, could begin immediately. Access and security arrangements with the KMCAS should consider the installation of a gate in this area. However, this is not absolutely necessary, if a small parking lot with an information board for the general public is provided adjacent to the pond at higher elevation near Bayview Drive.

While the previously listed procedures are being accomplished, the grow-out of juvenile mullet, *awa*, and *moi*, should begin. Once the perimeter is secure, and the predator/competitor population is removed, the broodstock could be released into 'Ekahi, to begin their natural breeding cycle. The technology is already in place for controlled spawning in large numbers of both mullet and *awa*, at the Oceanic Institute hatchery. During the spawning season, the broodstock would be corralled into a net pen to select the best mates.

Once the juvenile fish reach 3 inches in length, they will be released into 'Ekahi to feed on their natural foods until reaching 6", when they will be distributed by use of *makaha* and trucked to appropriate sites throughout the Bay. *Moi* would be managed in separate enclosures.

Heleloa (taken from the <sup>recommendations</sup> description in Aecos, 1983; pp 55-56)

No maricultural use is recommended because of poor drainage. We recommend restoration of the pond for a possible wildlife refuge or recreational fishing.

Halekou (taken from Aecos, 1983; p 59)

We recommend repair of the broken fill between the drainage canal and the north end of the canal, and the clearing of mangrove around culvert #7. We



recommend an increase in the height of the wall between Ekolu and Elua, and the repair and rebuilding of the *makaha*. We also recommend the clearing of mangroves from the gate areas.

#### Elua

We recommend the clearing of mangroves blocking culverts and *makaha* to 'Ekahi, Halekou, and Ekolu. We also recommend the repair and rebuilding of the wall between Ekolu and Halekou and the rebuilding of the *makaha*. 3 to 'Ekahi, 2 to Halekou, and 2 to Ekolu.

#### Ekolu

We recommend clearing the two culverts leading into 'Eha, and controlling the salinity of the pond by clearing the *makaha*, especially the Kailua *makaha*.

#### 'Eha (Aecos, 1983; p 75)

We recommend clearing and repairing culverts number 1 to Kaluapuhi, and 2 to Ekolu.

#### Kaluapuhi (Aecos, 1983; p 83)

We recommend clearing the culvert.

#### Pa'akai

We recommend clearing the Kailua channel and installing a water control structure for wildlife management.

The eastern ponds and Ekolu should remain a bird sanctuary for the Hawaiian stilt, with eventual removal of tilapia and barracuda, and reintroduction of mullet and *awa* after *makaha* repairs.

We believe that the above plan for the fishponds is capable of fulfilling the recommendations of the Kane'ohe Bay Master Plan, and would accommodate the various needs of the windward community, including KMCAS, the Hawaiians, the fishermen, our youth, and endangered Hawaiian waterbirds. Protecting our environment should be every citizen's responsibility, with the assistance of appropriate government agencies. The Nu'upia plan is a unique opportunity for different groups to work together towards these common goals:

- 1) revitalize our depleted fisheries,
- 2) restore Hawaiian fishponds,
- 3) increase Hawaiian stilt populations, and
- 4) provide a food and cultural resource center for future generations.

### **GENERAL RECOMMENDATIONS**

Implementation of the above plans for each fishpond will require changes in the way that government views and controls the activities required for fishpond restoration and operation. In addition, technical assistance is needed for the planning, design, and regulatory approval to accomplish the recommendations. The outlook for reestablishing functioning Hawaiian fishponds looks bright, provided there is cooperation among land owners/managers, tolerance of alternative viewpoints, and a willingness to base decisions on facts and accurate data. It is a consensus among us that restoration of fishponds for use as fishponds should take precedence over restoration for alternative functions and uses, consistent with retention of historic characteristics and values, and established wildlife habitat functions. We also realize that Hawaiian fishponds have also taken on more importance as wildlife habitats for endangered Hawaiian waterbirds, a consequence of wetland habitat degradation during the past century, primarily by non-Hawaiians. We also believe that mariculture and wildlife use of individual ponds are fully compatible. We strongly believe that the four ponds now serving as important habitat for endangered waterbirds should be retained as such. We have evaluated the remaining ten ponds and determined that two are suitable for wildlife and eight are suitable for mariculture development, demonstration, and education (see Table 1). We consider the following general recommendations essential steps in fulfilling the goals of this fishpond plan:

Simplify the bureaucratic and regulatory procedures to accomplish restoration of fishponds. Several recent evaluations of fishponds in Hawai'i have pointed out that regulatory and other government approval procedures are the principal impediments to fishpond restoration (DHM, Inc., 1989; Oceanic Institute, 1977; Hawaiian Fishpond Revitalization Project, 1991). We agree with these opinions. Therefore, we recommend that the regulatory and bureaucratic burden be relieved through the following action:

- 1) Convene a working group among government regulators to develop a set of acceptable design standards, construction materials, and techniques to restore the structural integrity of Hawaiian fishponds, focusing initially on Kane'ohe ponds.
- 2) Convene workshops to educate fishpond owners, managers, operators, and regulators about the new design standards and techniques.
- 3) Request the U.S. Army Corps of Engineers, in cooperation with the State Dept. of Land and Natural Resources, to establish a general (regional)

permit for Kane'ohe fishponds that will specify the requirements to allow fishpond restoration and operation with minimal government oversight.

4) The general permit should identify the "candidate" fishponds for simple repair actions, as opposed to other fishponds which may require more elaborate rebuilding. We believe all of the Kane'ohe ponds qualify for the "repair" category.

5) The general permit should also identify "candidate" fishponds for historical, cultural, and educational use. These are not necessarily different from the fishponds in the previous recommendation.

6) Establish an authority or clearinghouse to facilitate fishpond restoration actions including funding. For Kane'ohe ponds, this authority should be the proposed Kane'ohe Bay Regional Council.

7) Develop the legislative agenda and administrative directives necessary to implement the recommendations.

8) Support physico-chemical and biological monitoring of all fishponds proposed for mariculture and wildlife use, to protect public health and ecosystem health.

9) Investigate incentives to encourage fishpond restoration and utilization, including zoning, property tax, income tax, and grants-in-aid initiatives (see Kane'ohe Bay Master Plan, 1992; recommendations #150-167).

## RECAP OF POND-SPECIFIC RECOMMENDATIONS

Dredging to remove sediments and mangroves. We do not believe that dredging or removal of mangroves is required for any of the Kane'ohe fishponds, except at gates and intakes (*makaha*) to improve tidal flushing. All remaining fishponds appear to be deep enough.

Mangrove control. We believe that mangroves benefit fishponds by protecting walls from erosion, inhibiting access by poachers, providing organics and nutrients to fish populations, and indirectly contributing fertilizers to the ponds via seabirds and waterbirds that roost on mangroves. Spreading of mangroves can be controlled through manual cutting and thinning carried out on a periodic but regular basis.

Fishpond wall repairs. We recommend that fishpond walls be rebuilt in several of the ponds, including the seaward section of He'eia pond, and the walls between Halekou, Nu'upia Ekolu, and Nu'upia Elua.

Cleaning of culverts and *makaha*. Clear the culverts, gates, and *makaha* at Halekou, between Nu'upia Elua, Nu'upia Ekolu, Nu'upia 'Ekahi, and Halekou; between Nu'upia 'Eha and Kaluapuhi and Elolu; and along Kaluapuhi.

Clearing of channel. The channel between Pa'akai and Kailua Bay needs to be periodically cleared in order to adjust water levels and salinity for wildlife in the pond. It may be possible to install a water control structure in the channel to effect better control over water flow, sedimentation, and salinity.

Predator control. Using small eye nets, remove predatory fish (barracuda, white mullet) and other competitors (tilapia) from ponds designated for mariculture production.

Portable enclosures and net pens. Install screened or netted enclosures for rearing of fry in selected ponds (including Nu'upia 'Ekahi).

Sequence for Nu'upia pond restoration and revitalization. Efforts should be initiated first in the western most pond (Nu'upia 'Ekahi), and then work eastward to restore or improve the 7 remaining ponds for either wildlife, mariculture, or both, as elaborated earlier.

Demonstration and education. Mariculture demonstration and education should be focused in Waikalua, Nu'upia 'Ekahi, and possibly He'eia (the last depending on the specific desires of the landowner and lessee).

Broodstock. Parts of Nu'upia 'Ekahi should be restored for broodstock rearing.

Security and access. Take actions necessary to improve access to Nu'upia 'Ekahi, other fishponds in the Nu'upia complex, and to Waikalua for training, demonstration, and educational purposes.

Historic Preservation. The restoration of all ponds should be accomplished in a manner to retain the historic integrity, in terms of both appearance and functional use. The latter may require some incorporation of acceptable modifications to modernize *makaha* and other structures that would benefit from the use of concrete, wire screens, etc.

## REFERENCES

- Aecos, Inc. 1983. Hydrological patterns and water quality of the Nu'upia Ponds, Marine Corps Air Station, Kaneohe Bay, Island of O'ahu, Hawai'i. Prep for U.S. Fish and Wildlife Service. Rep. No. Aecos-374.
- Ahuimanu Productions, 1977. Ornithological survey of Hawaiian wetlands. Prepared by R. J. Shallenberger for the U. S. Army Corps of Engineers, Pacific Ocean Division, Honolulu.
- Apple, R. A. and W. K. Kikuchi, 1975. Ancient Hawaiian Shore Zone Fishponds: An evaluation of survivors for historic preservation. National Park Service, U. S. Dept. of Interior. 157 pp.
- Cobb, J. N. 1902. Commercial fisheries of the Hawaiian Islands. Report, U. S. Fish and Fisheries Commission for 1901. Wash. D. C., U. S. Gov't. Printing Office.
- DHM, Inc. 1989. Hawaiian Fishpond Study, Islands of O'ahu, Moloka'i, and Hawai'i. Prep. by DHM Planners, Inc. and Public Archaeology Section, B. P. Bishop Museum, for the State of Hawai'i.
- Devaney, D. M, M. Kelly. P. J. Lee, and L. S. Motteler, 1976. Kaneohe, A History of Change. Prep. by the B. P. Bishop Museum for the U. S. Army Corps of Engineers, Pacific Ocean Division. (reprinted in 1982 by the Bishop Museum).
- Fishponds Subcommittee, 1991. Kaneohe Fishponds. Kaneohe Bay Task Force.
- Hawaiian Fishpond Revitalization Project, 1991. Physical restoration of Hawaiian fishponds - problems and issues: Proc. of Symp. of Sept. 19-20, 1991, at Hana, Maui. Maui Econ. Dev. Bd. and Oceanic Institute.
- Hiatt, R.W. 1947. Food Chains and the Food Cycle in Hawaiian Fishponds. Part 1: The food and feeding habits of mullet... milkfish... and ten-pounder...; Part 2: Biotic interaction. Transactions American Fisheries Soc. 74:250-280.
- Kamakau, S. M. 1976. Na Hana a ka Po'e kahiko: works of the people of old. From newspaper articles written by Kamakau 1868-70. Translated by Mary Pukui; arranged and edited by Dorothy Barrere. Bishop Mus. Spec. Publ. 61. Honolulu.
- Kane'ohe Bay Master Planning Task Force, 1992. Kane'ohe Bay Master Plan, Prep. for the Office of State Planning, Hawai'i State Government, Honolulu.
- Kelly, M. 1975. Loko I'a O He'eia: He'eia Fishpond. Dept. of Anthropology Rept. 75-2. Honolulu: B. P. Bishop Museum. Honolulu.
- Kikuchi, W. K. 1976. Prehistoric Hawaiian Fishponds. Science 193:295-299.
- Malone, T. C. 1969. Primary productivity in a Hawaiian fishpond and its relationship to selected environmental factors. Pacific Sci. 23(1):26-34.
- McAllister, J. G. 1933. Archaeology of O'ahu. B. P. Bishop Mus. Bull. 104.

Honolulu.

- Norris, K. S. and J. J. Crouch. 1972. Refurbishing a Hawaiian fishpond. Oceanic Institute Report 1-72-78-1. Prep. for the National Sea Grant Committee, pp 23-40.
- Oceanic Institute, 1977. The potential for mullet and milkfish culture in Hawaiian Fishponds. Prepared by W. D. Madden and C. L. Paulsen for the State of Hawai'i Dept. of Planning and Economic Development. 54 pp.
- Summers, C. C. 1964. Hawaiian Fishponds. B. P Bishop Museum Special Publications 52:26 pp.
- Summers, C. 1971. Moloka'i: A Site Survey. Pacific Anthropological Records 14. Dept. Anthropology, B. P. Bishop Mus. Honolulu.
- U.S. Fish and Wildlife Service, 1977. Hawaiian Waterbird Recovery Plan. Honolulu.

## GLOSSARY OF HAWAIIAN TERMS

āholehole - *flaetail fish* *sub-district*

ahupua'a - *Land division*, usually extending from the mountains to the sea.

'āina - *Meal* *Land*

akua - God, goddess, spirit, image, *idol*; divine, supernatural, godly.

'anae - Full sized 'ama'ama mullet fish.

'aumakua - Family or personal god.

awa - Milkfish.

*awa'awa* →

hina'i - A kind of basket fish trap.

iwilei - Measure of length (yard).

kahuna - Priest, minister, sorcerer, expert in any profession; to act as priest or expert.

kala - *Sturgeonfish*.

kama'āina - Native born; host; native plant; familiar.

kini - Multitude, many; forty thousand.

kuapā - Wall of a fishpond.

*kupuna*

lā haku - Landholder's day.

lau - Very many, numerous; four hundred.

limu - General name for all kinds of plants living under water, both fresh and salt; also algae growing in any damp place.

loko kuapā - A fishpond of littoral water whose side or sides facing the sea consist of a stone or coral wall usually containing one or more sluice gates.

mākāhā - Grates or gates connecting a fishpond to the sea or fresh water supply, which retain the fish.

makai - Towards the sea.

manō - Many, numerous; four thousand.

mauka - Towards the mountains.

moi - Threadfin fish.

pai - To rouse, encourage, clap.

*pai or pali (?)*

pa'akai - salt

*glottal stops should be thus: ' , not ' . Ahupua'a,*

*Jim Maragos at E-W Center  
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