Restoring Hawaii’s past, for the future

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Abstract:

Worldwide, the lack of sustainable food sources within small communities is a serious problem. Here in Hawai'i, the dependence on imported fish and meat has been steadily increasing. We have an opportunity to become self-sufficient through the restoration of loko I'a (fish Ponds). In ancient Hawai'i there were approximately 461 fish ponds, with about 365 left in the 1900's. Less than 100 ponds are active today. Fish Ponds main purpose is to maintain and increase food production. After the reduction and loss of sustainable practices in the late 1800's, Loko i'a offer the key to revitalization of sustainable agriculture and reconnecting with traditional cultural practices here in Hawai'i. They require minimal inputs, low stocking densities, and no fertilization to provide large amounts of fish that can be harvested almost year round. Understanding how they function and the management of the fish ponds is important for us and future generations to protect and sustain the resource. Hale o Lono loko i'a in Keaukaha, BigIsland is the site for my internship. This loko I'a is currently being restored by the Edith Kanaka 'ole Foundation (EKF). I worked with Luka, a member of the EKF council and one of the caretakers of the pond. Most of the work was conducted at the community work days every second Sunday of the month. Working with Luka and other members of the community showed me a first hand look of what it takes to run a loko i'a, it allowed me the opportunity to gain hands on experience in traditional loko i'a management and maintenance. Some of the main skills learned was, brush and tree clearing techniques, rock wall rebuilding, dry stacking techniques, removal of invasive species and the relationship of how these various components benefit the pond. In order to better understand the pond, I conducted fish presence/absence surveys. The fish surveys revealed 19 fish species in the largest pond within Hale O Lono, 31.6% of the fish being endemic. Benthic surveys in and outside of the pond showed no corals and a dominate mean benthic composition of rock. Salinity measurements were taken using a refractometer at high and low tide. The mean salinity of the pond at high tide was 14.67 ppt. inside and 22.67 ppt. outside. The low tide mean salinity inside of the pond was 11.00 ppt and outside was 16.17 ppt. Many fresh water springs are present along the Honohononui ahupua'a where Hale O Lono is located, they attribute to the brackish water and have ideal nursery conditions for raising fish and limu. This project is part of a large community effort to bring back a traditional practice and restore fish ponds to their former greatness. If every one does their part, we can provide a lifelong supply of fish for our families and the future generations to come.

Introduction:

Throughout the world, many small communities lack sustenance, but they have the opportunity to become self-sufficient. In a modern society, we go to the grocery store or farmer's market for food. In ancient times, everything consumed was grown and raised by the people within small communities (Keala & Graydon 2007). Most people within the community believe in taking care of the land and allowing it to thrive for future generations.

The people of Hawai'i have strong values but are vulnerable in the sense of food security. The State of Hawai'i imports many different items. Although the total number of all imports has gone down, the importing of foods such as tuna and skip jack has increased by 8.7% between 2015-2016 and has increased by over 625% since 2013 (Census 2017). It's speculated that if the food shipments stopped, grocery stores would run out of food in less than two weeks. We would have to turn to our own resources for survival.

The sustainable way of living in Hawai'i was almost lost, but in over the past hundred years a revitalization has been reoccurring (Bond & Gmirkin 2003). A valuable resource are fish ponds (loko I'a). In modern times, the loko i'a offer an opportunity for people to come together, reconnect with Hawaiian culture, and traditional Hawaiian practices. Many of the ponds can be repaired to a productive state. Some ponds have been restored, but many are still in disrepair. The Ahupua'a land management system used by ancient Hawaiians went from the mountains to the ocean; each ahupua'a typically contained a loko i'a. The ahupua'a system ended in the late 1800's with the great Mahele (Land Division). The great Mahele allowed private ownership of land for the first time; eventually leading divisions and loss of land, and a switch from a barter system to money based economy. An ahupua'a containing fish ponds were considered "fat" or "rich". The Konohiki were workers of the ponds, these caretakers maintained the rock walls and did the harvesting. The collection of different fish, limu, and inverts was done in accordance with the Hawaiian moon calendar. By being aware of the various spawning seasons, the Konohiki could insure the food source was harvested at the appropriate time. Prized fish such as Awa were kapu and were reserved for Ali'i (chief) or royalty, while other fish such as āholehole could be consumed by the caretakers and commoners.

If we can restore fish ponds to their traditional state, we could all benefit. A fish ponds main purpose is to maintain and increase food production (Keala & Graydon 2007). In the 1900's there were approximately 365 fish ponds producing approximately 679,692 pounds of fish every year (Keala & Graydon 2007). The estimated population in ancient Hawai'i was placed at about 400,000 by Capt. James Cook (Schimitt 1968). Also, different locations within the state offer a wide range of species that can be cultivated for consumption. Here in Hawai'i we can raise organisms such as limu, fish, shrimp and other crustaceans. Awa (Mullet) was the main fish raised in these ponds, but many other fish species were raised such as: āholehole (Flag tail), akule (big eye scad), hīnālea, nehu, moi and many other fish species that would find their way into the pond. The fish and limu could be harvested throughout the year. The fish, invertebrates and limu ponds can be either eaten, sold, or used to restock other ponds. Loko I'a offer an opportunity in areas which lack agriculture to expand on an existing system or natural feature.

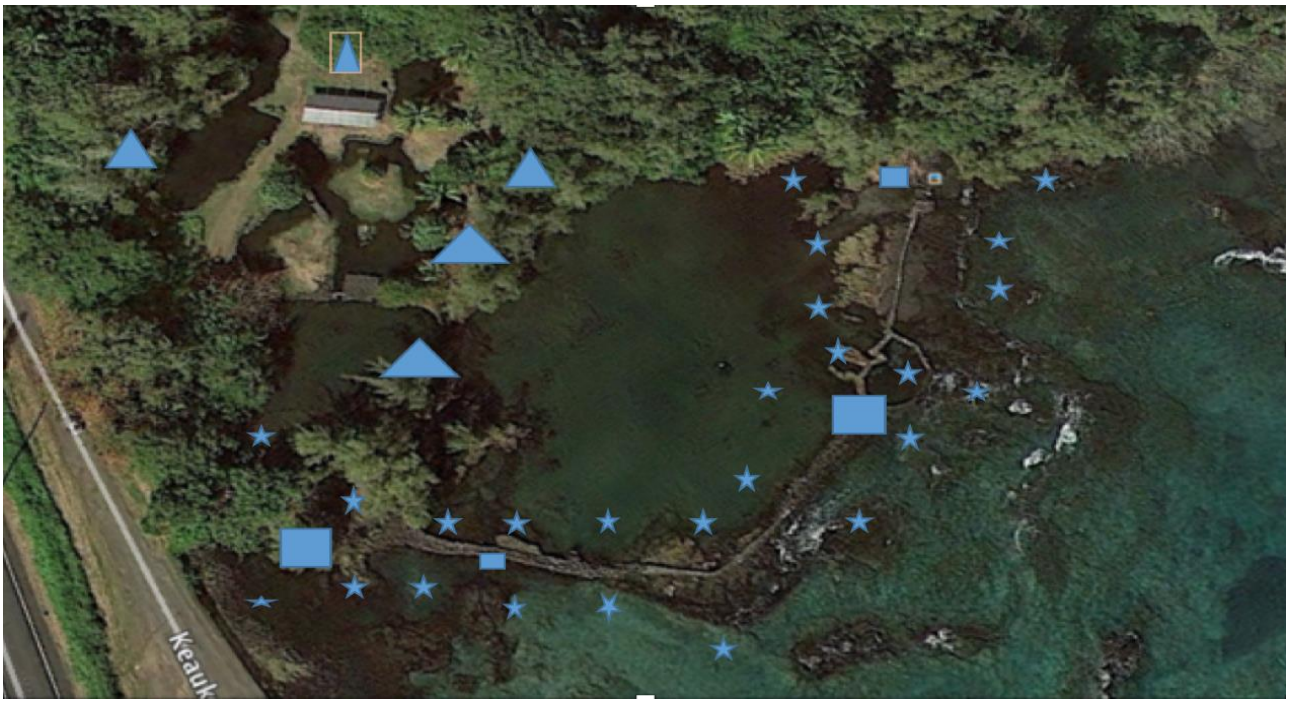
There have been some issues that many ponds deal with, including natural and manmade stressors. Some problems are unauthorized taking of fish from the pond, environmental pollutants, tsunami damage and predators going unchecked or unnoticed. Various obstacles and challenges must be kept in mind when designing, managing, or working at a loko i'a. Permitting to restore a pond has been difficult in the past. In 2012, a project was done called the Statewide Programmatic General Permit and Programmatic Agreement for the restoration, repair, maintenance and reconstruction of traditional Hawaiian fishpond systems across Hawai'i (Honua Consul. 2013). This project was meant to stream line the process to begin restoration of a loko i'a. An environmental assessment they had done found no significant negative impact for the restoration of loko i'a across the state.

For my project I worked at Hale o Lono fish pond. I was involved in different aspects of loko i'a management restoration and maintenance at the pond. After working on this project I learned about traditional management, restoration, and harvesting practices still being utilized in a modern society. I learned through hands on experience while completing the following objectives. I gained hands on experience in traditional loko i'a management. Working in this field allowed me to apply my marine science knowledge and landscaping background. Information acquired through study, hands-on experience and pre-existing methods can be applied to other ponds currently in disrepair. With no negative impacts and the regulation process being simplified, Hawaiian fish ponds are the right choice for Hawai'i. Fish ponds such as Hale o Lono offer a solution to communities who lack a sustainable food source. This project is a small step towards a sustainable future and retention of traditional knowledge.

Site Description:

Hale o Lono loko i'a is located in Ahupua'a of Honohononui, in the district (moku'okana) of Hilo, on the island of Hawai'i (figure 1). This loko i'a is considered a loko kuapā (seawall), although it has features of the pond that are like the other four types of loko i'a encompasses approximately 6 acres and has actively been restored over the past 20 years. The fish pond contains numerous nursery ponds inland connected by a series of channels and bridges to the main grow-out pond. Fresh water springs feed the pond from various locations, mainly along the western end of the pond. The pond contains four main sluice gates (makaha) along its outer wall and approximately 7 inner makaha separating the nursery ponds from each other. The northeast end of the pond faces the ocean and large surf year round. "The Edith Kanaka'ole Foundation (EKF) is a Hawaiian cultural-based organization established in 1990 to maintain and perpetuate the teachings, beliefs, practices, philosophies and traditions of the late Luka and Edith Kanaka'ole." (EKF 2016). The EKF is currently responsible for the care and management of Hale o Lono. The pond is primarily utilized for education and cultural purposes through outreach and community work days. "This loko continues to be a learning center for not only perpetuating our traditional practice, but also the sustainable future for our islands" Luka Mossman. Many types of fish can be found here such as awa, āholehole, manini, moi and many more. The brackish conditions in the area of the pond make the site optimal for raising fish.

Fig 1. Hale o Lono loko i'a, Keaukaha Hawai'i Island: The figure displays areas where I have worked within the pond. The larger the shape the more work was done in that area. The triangles represent areas where I worked on tree and brush clearing. Squares show rock wall work. Stars show approximate salinity and benthic sampling locations. The triangle with the box around it is the location of the mulch pile.



Methods:

Objectives

1. Gain hands on experience in loko i'a maintenance and management.
2. Look at how the varying tides, salinity, and benthic substrates effects the distribution of specific fish species in the pond.

To achieve my first objective, I performed these tasks:

1. Fish pond restoration and maintenance:
    - Brush and tree clearing
    - Rock wall construction
    - Rock gathering
    - Marine Debris removal

To achieve my second objective, I tested these Hypothesis:

1. Different areas of the pond have different salinities.

2. The salinity inside the pond will be lower than the salinity outside the pond.
3. Fish presence/absence survey inside the main pond.
4. There will be more fish on the inside of the sluice gate when the tide going from ebb tide (Low to High) and more fish will congregate on the ocean side of the fish pond when the tide is draining out from the pond, midpoint sampling. (High –Low)

Fish pond restoration and maintenance

For this internship I worked at Hale o Lono loko i'a under the supervision of Luka Mossman. A bulk of the work was done with the Mossman family and other volunteers at the community work days every second Sunday of the month. In addition, I helped with various projects they have going on at Hale o Lono loko i'a. While I was at the loko i'a, I completed assigned tasks which included clearing of brush, cutting down invasive trees, selection of loose rocks from areas surrounding the fish pond, assisting in mowing large rocks for the construction of pond walls, and placement of large stones base and corner stones.

Brush and tree clearing

To complete the task of clearing invasive and encroaching brush from around the pond, it was best to work in groups of three to six people. Working as a team drastically reduced the effort needed to conduct large tasks. One or two people would hand cut trees and shrubs, while the rest would remove the fallen branches from the water and along the edges of the pond. Large branches that fell into the pond had to be dragged out of the water. Smaller material such as leaves, branches and seeds from different plants was mulched on the property while larger green waste materials were hauled off site. Smaller brush had to be chopped and clipped back long edges to prevent sedimentation. I worked doing the various task to get a holistic approach. Many times I found myself chest deep in the pond walking through unknown water and mud dragging a large tree branch. The entire process was definitely a humbling experience.

Rock wall Maintenance

Recently, large storms damaged sections of the outer wall. They needed to be repaired before the fish stock was lost to the sea. After discovering that a large piece of the wall was missing, we had to elevate a section of the wall by two feet or more. Luka and I, along with a few other volunteers scoured the seafloor for large stones that had been reclaimed by the sea. Walking these stones along the bottom was the only way to move some of the them. Once I was close enough to the wall I used the force of the waves to get the stone out of the water and up on to the wall above. The smaller stones served as wedges and anchors for the large rocks by bridging any gaps. In some areas of lower wave action, smaller stones can be used. After the largest rocks could be found in the vicinity, smaller rocks had to be hauled from the closest source. Sources of rocks were mainly taken from areas parallel to the ponds outer wall, as well as a beach about 400 yards away that’s managed by EKF.

A technique that is currently being used a is a dry-stacking method. This means no mortar is used to hold the stones together. A benefit of the dry-stack method is that it allows for more water flow and habitat for small fish and invertebrates. Dry stacking involves placing the largest stones on the outer edges and bases of the wall. Other rocks are than placed in an interlocking puzzle like formation but also has multiple layers. If the first layers of rocks are taken back by surf the other layer's act as a second defense.

Fish survey

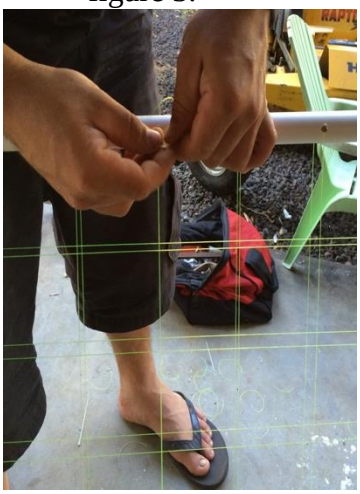
Two presence absence fish surveys were done in the largest section of the pond. The surveys were conducted by using the pond wall as a transect. Two approximately 30m areas were selected and used for the survey. The fish were recorded, if presence along the transect. The surveys were combined to give an over all presence absence of the study site.

Quadrat Construction

A ¾ (70 cm x 70cm) meter quadrat was constructed using ¾ inch PVC and ¾ inch 90° PVC elbows. A center hole was drilled on all sides. The corners were also drilled out to allow the quadrat to sink rapidly. The next set of holes were exactly 8.5 cm from the center holes. So each side had seven holes for a total of twenty-eight on the pipes plus four on the corners for a grand total of 32 holes. Holes visible in fig. 2.

figure 2.

figure 3.



The pipe holes were cleaned with a rough cloth to remove any shavings, after being taken apart. After cleaning the pipes ,4 small pieces of gravel were added inside the quadrat for extra weight. The quadrat was reassembled and then the stringing process could begin.

The monofilament fishing line was used to string through the holes. Starting with a center hole, attach line to frame by stringing through the designated "top" hole out the bottom. and tied it off. Going directly across, the line was put through the bottom and out the top of the pipe and returned to start positon to be tied off. The process was repeated till a double staked grid was made with an 8 x 8 layout shown in the fig. 3.

Benthic surveys

To get a better understanding of benthic substrate composition distribution, I looked at variations of substrate throughout the inside of the pond and along the outside. A ¾ meter quadrat was used to conduct benthic samples. The quadrat was randomly thrown at 12 locations inside and 12 locations outside of the ponds outer wall. The benthic substrate was categorized as either sand, algae, coral, mud or other (sticks, leaves, marine debris). The data was averaged and used to calculate the mean benthic cover.

Salinity Measurements:

In addition, I took water salinity measurements at Hale o Lono fish pond. These measurements were done inside and outside the ponds outer wall at low and High tide. All measurements were done using a refractometer.

Stats

Doing the statistical analysis on the different parameters will help with interpreting the data and look for any correlation between them. All data was analyzed by using excel.

Results & Discussion:

Fish pond restoration and maintenance:

Brush and tree clearing

Table 1. Plants removed or cut back

#	**Common Name**	**Scientific name**	**Hawaiian name (if applicable)**
1	Common ironwood	*Casuarina equisetifiolia*	----------
2	Pandanus	*Pandanus tectorius*	Lau Hala
3	Portia tree	*Thespesia populnea*	Milo
4	Coconut palm	*Cocos nucifera*	Niu
5	False Kamani	*Terminalia catappa*	Kamani haole
6	Coastal hibiscus	*Hibiscus tiliaceus*	Hau

Various areas of the pond were cleaned with non-power equipment, mainly handsaws and pruners. No herbicide or gas powered tools were used in the removal process.

Rock wall Maintenance

Having a good rock wall around your pond is very important in having a healthy pond. Adequate height, water flow, and placement of stones must be considered when constructing or repairing a wall. You want to keep your fish in and predator fish out. Preventing predator fish from entering the pond during high tide, has been a battle against the elements. Through close observation and maintenance, the pond had been able to stay intact. One person can watch over a pond but it takes a community to keep it healthy and intact. I realized the importance of team work after taking part in the gathering and passing of stones while assisting with rock wall rebuilding. It was nice to be included in the collection and placement of key stones along sections of the outer wall. I learned great techniques for the construction of the walls.

Fish Survey

The fish presence/absence survey revealed 19 Species of fish residing within the pond displayed in table 2. The fish with the bold common name are endemic to Hawaii. These surveys revealed that 31.6% were endemic. It was very interesting to discover that so many fish were in the pond, especially in a wide salinity range of 4-20 ppt. The fish appeared to be most abundant during high tide and were easily identifiable at the makaha.

Table 2. Fish presence/absence survey.

#	**Common name**	**Scientific name**
1	**Bay cardinal**	*Foa brahygramma*
2	**Hawaiian Flagtail**	*Kuhlia xenura*
3	**Hawaiian Sergeant**	*Abudefduf abdominalis*
4	Raccoon butterflyfish	*Chaetodon Lunula*
5	**Whitesaddle Goatfish**	*Parupenus porphyreus*
6	Yellowfin Goatfish	*Mulliodichthys vanicolensis*
7	Saddle wrasse	*Thalassoma dupperey*
8	**Spectacled Parrotfish**	*Chlorurus perpicillatus*
9	Christmas wrasse	*Thalassoma trilobatum*
10	Black Tail Snapper	*Lutjanus fulvus*
11	Moorish Idol	*Zanclus cornutus*
12	Ringtail Surgeonfish	*Acanthurus blochii*
13	Whitebar Surgeonfish	*Acanthurus leucopareius*
14	Dwarf Squirrelfish	*Sargocentron iota*
15	**Stripped mullet**	*Mugil cephalus*
16	Sharpnose mullet	*Neomyxus leuciscus*
17	Great Barracuda	*Sphyraena barracuda*
18	Giant Porcupine fish	*Diodon Hystrix*
19	Convict tang	*Acanthurus triostegus*

Benthic Survey

Table 3. Benthic survey of outer pond.

Mean benthic Composition		
Benthic type	Inside	Outside
Rock	45.6%	58.9%
Sand:	19.1%	15.3%
Algae:	15.6%	21.5%
Coral:	0.0%	0.0%
Mud:	15.0%	0.0%
Other:	4.6%	4.3%

The benthic surveys revealed that the dominant substrate inside the pond was rock. This was to be expected. Sand and algae were alternated inside verse outside the pond. Algae was present at both site but at a higher abundance outside. I believe this is due to the large biomass inside the bond consuming the algae, although this theory has not been proven. The lower flow conditions of the pond cause the sediments to settle, verse being washed out by waves and currents. The difference in water motion is a main factor contributing to the muddy bottom along the area sampled. All sample sites lacked coral completely. Many mixed debris such as wood leaves, plastic cans and glass made up the "other" category of the survey. The lack of coral can most likely be attributed to the low salinity inside and outside of the wall.

Salinity Measurements

Table 4. Outer pond salinity data.

Outer Ponds Salinity	**Low tide**	**High Tide**
Mean Salinity In	11.00ppt	14.76ppt
Standard Deviation	±2.92	±3.45
Mean Salinity Out	16.17ppt	22.67ppt
Standard Deviation	±6.63	±6.57
Range	4-24ppt	5-28ppt

As predicted, the salinity inside of the pond was lower than the outside. The average salinity inside the pond at low tide was more than 3 ppt. lower then high tide. The max salinity of the pond at high and low tide were less than the average sea water of 35 ppt. These measurements suggest that fresh water springs are not just occurring within the pond but also along the coastline and from underwater seeps. The fresh water is coming from ground water discharge. Further studies would need to be done in order to prove this theory. Seasonal changes were not tested in this study.

Conclusion: While conducting this project I gained the skills necessary for the management and maintenance of loko i'a. I learned techniques in the removal and control of invasive brush and trees, traditional dry stacking techniques for construction of the rock walls and gained a large social network. With the different skills I have acquired I will continue working on this fish pond and others throughout the islands. Having worked in teams we were able to accomplish large tasks such as movement of thousands of pounds of stones, large trees and huge piles of debris. Hale o Lono serves as a good example of how community effort can restore a valuable resource. Even though there is still a lot of work to be done every piece counts. Future studies must be conducted to determine exactly how the tides and benthic substrate are affecting the fish distribution in the pond. After completing this project, I understand the need for fish ponds in Hawaii and the ability to apply these techniques to the rest of the world.

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