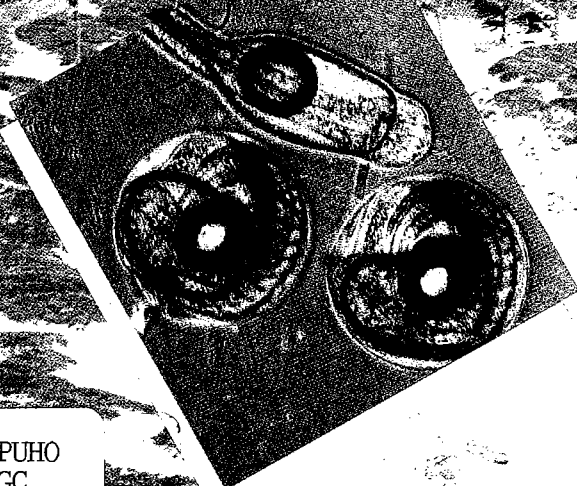
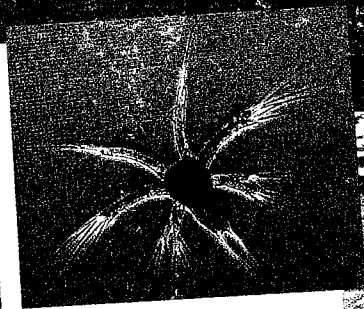


EVALUATION OF ANCHIALINE FISHPONDS
HELE 'I PALALA AT PU'UHONUA O HONAUNAU
NATIONAL HISTORICAL PARK
HONAUNAU, HAWAII



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From the Oceanic Institute
Waimanalo, Hawaii

**EVALUATION OF ANCHIALINE FISHPONDS
HELE 'I PALALA AT PU'UHONUA O HONAUNAU
NATIONAL HISTORICAL PARK
HONAUNAU, HAWAII**

By

**The Students And Staff Of The Oceanic
Institute's Summer Aquaculture Workshop**

For

**The National Park Service
Pu'uhonua O Honaunau National Historical Park**

August 25, 1992

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EXECUTIVE SUMMARY

Hands-on learning has always been a big part of The Oceanic Institute's summer aquaculture workshops and the 1992 sessions were no exception. Now in its third year, the Academically Gifted and Talented (AGT) Aquaculture workshops enrich education for native Hawaiian children and their teachers by carrying out innovative aquaculture projects.

One of the new activities in 1992 was the completion of the fishpond biophysical inventory and assessment for Pu'u Honua O Honaunau Historical Park. The purpose of the study, which was conducted entirely by workshop participants, is to provide the National park with valuable baseline data about two fishponds. The fishponds, once used by Hawaiian ali'i, are currently in a process of degradation due to a variety of alien fish species inhabiting the pond.

The scope of work called into play many of the aquaculture skills the students studied, allowing them to test their knowledge in a "real world" setting. Participants were responsible for carrying out a water quality analysis, including testing for dissolved oxygen, salinity and pH; a biological description, including algae identification and abundance and vertebrate identification and population sampling; and a physical description including anchialine pool characterization, mapping and tidal fluctuation and lapse time.

Based on the findings of this study, the students determined that the overall ecological health of the ponds is poor. They are not a viable habitat for fish traditionally stocked for ali'i because of degraded water quality and competitive tilapia.

The ponds are also important from a biogeographical perspective since no other anchialine ponds are recorded between Kailua-Kona and Milolii. The detrimental effects of alien fish introduction and accelerated sedimentation in anchialine ponds has been documented throughout the Hawaiian Islands.

However, if the ponds are to be cleaned and restored, an alternative to Alii fishponds is to use the deeper pond for aquacultural purposes and allow the shallower pond to remain as a preserved natural habitat. This would allow for recolonization of the shallower pond by native species.

INTRODUCTION

The fishponds at Honaunau are unique coastal features with historic, cultural, and biological significance. The ponds at Honaunau are characterized as anchialine. In the United States, anchialine ponds are geographically limited to Hawaii, with the highest percentage of ponds located along the Kona Coast on the Big Island of Hawaii. Anchialine ponds are a valuable resource and were extensively used by ancient Hawaiians for drinking, cooking, bathing, irrigation, and aquaculture. In addition, anchialine ponds provide critical habitat for a number of endemic organisms having a distinct community structure. Unfortunately, the occurrence of alien fish within the ponds at Honaunau has contributed to the degradation of water quality and the biological integrity of the ponds.

This study is a description and evaluation of the physical, biological, and water quality aspects for the fishponds at Honaunau during the months of June, July, and August 1992. The data collected during this three month period is intended as a baseline for more extensive research in the future. The information provided in this document may be used for future resource management by the National Park Service.

Appreciation is extended to the National Park Staff and Administration at Pu'uhonua O Honaunau National Historical Park for their valuable assistance.

STUDY APPROACH AND METHODS

Two ponds were surveyed for a total of nine days over a three month period; June 16,20 and 23, July 7,11,14, and 16, and August 18 and 20, 1992. Only biological sampling was accomplished on July 16. Pond 1 was more northerly and bordered on the west side (makai) by a man-made stone wall. Pond 2 was shallower but with a larger surface area. Surveys occurred during a.m. and p.m. hours and at various tide levels (see chart below). No nighttime surveys were accomplished.

<u>Tide</u>	<u># of Sampling Periods</u>	<u>Date</u>
Low	1	7/14
Median	5	6/20, 6/23, 7/7, 8/18, 8/20
High	3	6/16, 7/11, 7/16

Four sample points within the two ponds were monitored in the complex known as Hele 'I Palala (see map).

Most of the physical description was accomplished with meter sticks and fiberglass tape. Determination of average water depth and sediment characteristics were conducted along 10 meter transects within each pond.

The physical description includes:

- Mapping
- Pond surface area
- Average water and sediment depth
- Sediment volume and substrate type

A water quality analysis was accomplished in the field using a YSI dissolved oxygen meter, ATAGO refractometer (salinity), ORION pH and temperature meter, HACH spectrophotometer (ammonia, phosphate, nitrate). All samples were taken approximately 10 cm - 15 cm below the water surface. Subsurface water samples were taken from two points (north and south) within each pond.

The analysis includes:

- Dissolved Oxygen (ppm)
- Salinity (ppt)
- pH
- Temperature (°C)
- Ammonia (ppm)
- Phosphate (ppm)
- Nitrate (ppm)

The biological descriptions including a relative abundance determination, were accomplished through visual inspection from the

surface. Motile fauna were classified and counted while nonmotile fauna were sampled using 0.1 m² quadrats along 5 m transects in both ponds.

Included in the survey are:

- Riparian vegetation
- Macro invertebrate identification and abundance
- Vertebrate identification and abundance
- Macro algae identification
- Micro algae classification

Water quality samples were recorded during every survey except on July 16. The first set of graphs produced with the data collected represent monthly averages for each station. The second set of graphs include a.m. and p.m. averages for the recorded parameters at all sampling stations. The biological and physical descriptions were accomplished once in June and August and twice in July. The descriptions presented in this paper represent a composite.

Surveys were accomplished by crews of 10 students and at least 2 staff working together. In total, 30 students gained valuable experience in scientific data collection. Consequently, the techniques and instrument manipulation were not performed by highly trained individuals. Some water quality data may reflect this fact. However, there is minimal error, and the information provided in this document will be useful for management purposes.

Hele'i palala Ponds Honaunau, Hawaii

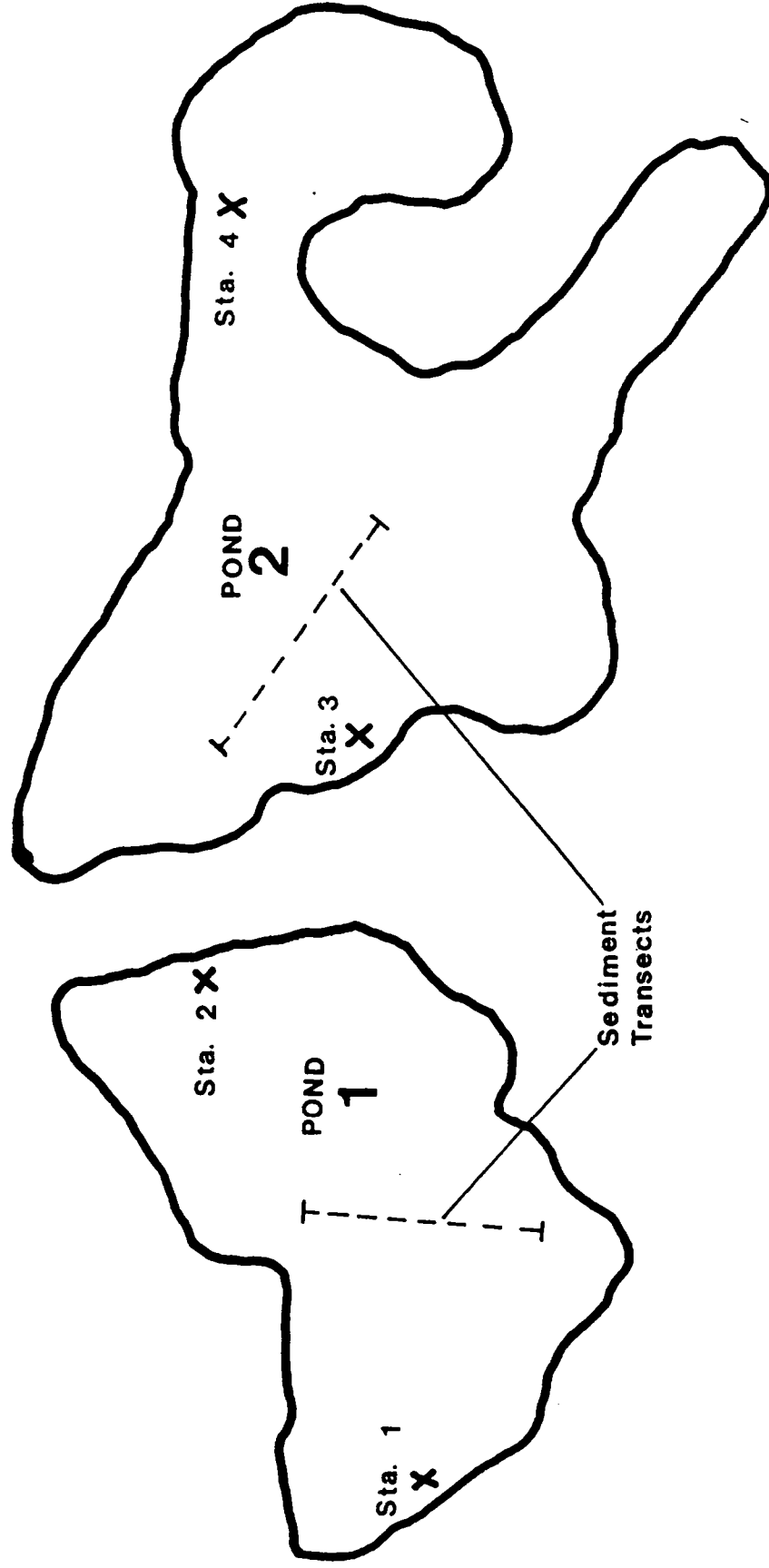


Figure 1.

RESULTS

Physical Description

The ponds can be classified as anchialine, having no surface connection to the sea, yet exhibiting tidal fluctuation and mixohaline water, indicating a subsurface connection. They are physically and structurally similar to other anchialine ponds along the Kona Coast. However, unlike many other ponds of similar age and physical characteristics, they are progressing toward obliteration at a more rapid pace. Typically, the residence time of water in anchialine ponds is on the order of hours and is related to high substratum porosity. The ponds at Honaunau exhibit a much reduced water exchange relative to most other anchialine pools in Kona.

Pond 1

The surface area of this oval shaped pond was approximately 300 m² with an average water depth of 52.2 cm. The average sediment depth throughout the pond was 27.5 cm. Consequently, the total volume of sediment was approximately 82.5 m³.

The sediments are primarily composed of biogenic material near the top while the bottom layer contained calcareous sand deposits.

Evidence exists of poor water exchange because of deep flocculant sediments containing anaerobic decay, high turbidity, and high diel temperature fluctuation. The bottom substrate is a pahoehoe platform with scattered loose rock debris.

During low tide, basal springs or points of increased groundwater influx were noted at two locations on the east (mauka) side of the pond. Indications of these springs were determined by water movement and relatively lower salinity and temperature readings at the source points.

Pond 2

Early archaeological maps (1960's) of pond 2 show it to be much larger, and connected to the shallow pond on the west side (makai) of the Pu'uhonua wall. Observations indicate that even during high (+ 0.6 m) tides, the pond is nearly 15 m from the wall and makai side pond. This may be a result of sediment infilling.

Water surface area in pond 2 was approximately 350 m² with an average water depth of 38.7 cm. Average sediment depth was 13 cm resulting in a total sediment volume of approximately 45.5 m³.

Sediments in this pond were predominantly biogenic with less than 20% soil and sand material. Similar to pond 1, the substrate consisted of a pahoehoe platform with scattered loose rocks. Water exchange was equally poor in this pond, indicated by the same factors existing in pond 1.

Basal springs were also noted at 4 points along the mauka side of the pond (see map).

WATER QUALITY ANALYSIS

The water quality analysis provided good insight into the physical, biological, and chemical processes occurring within the ponds. Anchialine ponds are exposed portions of the groundwater table. The chemical composition of anchialine waters along the Kona Coast are known to exhibit high spatial and temporal variability. A complex array of factors contribute to the extant chemical composition of anchialine ponds. Consequently, there are a number of factors that influence the water quality of ponds on a diurnal and seasonal basis. The greatest physical influences on the ponds at Honaunau during our short-term survey period were tidal fluctuation and degree of seawater-groundwater mixing, solar insolation, and rainfall. In addition, the biological components and interactions exerted considerable influence on the water quality of Honaunau ponds through assimilation and conversion.

Though all anchialine ponds contain individually unique characteristics, several generalities may be made regarding their water quality. Salinity of anchialine water is mixohaline, averaging approximately 7 parts per thousand (ppt) along the Kona coast. In well flushed anchialine ponds the temperatures are relatively cooler than surface seawater, averaging approximately 24-25°C, and the diel range in temperature is seldom greater than 3°C. Dissolved oxygen ranges from 2-4 parts per million (ppm). Dissolved nutrients are relatively higher in anchialine ponds relative to surface seawater. A study by Brock (1988), showed that nitrate, phosphate, and silicate, decreased in anchialine pools with proximity to the shoreline, and that these gradients appear to be relatively stable features (no statistically significant changes through time). This phenomenon is probably caused by the dilution of groundwater with seawater on its movement toward the sea, together with modification due to biological activity in the ponds.

Rainfall occurring within and adjacent to the park directly affects the physical and chemical properties of the pond water. Average monthly rainfall data provided by the Park during the study period was:

May.....	0.19 inches
June.....	0.11 inches
July.....	0.34 inches
August (1 - 20).....	0.11 inches

Results of the water quality analysis are provided in the following table.

Honaunau Water Quality Data
June - August 1992

Date	TIME (hrs)	SAL (ppt)	TEMP (deg C)	pH (units)	DO (ppm)	PO4 (mg/l)	NO3 (mg/l)	NH3-N (mg/l)
STATION 1								
June 16, 1992	1400	13	29.5	8.3	7.0			
June 20, 1992	1500	10	32.7	8.2	6.0	0.8	1.5	>2.5
June 23, 1992	0750	14	26.7	8.3	4.0			
July 7, 1992	1400	10	31.1	8.2	8.2			
July 11, 1992	1400	10	32.0	8.2	7.3			
July 14, 1992	0745	13	26.5	6.8	5.0	1.2	1.0	>2.5
August 18, 1992	0800	12	28.5	8.3	5.0	0.4	1.9	>2.5
August 20, 1992	1400	5	32.0	8.5	10.6			
STATION 2								
June 16, 1992	1400	11	26.9	8.4	7.5			
June 20, 1992	1500	10	33.6	8.4	6.2			
June 23, 1992	0750	13	27.2	8.3	10.0			
July 7, 1992	1400	9	30.6	8.2	10.0			
July 11, 1992	1400	10	31.1	8.2	8.0			
July 14, 1992	0745	12	26.6	7.3	5.3			
August 18, 1992	0800	11	32.6	8.1	4.0			
August 20, 1992	1400	9	31.4	8.5	11.2			
STATION 3								
June 16, 1992	1400	15	29.6	7.7	5.5			
June 20, 1992	1500	11	32.6	8.1	5.5			
June 23, 1992	0750	14	26.7	7.9	3.8			
July 7, 1992	1400	10	31.4	7.8	7.0			
July 11, 1992	1400	13	30.9	7.9	7.1			
July 14, 1992	0745	15	26.5	7.2	3.5			
August 18, 1992	0800	13	27.2	7.7	3.0			
August 20, 1992	1400	10	34.5	8.1	8.2			
STATION 4								
June 16, 1992	1400	14	26.9	7.4	5.5			
June 20, 1992	1500	11	33.0	7.9	5.0	1.2	2.0	>2.5
June 23, 1992	0750	14	26.0	7.8	3.0			
July 7, 1992	1400	10	30.4	7.6	7.0			
July 11, 1992	1400	15	29.5	7.6	7.1			
July 14, 1992	0745	15	26.0	7.2	5.0	>2.5	1.9	>2.5
August 18, 1992	0800	10	26.5	7.5	5.0	0.6	2.8	>2.5
August 20, 1992	1400	10	31.6	7.0	9.2			

TEMPERATURE

Temperatures in both ponds exhibited a general increase between June and August which is typical of the warming season. However, there was a greater diurnal variation in temperature than an average monthly variation. Temperature was also cooler during lower tides due to the mauka influx of low salinity surface groundwater, and slightly warmer at high tide with the infiltration of seawater. In contrast, the adjacent ocean water exhibited a relatively stable temperature reading of 27°C, + or - 0.6°C.

The average range in temperature of 4.6°C between a.m. and p.m. hours is predominantly found in anchialine ponds with poor water exchange. Both ponds sometimes reached temperatures of 33°C - 34°C which is above the tolerance level of 32°C - 33°C for most native fish. The survival of the fish likely depends on the source points of cooler groundwater springs within the ponds.

SALINITY

Salinity values were consistent with other anchialine ponds in Kona. Salinity in pond 1 averaged 9.5 ppt. Salinity in pond 2 averaged 11.0 ppt. Salinities did not exhibit wide fluctuation and were generally lower during low tide and higher at high tide. Diel variation in salinity appears significant, however, the salinity refractometer used was not temperature compensated. Consequently, warmer afternoon temperatures caused the refractometer to indicate lower salinity values than cooler morning temperatures. More notable, was the downward trend in salinity over the three month period. This is probably caused by the increased rainfall during July. The August 18 and 20 sampling was probably affected by the 1.25 inches which fell during August 12, 13 and 14. In addition, basal springs located on the mauka side of both ponds were observed to have progressively greater output and lower salinity over the sampling period.

The ocean salinity was normal, and ranged between 32.0 ppt and 34.0 ppt depending on tide level. Salinity is a limiting factor that determines which organisms may inhabit the ponds. It was surprising to find Moano, Manini, and Mamo in the ponds since they are not usually associated with low salinity estuarian environments. A salinity of 12.0 ppt is the lowest threshold level for most reef fish and rare anchialine crustaceans such as Procaris Hawaiiensis, Caliasmata pholidota, Antecaridina lauensis, and Palaemonella burnsi.

pH

During this study, pH values were the most difficult to interpret. This was due to the inability to measure several factors that influence pH, such as dissolved organic acids. The levels of pH were consistently lower in the morning than the afternoon, except at station 4. The pH was most influenced by phytoplankton which consumes carbon dioxide, and causes the pH to rise. Consequently, as photosynthesis and phytoplankton density increased toward the afternoon, pH levels were elevated. The three month trend indicates that pH levels fell in July and rose again in August except at station 4. This may be attributed to the cloudy and overcast days occurring during both sampling periods in July. The p.m. sampling at station 4 in August is an anomaly, and is probably instrument or user error. pH was generally higher in pond 1 probably due to its greater depth and consequently its greater phytoplankton density.

It was interesting to note that the die-off of several tilapia and mullet corresponded to the drop in pH during the month of July. During this month pH levels were recorded at 6.8 in pond 1 and 7.2 in pond 2. These levels are well below those of other anchialine systems in Kona. The metabolism and physiological processes of aquatic organisms are considerably influenced by pH levels. Low pH levels also increase the toxicity of unionized hydrogen sulfide. Hydrogen sulfide was easily detected by a "rotten egg" smell emanating from the ponds whenever sediments were disturbed. Unfortunately, precise measurement of this toxic gas was not accomplished.

Dissolved Oxygen

Dissolved oxygen (DO) levels within the ponds were most influenced by phytoplankton density, and were always higher in the afternoon due to increased photosynthetic activity. Afternoon levels averaged 7.45 ppm while morning levels averaged 4.5 ppm. An anomalous reading of 10.0 ppm occurred at 7:50 a.m. on June 23, and may be due in part to instrument or user error. DO is a critical limiting factor governing populations of organisms. It is in a state of constant flux, easily influenced by a number of interacting factors. Parameters such as the biological and chemical oxygen demand, should be considered when monitoring DO levels and determining stocking density. In general, DO levels were within tolerable and optimal ranges. On only two occasions, June 23 and August 18, DO levels were recorded at a low of 3.0 ppm. Fish are typically stressed at prolonged levels below 4.0 ppm.

Ammonia and Nitrate

At every sample, ammonia ($\text{NH}_4 + \text{NH}_3$) levels were above the measurable range of our spectrophotometer, being greater than 2.5 ppm. However, the high levels of ammonia detected by our instrument may be erroneous. Final determination of ammonia levels should be made after samples are analyzed by more sophisticated instruments. If the levels are correct then the reef fish are tolerating extremely elevated levels. Prolonged exposure to ammonia above 2.0 ppm will usually kill most reef fish. It is important to note that increasing pH levels increases the toxicity of un-ionized (NH_3) ammonia. The highest pH levels occurred in pond 1 in August (8.5).

Nitrate is the end product of the nitrogen breakdown cycle. Again, the levels detected by our instrument are nearly 2x greater than average Kona groundwater which is 0.8 ppm. Though relatively nontoxic, it will accumulate in anchialine systems with poor water exchange. The high level averaging 1.85 ppm observed in both ponds, is probably derived from allochthonous sources or is possibly a result of the high bioload within the ponds.

Phosphate

Sources of high phosphate levels in anchialine systems are usually derived from landscape fertilization and cesspool leakage. Phosphate levels were detected in Honaunau ponds at nearly 5-10x greater than Kona anchialine pond water at 0.2 ppm. It is not known at this time if fertilizers are applied to plants surrounding the ponds. The phosphate spike that occurred on July 14, which was beyond the measurable range of our spectrophotometer (2.5 ppm), may be related to the relatively high rainfall amount of 0.7 inches on July 12. The phosphate levels existing in the ponds are high compared to other anchialine ponds in Kona that experience allochthonous input, usually from golfcourse and landscape fertilization. The highest measured levels were 0.62 ppm recorded at Waikoloa. (Brock, R. The Waikoloa Anchialine Pond Program Third Status Report. July, 1990. HIMB/Seagrant, University of Hawaii at Manoa). The existing levels of phosphate and other nutrients, together with poor water exchange, contributes to a relatively high phytoplankton density.

Biological Description

The biology of the ponds consists of both native and introduced organisms. The native fish species were either washed into the ponds during high surf, or, as in the case of the alien fish, a result of human introduction. The pond biota is dominated by non-native species of tilapia and minnows. The only typical anchialine species observed are the two mollusks Theodoxus cariosus and Thiara ranifera. Conspicuously absent are the crustaceans common to most anchialine ponds in Kona, such as Halocaridina rubra, Metabetaeus lohena, and Palaemon debilis, and several species of amphipods. The native and non-native fish have apparently disturbed the ecological balance that typically exists in these ponds and continue to degrade the ecosystem. It is known that the fish will directly affect the pond biota through predation and competition. Some anchialine pool experts hypothesize that indirectly, the alien fish initiate a change in the ecological succession of ponds by removing detrital feeders (amphipods and isopods, mollusks), and primary consumers such as Halocaridina rubra, Palaemon debilis, and various zooplankton. Furthermore, nutrients and sediments are added to the ponds through defecation. Subsequently, algae dominate the pond, sedimentation increases, and senescence is accelerated. In addition, minnows and tilapia are extremely hardy, and will continue to complete their lifecycles within the ponds, unlike native marine fishes which must return to the sea for reproduction and larval development.

The neritid shell, Theodoxus cariosus inhabits the hard surface of rocks and feeds on epilithic algae. Increasing sedimentation threatens to cover most of rocks in both ponds, subsequently decreasing available habitat.

The predominant phytoplankton comprising the dense bloom were unidentifiable, though most were single-celled diatoms. Others contained green chloroplast indicating that they were Chlorophytes. It was visually apparent that the algae bloom followed a typical pattern of lower density during the morning and higher density during the afternoon due to increasing photosynthesis. In addition, the absence of sufficient water exchange and high nutrient levels were primary causes of the dense algae bloom occurring in both ponds.

The only observed variation to the biological composition of the ponds occurred on two separate sampling days, 7/11 and 7/16. On these days, a die-off occurred of several tilapia, mullet, and aholehole. Factors related to this could be numerous, and an examination of several dead fish did not reveal any obvious causes. However, poor water quality is a probable contributing factor.

Following is a list of species occurring within ponds 1 and 2. A population count was made and a relative abundance determined.

Abundance Rating: F - few or one
S - several
A - abundant

Species preceded by an asterisk (*) are not native.

POND 1

<u>Group/Taxon</u>	<u>Abundance</u>
CRUSTACEANS	
<u>Metapograpsus thukuhar</u> (crab)	S
unidentified grapsid crab	F
MOLLUSCA	
<u>Theodoxus cariosus</u> (neritid shell)	S
<u>Thiara granifera</u> (spiral shell)	A
FISHES	
<u>Mugil Cephalus</u> (mullet)	F
<u>Kuhlia sandvicensis</u> (aholehole)	F
* <u>Oreochromis mossambicus</u> (tilapia)	A
* <u>Gambusia affinis</u> (guppies)	A

POND 2

CRUSTACEANS	
<u>Ligia</u> sp. (supralittoral isopod)	A
<u>Metapograpsus thukuhar</u>	S
MOLLUSCA	
<u>Theodoxus cariosus</u>	A
<u>Thiara granifera</u>	A
FISHES	
<u>Mugil cephalus</u>	F
<u>Paupeneus multifaciatus</u> (moano)	F
<u>Acanthurus triostegus</u> (manini)	F
<u>Kuhlia sandvicensis</u>	F
<u>Abudefduf abdominalis</u> (mamo)	F
* <u>Gambusia affinis</u>	A
* <u>Oreochromis mossambicus</u>	A

FURTHER RESEARCH NEEDED

In order to establish a more comprehensive understanding of the fishpond ecosystem at Honaunau, a greater number of parameters should be monitored on a seasonal basis. Nearshore marine waters should also be periodically monitored. A monitoring program could provide important information on the human impact to these aquatic systems, in the face of existing and impending development of the area. In addition to the parameters presented in this survey, it is suggested that other important water quality parameters should be monitored. The following list of parameters was formulated by the West Hawaii Coastal Monitoring Task Force entitled "West Hawaii Coastal Monitoring Program, Monitoring Protocol Guidelines," May 1992.

- Chlorophyll a
- Fecal Coliform
- Enterococci
- Total Nitrogen
- Total Phosphorus
- Silicate
- Pre-selected Toxic Pollutants
- Dissolved Organics
- Hydrogen Sulfide

In addition, if sediments are not to be removed, the following parameters should also be measured:

- Grain size
- Total Organic Carbon
- pH
- Redox Potential
- Pre-selected Toxic Pollutants

A water exchange rate should be calculated using a tracer dye before and after any action is taken to restore the ponds.

Biological monitoring should be continued to assess community dynamics and the effects caused by alien fish. Some nighttime sampling should also be included.

CONCLUSION

Based on the findings of this study, the overall ecological health of the ponds is poor. The ponds are not viable habitat for fish traditionally stocked for Ali'i because of degraded water quality and competitive tilapia. Consequently, their cultural significance as "Alii" fishponds is virtually nonexistent. The ponds are also important from a biogeographical perspective since no other anchialine ponds are recorded between Kailua-Kona and Milolii.

The detrimental effects of alien fish introduction and accelerated sedimentation in anchialine ponds has been documented throughout the Hawaiian islands. To reestablish the ecological viability and cultural significance of the ponds at Pu'u Honua O Honaunau, two initial measures in combination must be taken:

1. Eradicate alien fish from the ponds
2. Remove sediments from the ponds

If the ponds are to be cleaned and restored, a possible alternative to address both natural and cultural values would be to use the deeper pond 1 for aquacultural purposes and allow pond 2 to remain as preserved natural habitat. This would allow for recolonization of pond 2 by native species.

Appendix 1

Honaunau Water Quality Monthly Averages

Fig. 1a.

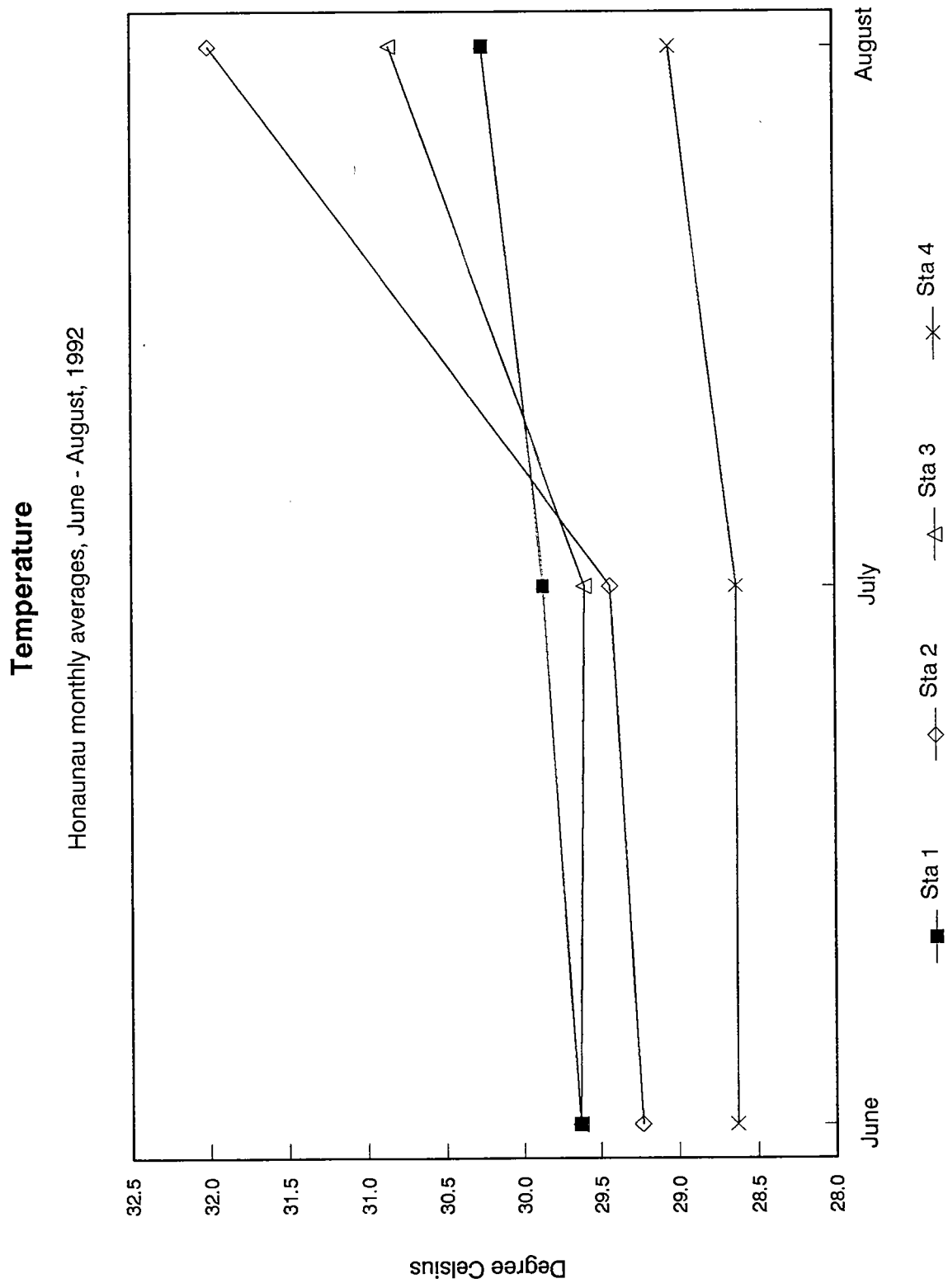


Fig. 1b.

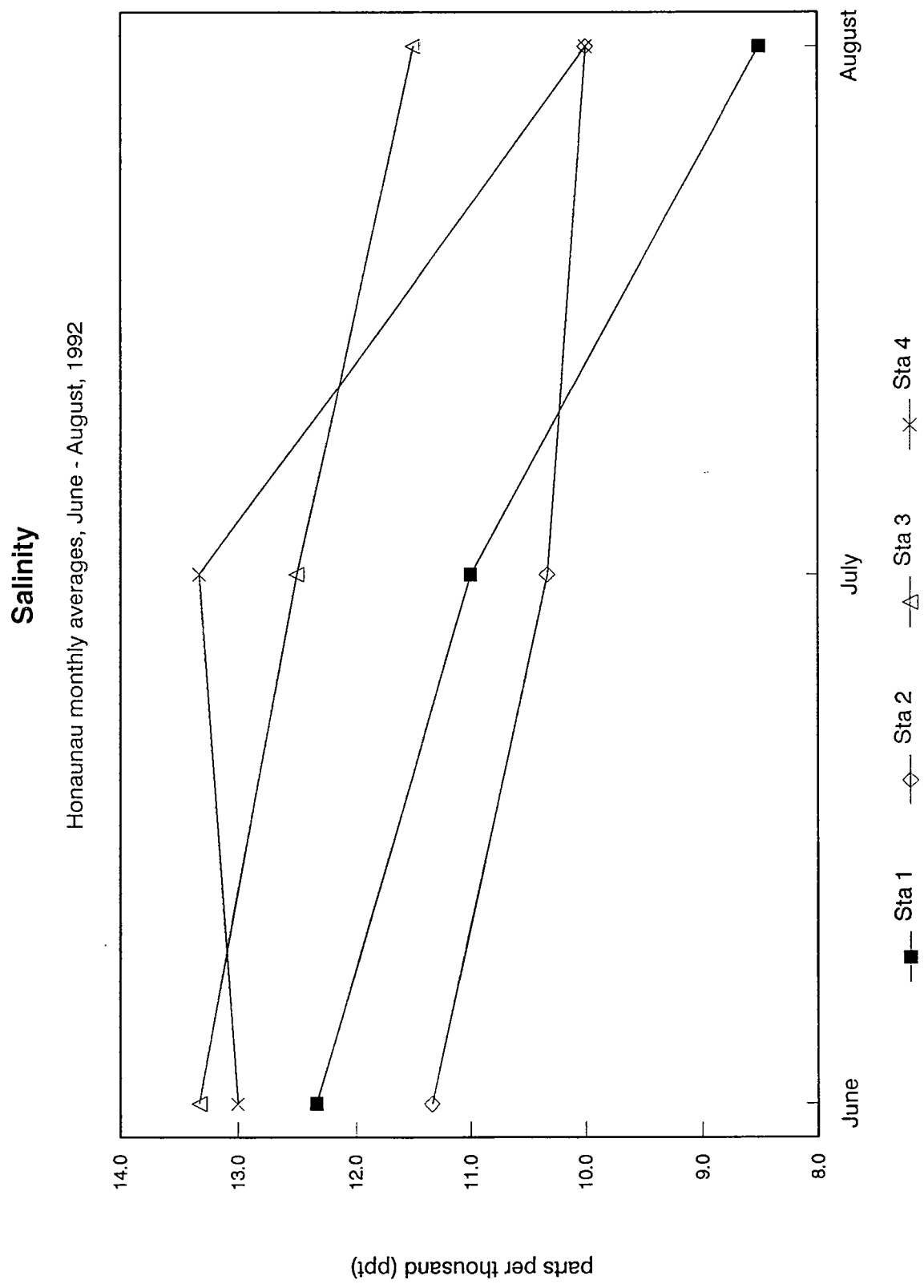


Fig. 1c.

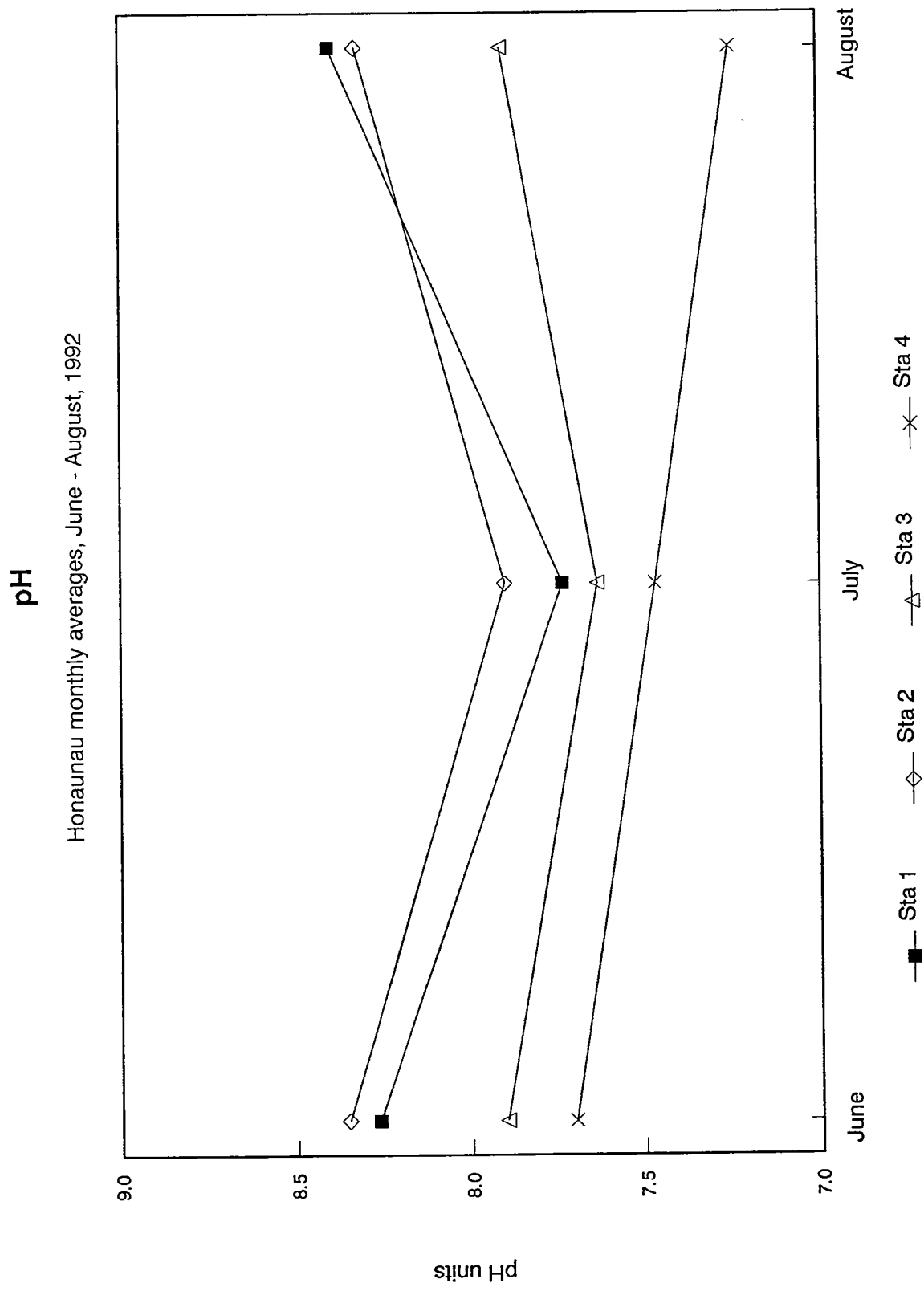
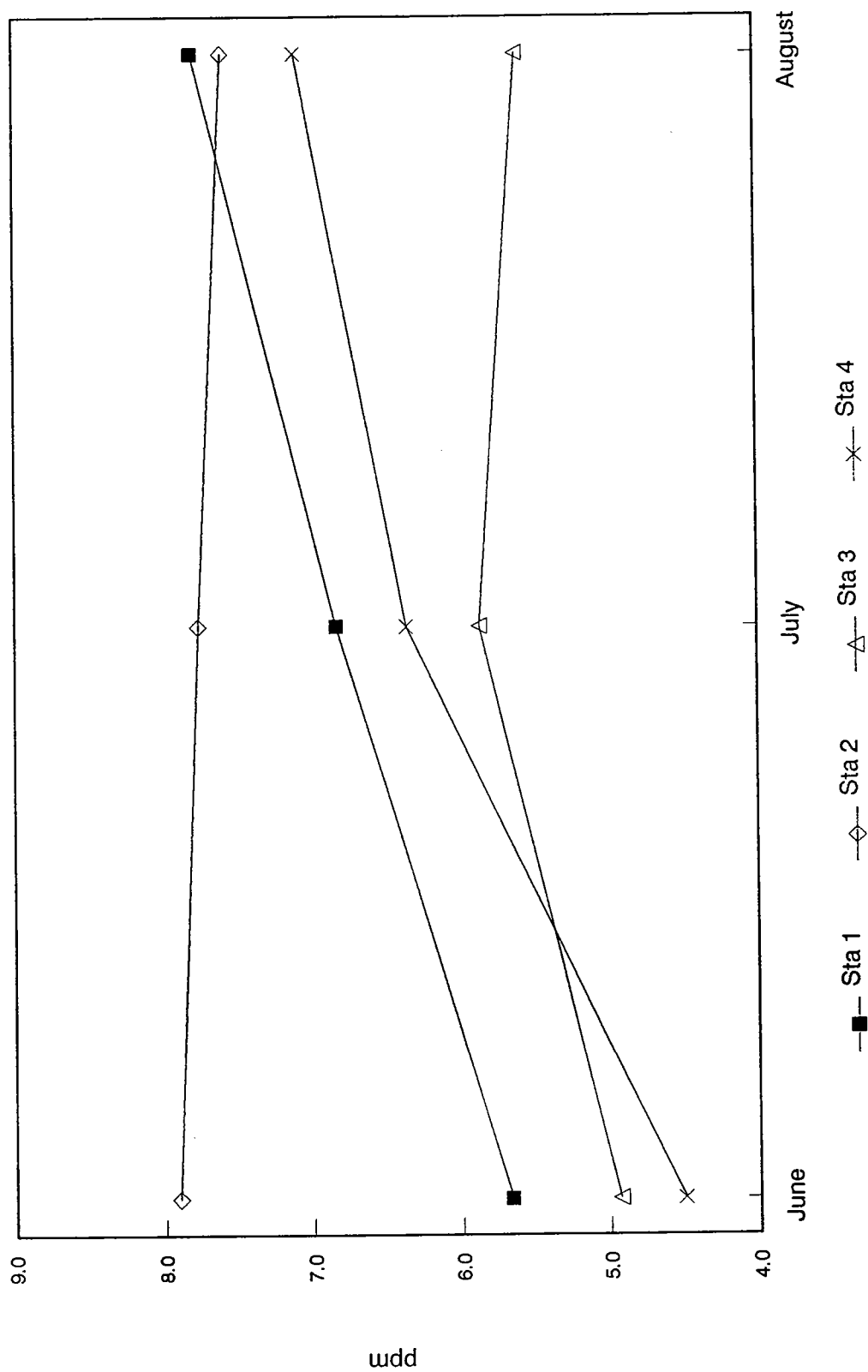


Fig. 1d.

Dissolved Oxygen

Honaunau monthly averages, June - August, 1992



Appendix 2

Honaunau Water Quality Stations

a.m. and p.m. Averages

Fig. 2a.

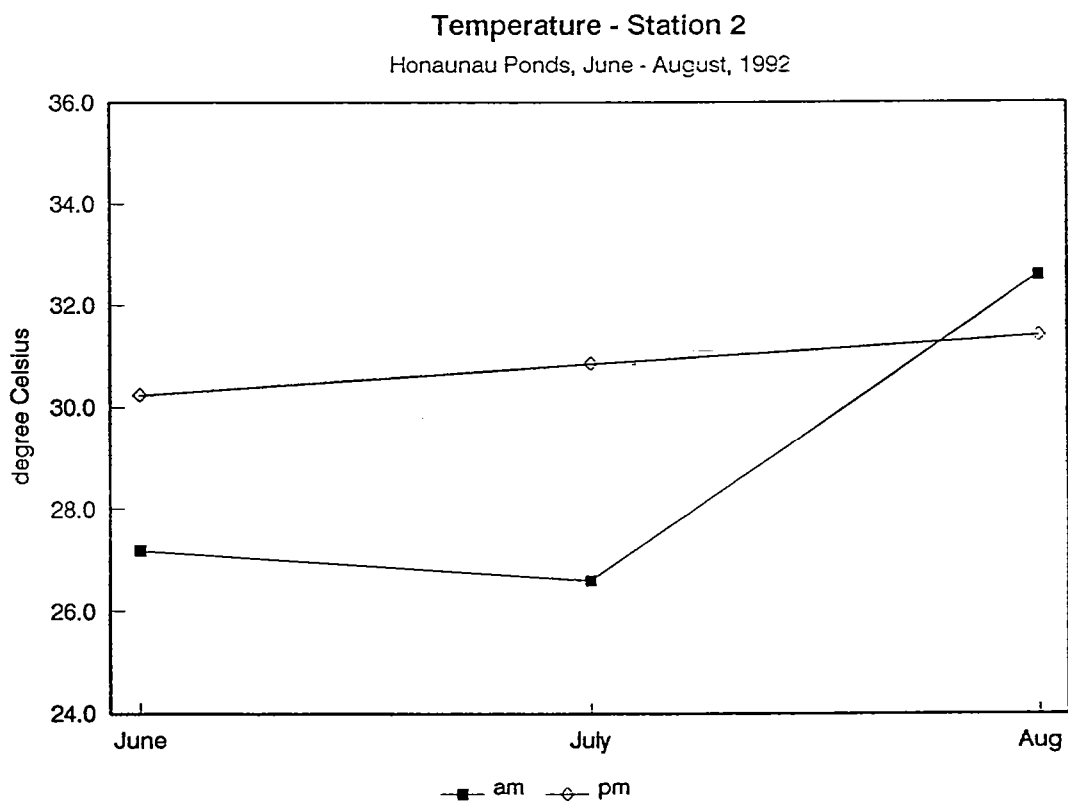
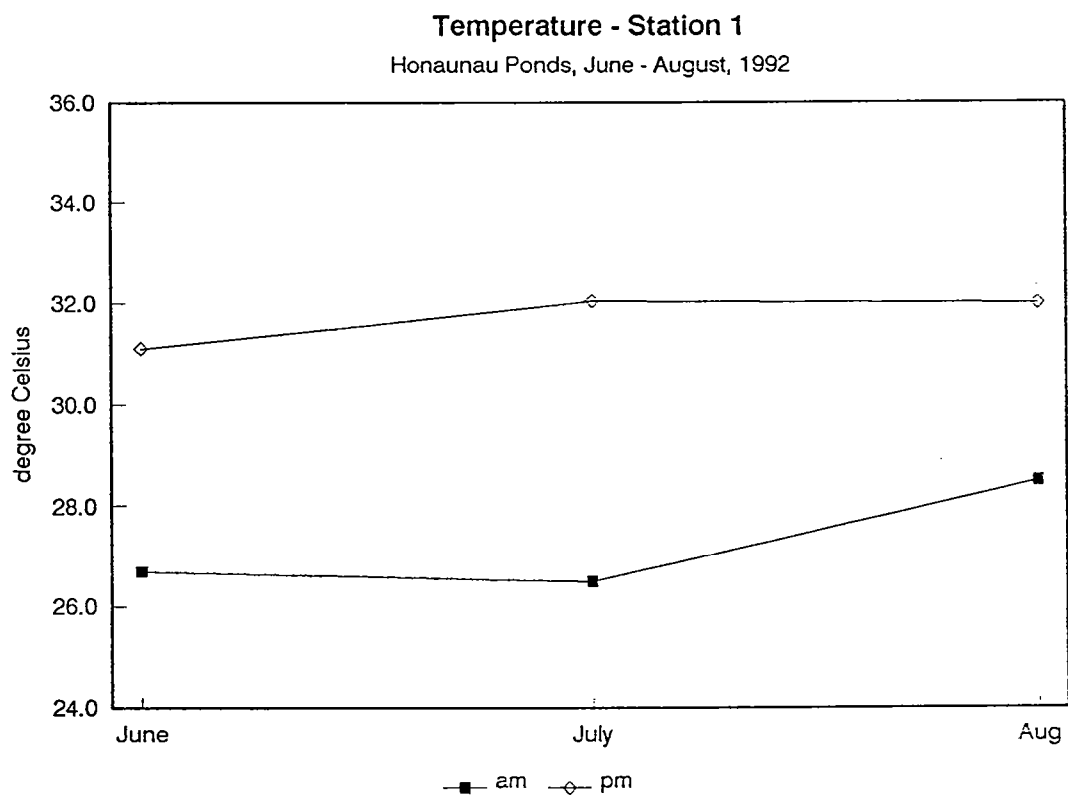


Fig. 2a.

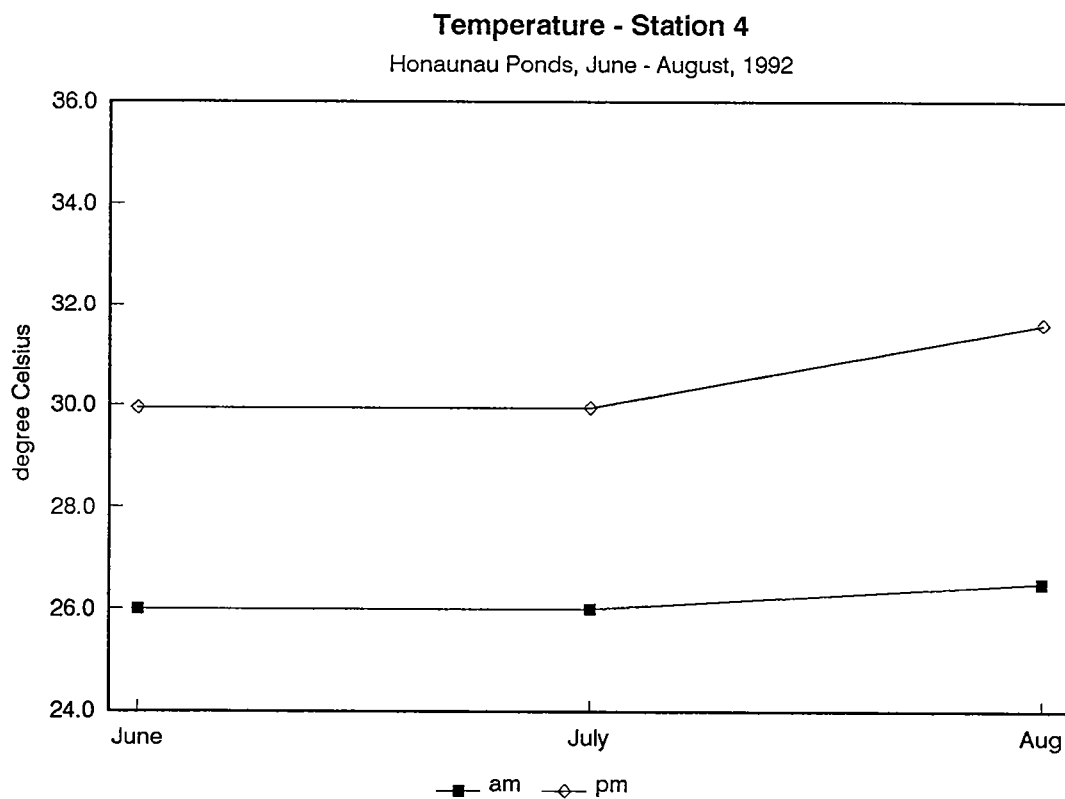
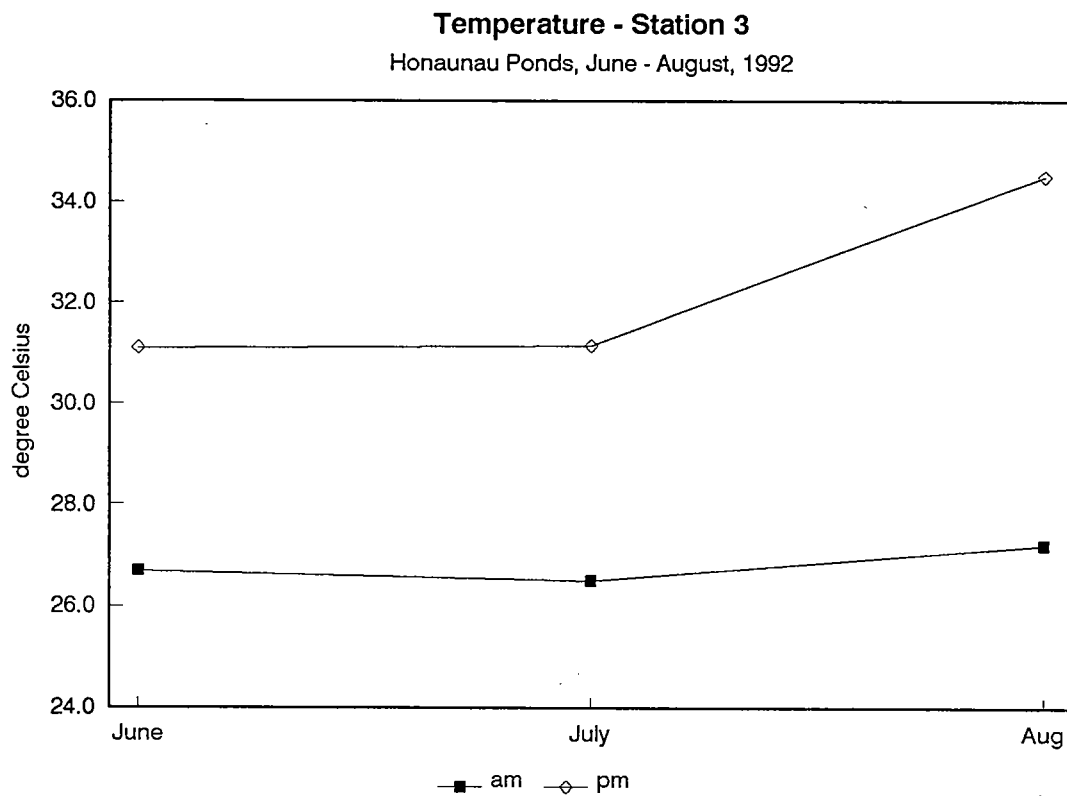


Fig.2b.

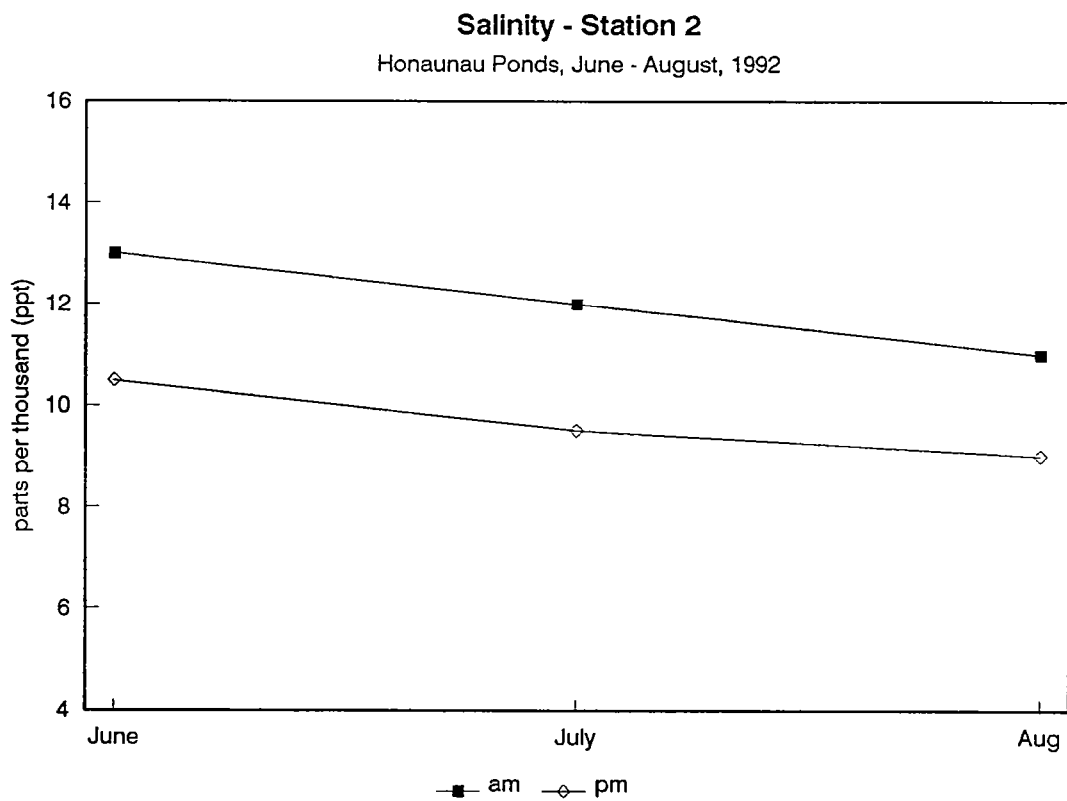
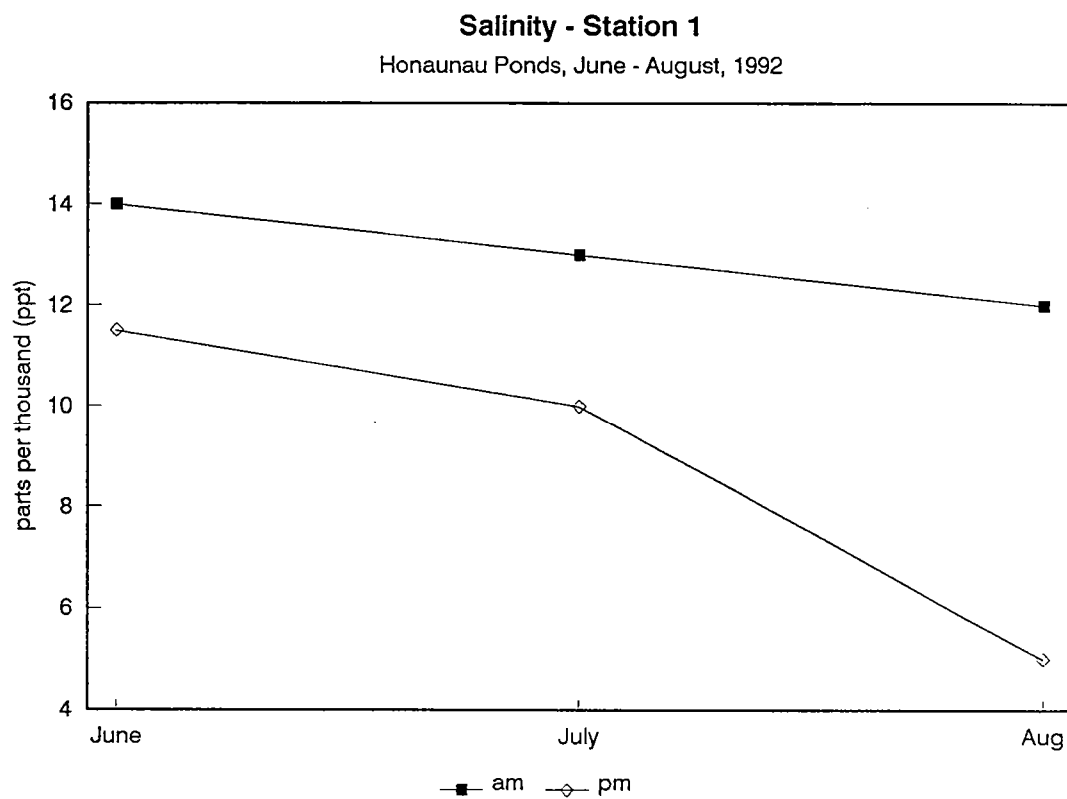


Fig. 2b.

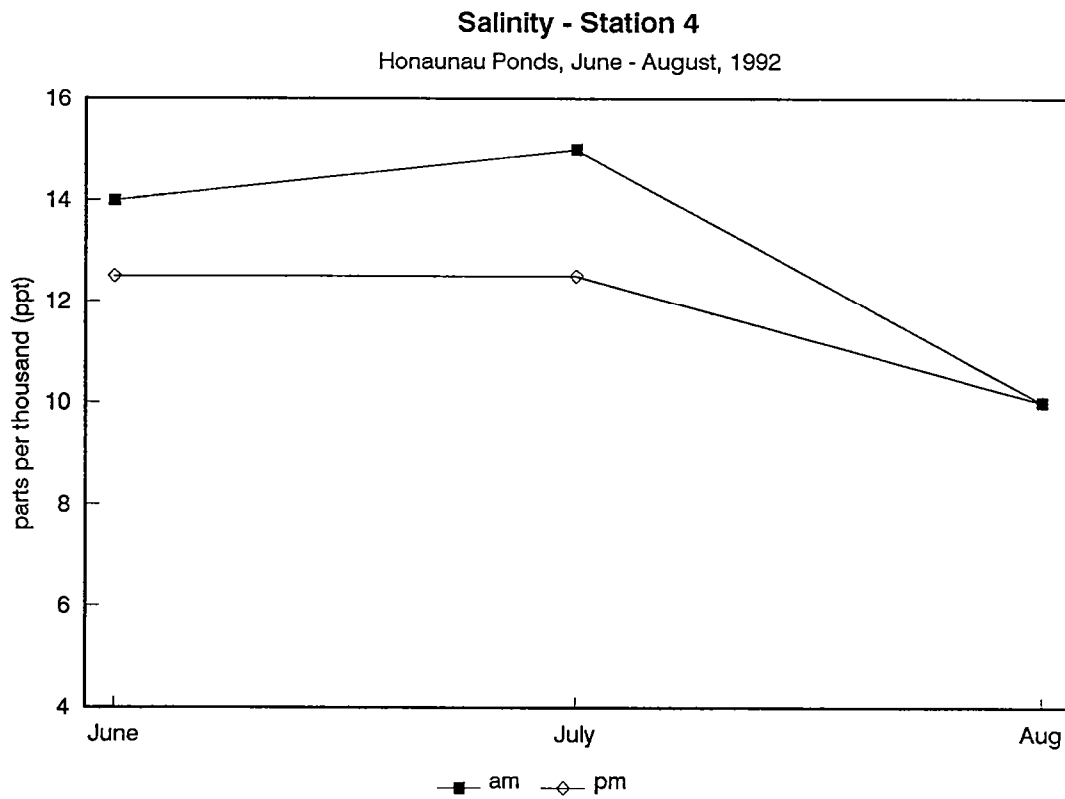
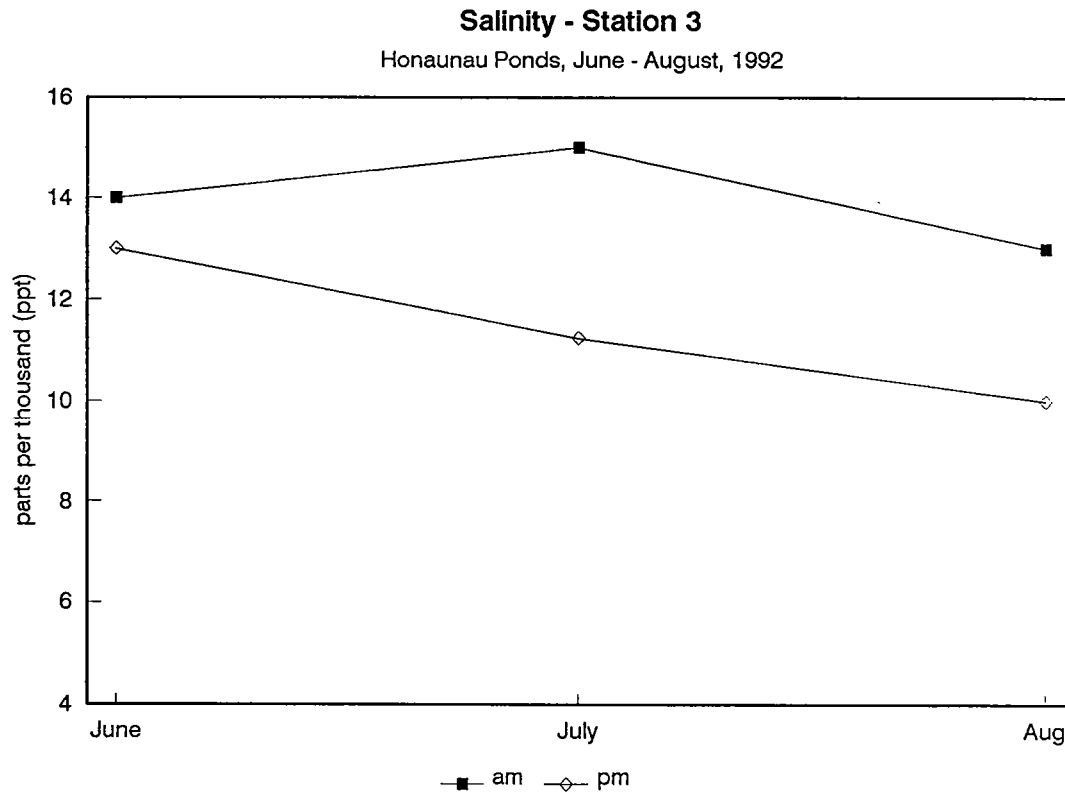


Fig. 2c.

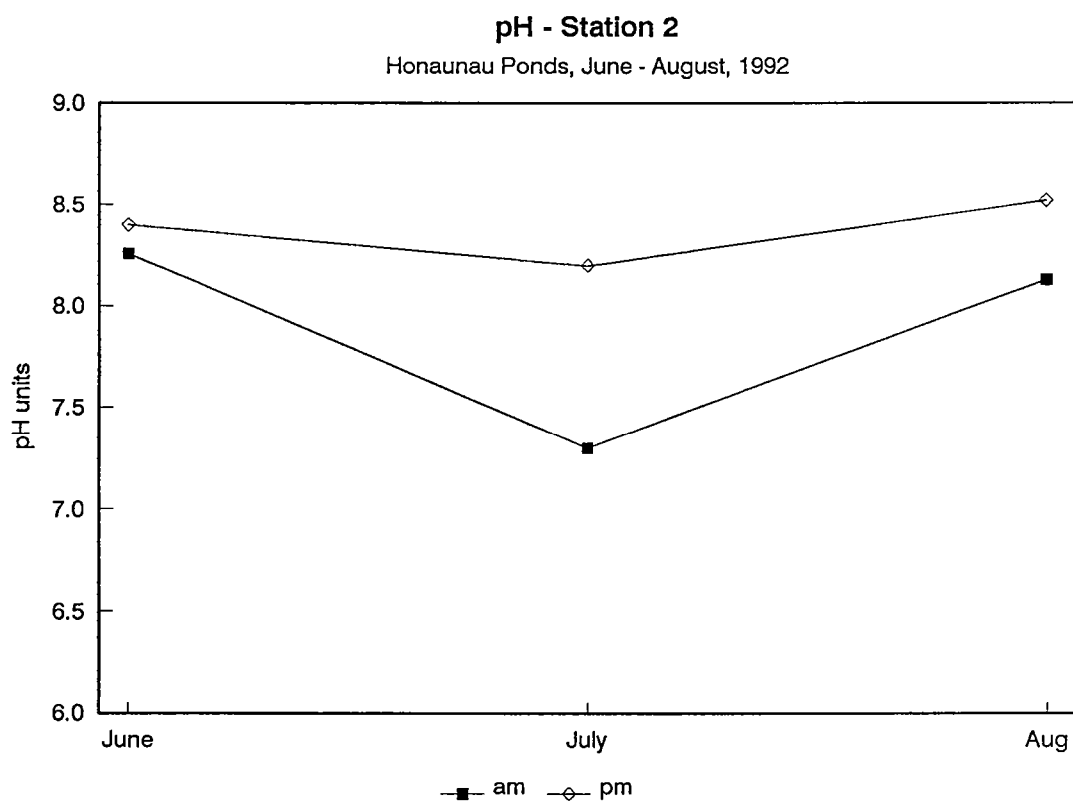
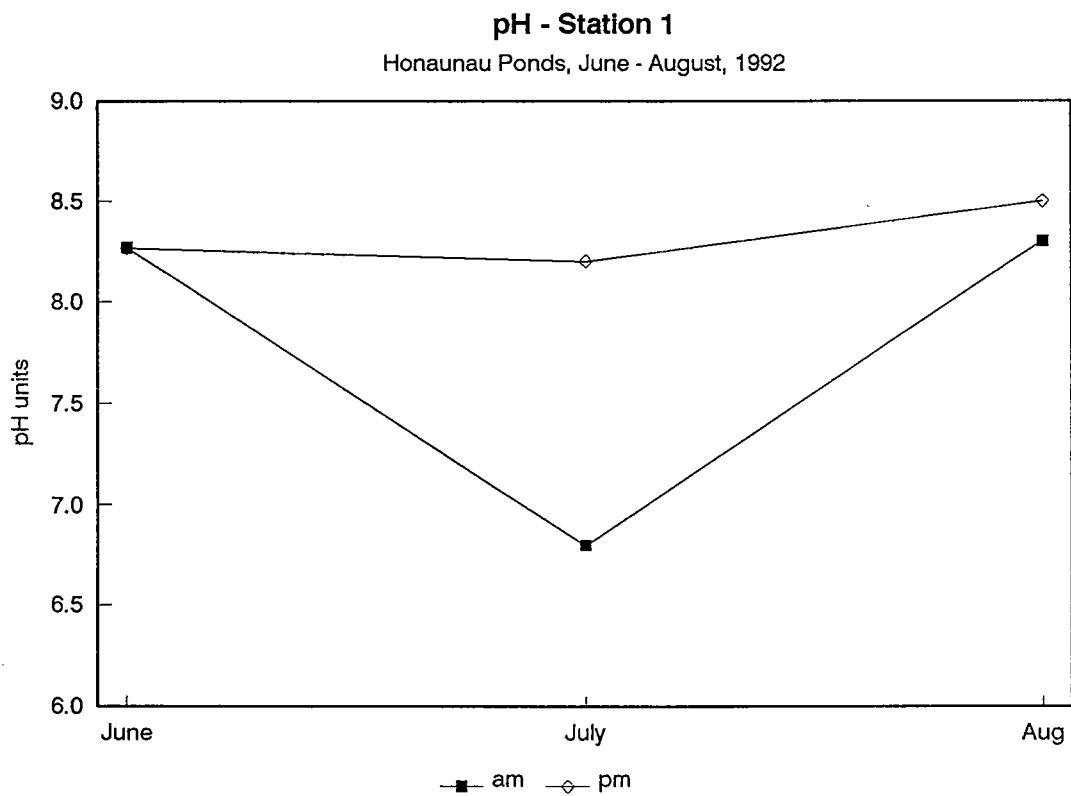


Fig. 2c.

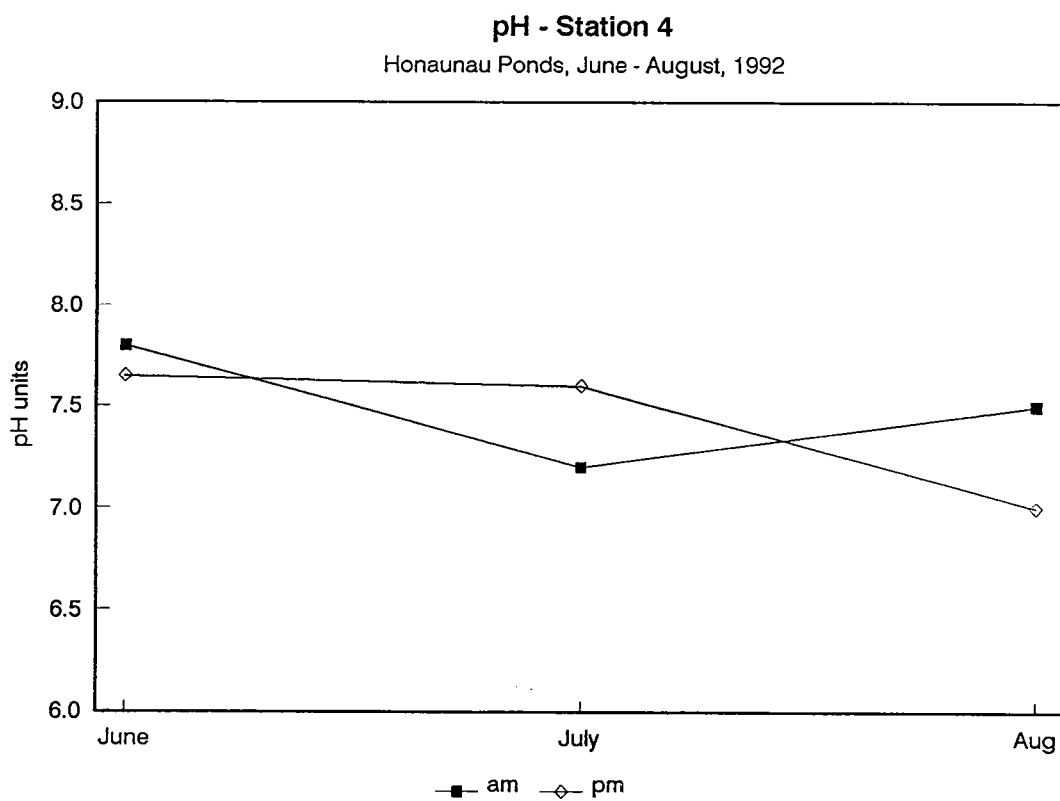
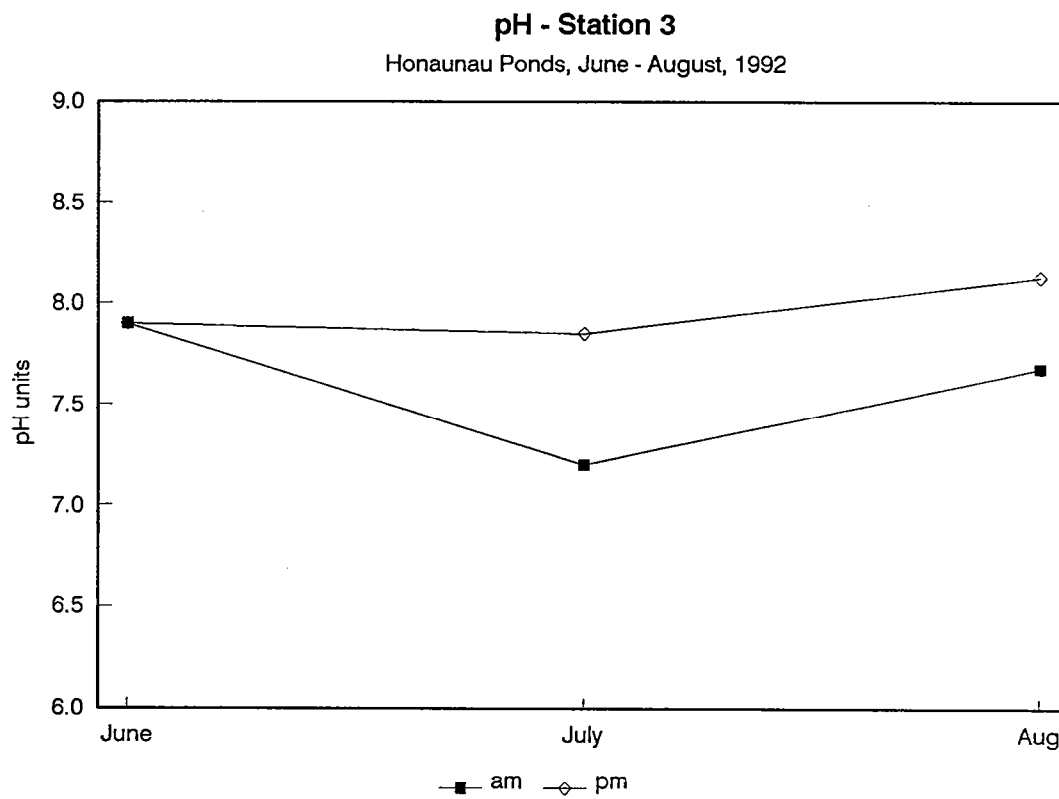


Fig. 2d.

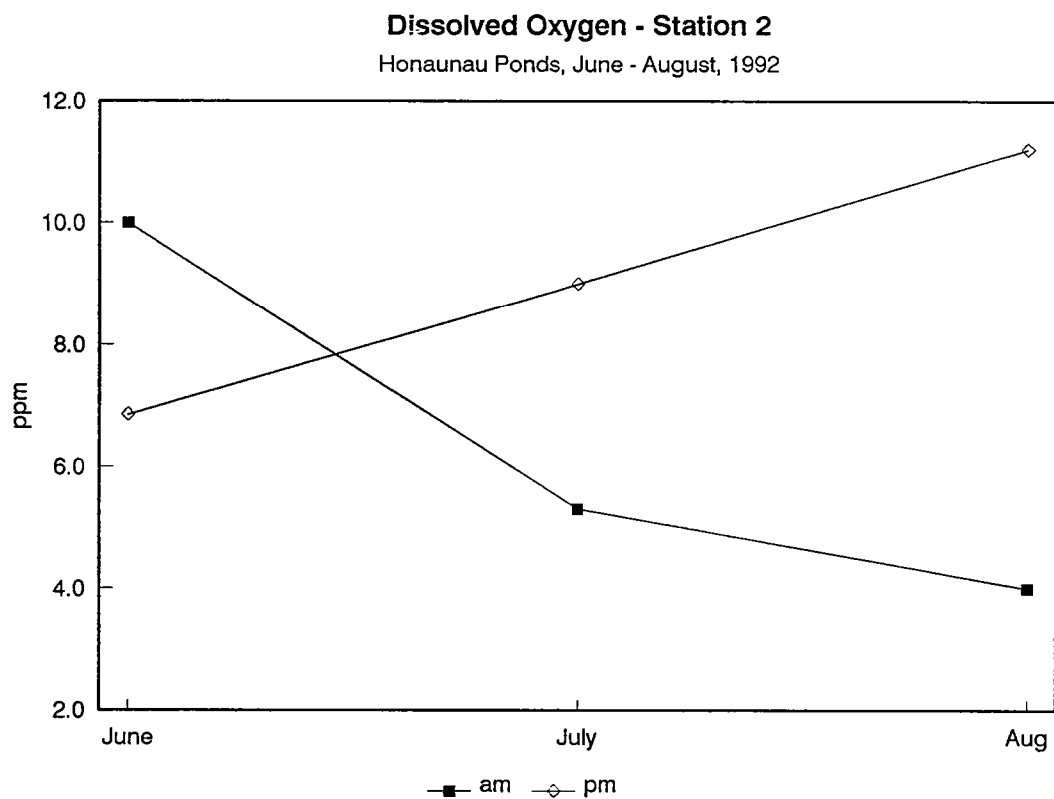
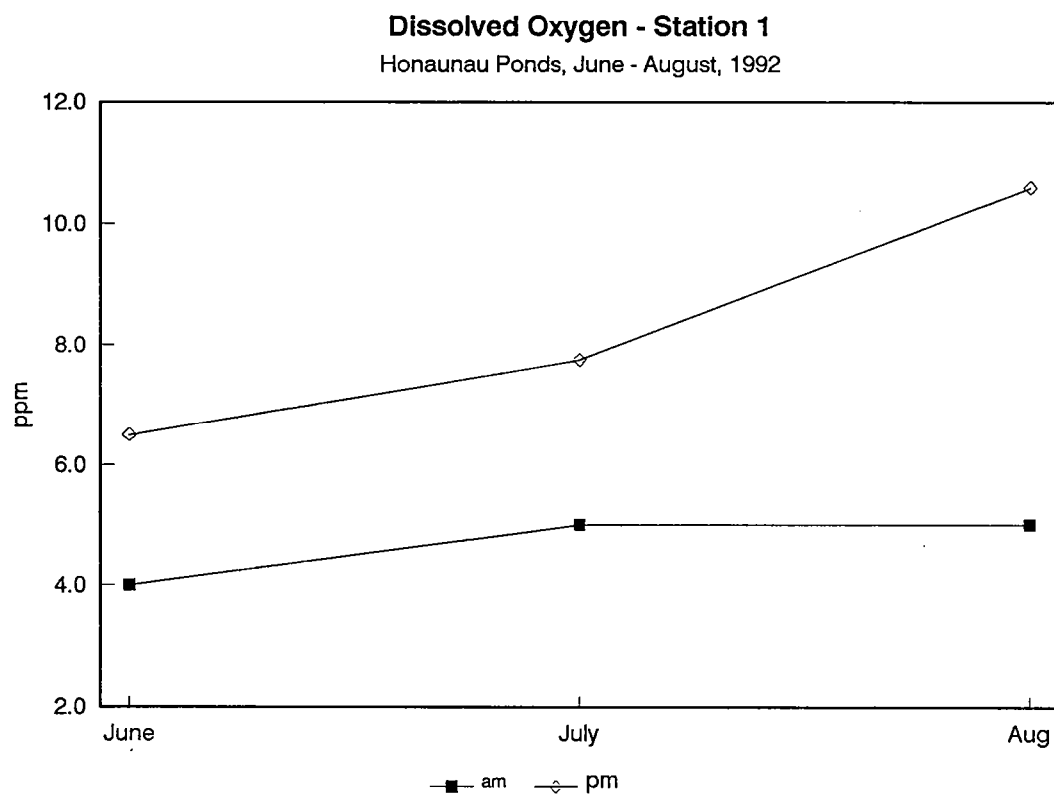


Fig. 2d.

