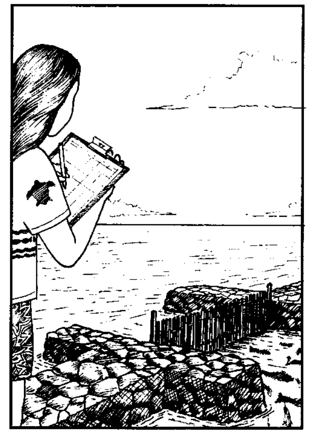
# Investigating Human Impacts on Hawaiian Fishpond Ecology

## Background



Before Westerners arrived in Hawai`i, the native people lived a life of self-subsistence and harmony with the land and sea. Early Hawaiians understood that by caring for the land and sea, they too, would be cared for by the land and sea. A great example of this is a native Hawaiian fishpond.

Fishponds were great examples of early ingenuity amongst a native people. Hawaiians studied the tides, moon, and sun and realized that they could harvest fish within a confined area. Similar to fishtraps in other areas of Polynesia, Hawaiian fishponds used the same idea of taking advantage of natural phenomenon to their advantage.

Basically, a fishpond consists of a wall and a sluice gate. The wall was made of boulders and stones of all sizes and was known as the *kuapa*. A sluice gate or *makaha* was placed at precise locations where currents occurred.

By studying nature, Hawaiians understood that fish would gather in areas of current. Going with the ebb and flow of the fishpond's water, Hawaiians were able to lure fish near the *makaha*. Small fish were able to enter the small slats of the *makaha* while larger fish were prevented from escaping.

The shallow depth (two to three feet) of Hawaiian fishponds provides the optimal light conditions for plankton and *limu* (seaweed) growth. Natural fertilizers such as nitrogen come from the marine animals wastes in the pond. Minerals such as phosphates and calcium come from the incoming streams, and to a lesser degree from the tides, which also contribute salt (NaCl). The fishpond *makaha* and pond walls were designed to allow water circulation from the tides. They allow water to circulate and prevent stagnation and the build-up of sediments, which is critical to maintain a healthy, balanced fishpond ecosystem.

## Natural fertilizers

Limu and microscopic plankton provide food for the fish grown in the pond- the 'ama'ama (stripped mullet) and awa (milkfish). The kia'i loko (fishpond caretaker) guarded and cared for the pond, just as a farmer tends his pastures for cattle. In addition to the nutrients that occur naturally in the pond, the kia'i "fertilized" the pond by adding additional food for fish such as kalo (taro), 'ulu (breadfruit), uala (sweet potato), mussels and stones with limu.

## Excessive Nutrients

Excessive nutrients from fertilizers can upset the balance of life in a fishpond by increasing the population of phytoplankton and limu. If too many nutrients are added, algal blooms may form. These blooms can decrease the clearity and light penetration, which causes limu to die. As the limu decompose, dissolved oxygen is depleted. Decreased dissolved oxygen then adversely affects the fish population. However, if algae blooms are rich in diatoms they can enhance the natural productivity of the pond. The diatoms in these blooms are nutritious and allow sunlight to warm the lower water layer and enhance natural productivity. According to Carol Wyban (1992) “Chinese aquaculturalist(s?) manage their water quality by color. Diatom-rich waters are golden-brown color.”

If excessive nutrients increase the phytoplankton concentration to high levels, a potentially lethal situation occurs in the fishpond, especially during the night, when there is no sunlight, no wind, nor circulation. During the evening, the phytoplankton that were making oxygen during the day stop as the photosynthetic “machinery” shuts down. Because the phytoplankton are also alive and need oxygen to live, they begin to take up the oxygen along with the other living organisms in the pond. If there is a large amount of fish, there will be almost no oxygen left in the water. This causes the fish to come to the surface of the water to breathe or gasp for air. Usually, in Hawaii, we are blessed with the tradewinds, but during the times of Kona winds, when there is almost no breeze and the water is still, catastrophic overnight fish kills in the fishponds have been recorded due to the lack of oxygen in the water.

**Situation**

Soil erosion from human activities near a fishpond may also have a negative impact on the fishpond ecosystem. Soil washing into the pond decreases the water clarity, blocking sunlight that the limu needs to grow. When the bottom sediments of soil and decayed organism matter in the fishpond get too thick, the sediment layer needs to be scraped toward the ‘auwai kai to be flushed out with the ebbing tide. This practice prevents the depletion of dissolved oxygen, which can occur when large amounts of organic matter are left to decay in the pond.

**Invasive Species**

One of the most visible invasive plants in the fishpond is the introduced red mangrove (*Rhizophora mangle*). This small tree was introduced to Hawaii from seeds brought in from Florida in the early 1900s. Mangrove trees were introduced to the Islands to prevent soil erosion. The American Sugar Company planted seedlings on the upper slopes of Molokai. However, the mangrove quickly spread to the coastlines where it now thrives in brackish water on most of the Islands. The mangrove root system established itself within the walls of the fishpond. This causes the sediment to be trapped, turning some fishponds into wetlands and mudflats. Mangroves also block sunlight, preventing the growth of limu, on which ‘ama’ama (striped mullet) feed.

Invasive limu species are also spreading on the reefs and in fishponds, displacing native species and altering the species and altering these structures of the ecosystems. Two of the most common aggressive species are *Gracilaria salicornia* and *Acanthophora specifiera*.

**Density and Diversity in a Fishpond**

**Background**

To monitor the diversity of species in the environment and the density of individual species, researchers have devised various ways to estimate plant and animal populations. Taking a total count of species is only possible with large or conspicuous organisms or with those that aggregate into colonies in a relatively small study area. The number of transects used and plots or areas sampled is determined by the size of the area to be sampled.

Line transect – Line transects are used when you wish to illustrate a particular gradient or linear pattern along which communities of plants and/or animals change. They provide a good way of being able to clearly visualize the changes taking place along the line. However, a line transect tells you what is there, but gives limited information on how much of it is present. A tape measure (50 -100 m) is laid out in a particular direction. Usually, species are counted that fall on the transect line at particular intervals (e.g., every 5 meters), but the distance between intervals depends upon the size of the area being studied.

Quadrat sampling – A quadrat is a square usually 1 meter by 1 meter made out of light and durable material such as PVC pipe. The quadrat is placed along intervals on the transect. Organisms are quantified and identified to get an estimate of the density of an area sampled. This number is usually reported in % cover or number of species found.

Pa'ipa'i method- (also known as gillnet fishing) to catch fish and other organisms in the pond with large surround nets that have weights on the bottom and floats on the top/ Nets will be secured and students will form a chain, an arm's length apart, and move across the pond toward the net. They will pa'ipa'i (strike) the water surface with fronds or hands and scare the fish into the net. The animals caught will be a sample of diversity of species in the pond. The fish will be placed in buckets for identification and study. *What are the some of the shortcomings using this method to evaluate fish populations in the pond?* Is this a question you want to students to actually answer? Or just something to think about?

## Factors Affecting Fishpond Productivity

**Water Depth:** ponds two to three feet deep allow sunlight penetration that favors the growth of phytoplankton, zooplankton, and limu.

**Circulation:** water circulated with the incoming tide to wash sediments out to sea and prevent stagnation and accumulation of bottom sediments. Bottom sediments are composed of silt and layer of decaying detritus or muck. These decomposing sediments take dissolved oxygen out of the water and produced hydrogen sulfides. These sediments appear as black mud that smells like rotten eggs. In areas of the pond with this decomposing layer, Apple and Kikuchi (1975) report that a hydrogen sulfide level above 3 ppm is considered injurious to young fish. A YSI can directly measure dissolved oxygen.

**Water temperature**: the temperature varies seasonally and throughout the day. In a healthy pond, the temperature is relatively even in the water column and ranges from 64 to 88$^{o}$F in Hawaii.

**Salinity:** the salinity (amount of salts dissolved in brackish or seawater) fluctuates with the tides, depths and proximity to freshwater streams and springs. Apple and Kikuchi (1975) reported a range of salinity in fishponds studied to be from 2 to 32 ppt.

**Dissolved Oxygen:** Apple and Kikuchi (1975) tested dissolved oxygen levels in 18 Hawaiian fishponds and found a range from 16 to 13 ppm (13 to 16). The mean sea level of 7.9 ppm indicated high levels of photosynthetic activity in the ponds. Like temperature, the level of dissolved oxygen will vary throughout the day with light and cloud cover.

**Turbidity** (water clarity): the clarity of the water is related to the presence of mineral or organic particles suspended in the water. Clear water allows sunlight to penetrate and the cooler water at the bottom to warm up. Cloudy water as a result of high turbidity reduces this sunlight and may reduce the growth rate of the limu, phytoplankton and fish.

**pH**: the pH (degree of alkalinity or acidity) of the water is measured on a scale of 1 to 14, with 1 being the most acidic and 14 being the most alkaline. Due to the presence of minerals in Hawaiian waters, the pH of brackish water fishponds is generally alkaline (8-9).

| **Fishpond Water Quality Data** | | | |
|---|---|---|---|
| | Fishpond (Inland) | Fishpond (Ocean) | Open water |
| Temperature | | | |
| Salinity | | | |
| Dissolved Oxygen | | | |
| Turbidity | | | |
| pH | | | |

**<u>Water Quality and Animal Diversity Questions (Due at the end of the lab)</u>**

1. How do tides affect water temperature?

2. How does water temperature affect the solubility of dissolved gasses like $O_2$?

3. What is water hardness?

4. What are the results from your experiment?

5. Why is salinity different in the samples?

6. How is salinity related to water hardness?

7. Why is dissolved oxygen less in saltwater than freshwater?

8. What is the role of phytoplankton in the fishpond? How does the amount of phytoplankton in the pond affects the level of dissolved $O_2$?

9. Why is the shallow depth of a Hawaiian fishpond an ideal place for plankton and limu growth?

10. What are the natural fertilizers that keep the plankton and limu growing?

11. What kind of fish were caught in the net using the pa’ipa’i method?

12. Which fish were most common? Which were least common?

**Sampling Plants around the Pond**

1. Lay the rope transect out along the pond wall in the area designated. Place the quadrat at the beginning of the transect. Line one side of the quadrat with the edge of the rope.
2. Use the coastal plant sheet to identify and record each plant plant species that you identity within the quardat. If you are not able to identify a plant, sketch it and give it a name.
3. Within the quadrat, count the number of each type of plant, or record the percentage of area that each species covers. Then move two meters along the line, place the quadrat down and record again. Repeat the process until you have sampled at least three areas.

| **Sample Area** | **Plant Species Found / Status** (Status: E= endemic, Ind = indigenous, Int =introduced) | **Percent cover/number (for each species)** |
|---|---|---|
| | | |
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| | | |

**Group Discussion Questions – Diversity of Plant Life (Due at the end of lab)**

1. What species of Limu (and plants) did you find?

2. Which were most abundant? Which were least abundant?

3. Were there any differences between the areas that you sampled? If so, what factors might account for those differences? (For example, in the pond- proximity to currents; on the pond wall- protection from salt spray, shade versus sun, depth of soil)

4. How could we use the data collected to estimate the density of plant species in the fishpond and along the shore? Calculate the density for the most common species found.

$$\text{Density} = \frac{\text{\# of indiviuals}}{\text{Area}} \quad \text{or} \quad \frac{\text{total \% in quadrat}}{\text{Area}}$$

   To calculate the density, count the total number of plots sampled and determine the area in square meters. For example, if three areas were sampled, the total area is 3 $m^2$. If 60 individuals were counted the density would be 20 plants/$m^2$. If you are using % cover, add up the total % cover for each species and divide this by the area – the number of meters sampled.

5. Was the species with the highest density native or introduced?

6. What impacts are introduced plants having on the fishpond and surrounding environment? Explain your ideas.

**Assignment: LAB REPORT (Due next lab)**
As part of a formal lab report, discuss the diversity and ecology of the plants and animals in the fishpond. Discuss each water sample in terms of its overall quality and potential risk to the environment. State in which samples pollutants were identified and what type of pollutants caused the quality to drop.

For lab report guidelines, see
https://writingcenter.unc.edu/tips-and-tools/scientific-reports/

**Resources:**


Apple, Russell A. and William K. Kikuchi. (1975) *Ancient Hawaii Shore Zone Fishponds: An Evaluation of Survivors for Historic Preservation.* National Parks Service, U.S. Department of the Interior. Washington, D.C.

Project Kāhea Loko - A Teacher's Guide to Hawaiian Fishponds. Pan Pacific Foundation. (2019). Retrieved from http://ulukau.org/gsdl2.81/cgi-bin/cbook

Wyban, Carol A. (1992). *Tide and Current: Fishponds of Hawai'i.* University of Hawai'i Press. Honolulu, HI.