Aquaculture Project:
A Survey and Initial Design

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Aquaculture

In its most simple terms, aquaculture is the cultivation of water dwelling organisms for human consumption. According to the World Wildlife Fund, aquaculture is the ´fastest growing food production system in the world´ due primarily to the increasing human population and its growing demand for seafood. Aquatic environments are substantially more productive than terrestrial ones since aquatic organisms are more efficient at converting food to energy and body mass. This means that aquaculture is a very attractive endeavor for an organization looking to become self-sustainable and could potentially influence the surrounding community into pursuing more economically and environmentally sustainable endeavors.

Despite the obvious potential benefits of aquaculture, there are many more complex factors that influence the decision to pursue aquaculture. Like all ecologies, aquatic environments function at a highly complex level, and if one is to mimic natural ecology in agriculture, substantial time should be dedicated to on-site observation and extensive research before implementing any physical structures especially if it is being carried out by someone with little prior experience in aquaculture. It also should be noted that, as with most projects, one would be wise to start out small and experiment so that proper time is given to the evolution and growth of a project rather than rushing into production and risking failure. But despite these warnings, an aquaculture system at the Jama-Coaque Reserve has the potential to bring a large quantity of edible and useful products to its residents in a way that is harmless to the surrounding ecosystem.

Aquaculture at the Reserve

The specific site of potential systems of aquaculture, the Jama-Coaque Reserve, has numerous inherent positive qualities that encourage the production of aquaculture and very few negatives. The most obvious spot within the reserve for aquaculture is the low-flow natural stream that runs through the ´Norte´ section of the reserve. Although aquaculture can be utilized in almost any area, this stream and its surroundings will be the focus of this document and most likely the site of any future aquaculture endeavors. The stream is an ideal spot for aquaculture because it has a natural supply of freshwater. The water never rises above a few inches but could easily be enhanced by redirecting water from the river via the reserve's hose system. It's also located on a slope, which allows for a constant flow of water providing natural aeration and potentially easy drainage for future harvests.

The project I am proposing for this site will not take place in the stream but beside it due to construction and drainage issues. But future projects could most defiantly take place within this stream and it is partly the purpose of this project to inform any future aquaculture activities of this nature.

Aquaculture encompasses a broad spectrum of organism cultivation so it was important to consider which specific organisms would be most accessible and suitable for this site. Immediately, it is clear that the local freshwater shrimp are the best species to focus on since they were so easily accessible within the surrounding rivers and such a tasty source of protein. After this initial realization however, it was difficult to imagine how to create a system of aquaculture for the production of these shrimp that was more productive (gives a higher yield per area) than the river and easier to harvest than hunting. After a great deal of research, I discovered that it is possible to increase yields and make it much easier to frequently harvest shrimp with the construction of a shrimp "pond". The other immediate benefit of cultivating shrimp in a pond as opposed to hunting them is that opportunities for the cultivation of other aquatic organisms present themselves, such as the addition of aquatic plants, fish, or ducks. With this understanding, I set out to design a small shrimp pond that could potentially provide the reserve with a constant source of shrimp, allow for the addition of aquatic vegetables, and would function as an experiment that would inform future aquaculture projects, most obviously the construction of a larger shrimp pond with more components.

Design

The following is an illustrated design of what I'm proposing as a functional shrimp pond followed by a description of the design components:

Construction Considerations

Materials Required:
Clay collected from leafcutter ant hills
15 square feet of filter screen
Spare wooden boards
Bundles of spare hoses cut to various lengths
String to tie the hose bundles
Nets (3 already constructed)
Spare hose for the piping of water to and from the pond

Labor: About a week's worth of labor from interns and reserve employees

Cost: $0 to construct but above mentioned materials will be taken from the reserve's supply. Small amount of money may need to be invested in the future for replacement parts and possibly a water thermometer for checking water temperature. If aquatic vegetables were added, seeds would have to be purchased, most likely in the U.S.

The Pond

At this time, I am proposing that the pond should be constructed next to the stream rather than in it for various reasons. One, the pond will be small (no more than 40 sq ft.) and function primarily as an experiment and, like all experiments, it is best to have the most control you can; a continuous stream cannot easily be controlled in terms of flow while piped water can. A pond fed by piped water can also easily be drained for harvest time and refilled afterwards. Also, the stream has a large amount of groundwater under it which would make it quite difficult to landscape without unforeseen collapsing of soil, rocks etc. During a flood or heavy rain situation, the structures in the pond may become damaged or shrimp could escape due to overflow; this could be prevented with a drainable pond. Another significant benefit to building a piped pond next to the stream is that the outflow of the pond can be guided into the stream providing it with a higher flow of water and, in turn, further develop the natural landscape of the stream so that future aquaculture projects can be more informed of its natural flow and shape. In the future, it will most likely be wise to pursue aquaculture in the stream but is out of the scope of this project since it is small-scale, experimental, and requires more control.

The decision to build a canal shaped pond as opposed to a traditional circular or square pond was based on the fact that edges are much more productive areas in ponds (and most ecologies) and allow for much greater variance in habitat which allows for greater yields per area. Canals can be snaked and formed into shapes that fit the requirements of the landscape where as specific shapes like circles impose their requirements on the landscape instead of working with it. A canal mimics the natural structure of the river (where we know shrimp thrive) and will better inform any projects done in the natural stream than a pond shaped differently. The exact dimensions of the pond will be small and will be worked out when landscaping begins (due to physical limitations i.e. the position of fruit trees etc.). The Food and Agriculture Organization of the United Nations recommends a ratio of 3:20 (width:length) although this is for large commercial ponds and should be adjusted to mimic more of a natural river setting and meet the needs of this site. The pond will be small, no more than 10 feet long by 4 feet wide. The depth of the pond will vary from 2 inches to 2 feet to give the shrimp variable habitat.

The pond will be built below the path that leads from the bamboo house to the waterfalls, directly above where there is a steep drop-off and the stream begins (there is a half-pipe shaped dip in the soil at this location). The exact position of the pond was determined by considering various factors. One was to keep it away from fruit trees so as not to disturb their root systems. Also if the pond were to erode, a location for the pond that would avoid erosion into an orchard area was important. A spot containing a significant amount of clay was chosen to prevent erosion. A thick layer of clay (2-3 inches) will be placed over the pond sides and bottoms after excavation to ensure the stability of the pond over time. The end of the pond will be damned up with clay to prevent the pond from eroding over the ledge and into the stream. If for some reason this is not enough to prevent the pond from eroding, there will be no losses to the reserve, as the soil will simply flow over the ledge and into the stream. The water flow could then be stopped and the pond filled in. This location is also a particularly ideal spot because in the future it will be easy to add on ponds further down the stream that could hold various aquatic vegetables, fish (scavenging, herbivorous, carnivorous), and/or ducks.

Pond Flow

The water will be pumped through a hose from the on/off gauge that is connected to the hose unit located at the beginning of the natural stream in Norte (near the fence). The water will flow into the pond in waterfall fashion to encourage aeration. Sufficient aeration is important so that the shrimp have enough dissolved oxygen available in the water. A hose will be placed at the end of the pond with a filter to prevent the escape of juvenile shrimp. It will be buried into the dam and located at the top of the pond where water level ends. This hose will allow water to continuously flow out of the pond so that it is properly aerated and mimics the natural flow of the river. Multiple hoses may be needed to provide a sufficient width of flow since in a river the water most always have a flow wider than the width of one hose. Another option would be to carve a small canal that leads over the damn and into the stream so that room for a hose won't have to be dug into the dam, which may encourage erosion. This decision will be made when the dam is built and options can be weighed. It will drain out into the stream so that the natural development of the stream can be observed as it receives more water. When the pond is harvested, the water input will be turned off and the pond will be allowed to flow off as much as possible. More water can then be easily siphoned off until the water level is low and shrimp can easily be fished out with a net. This system will allows for complete control of the flow so that the ideal strength of flow (controlled by the gauge) can be determined over time and so that the pond can be fully drained when the time for harvest comes.

Water Quality and Temperature

Water quality and temperature will most likely not be an issue in this project as the shrimp are native and the water comes directly from the river. The pond will most likely get more direct sunlight than most spots along the river and if this heats the pond to a significantly higher temperature than would be found in the river a tarp might have to be placed over the pond in a tent like fashion when the sun is hitting the pond. Temperature can be measured with the thermometer at different times and depths and compared to the river upon completion of the pond.

Habitat

Habitat will be one of the two major limiting factors in yield. The native shrimp need proper habitat to protect them from predators, reduce stress levels, and to provide a place for shrimp to feed and breed. In the river, shrimp dwell under rocks, dead leaves, algae, and riverweeds as well as under the overhangs of hard soil, plant roots. It is very important to mimic this habitat in the pond so that yield can be increased. Having structures for habitat decreases competition for space and allows each shrimp more room to grow. It will also give smaller shrimp places to hide from larger ones that may turn cannabilistic. Wooden boards for overhang, rocks of various sizes collected from the river, and bundles of unused hoses can be used as shrimp habitat. These pieces will be made so that they are easily removable during harvest and don’t hinder the collection of shrimp at this time. The addition of a large amount of habitat is not possible at commercial scales due to difficulty in harvesting so it is a huge benefit that small-scale ponds such as this one can use more habitat to increase yield.

Pond Management

Fertilizer/Feed

The second major limiting factor to yield will be the available food. Fertilizing the pond can increase the amount of natural microscopic organisms that live in freshwater. The shrimp in the river obviously survive without fertilizer (apart from the natural fertilizer of dropping leaves, dying insects etc.) and so I do not think that large amounts of fertilizer will be necessary. However, the addition of fertilizer into the pond regimen will increase the available food and therefore the carrying capacity of the pond.

Freshwater shrimp feed mainly on zooplankton, which are tiny microscopic aquatic organisms that primarily feed off decaying matter in the water (although there are many kinds of zooplankton that perform other functions as well). Many shrimp species also feed on detritus (decaying organic matter) and I have personally observed the shrimp picking tiny bits of matter off dead leaves. Although these two sources of food will most likely be more than enough for the shrimp, other sources of food can be explored. There is a wealth of information on the diets of the most commonly farmed freshwater shrimp, the giant Malaysian prawn (prawn refers to freshwater shrimp). This species feed off zooplankton as well as worms, larval stages of other aquatic organisms, larval and adult insects, algae, mollusks, fish, and feces of fish and other animals. Since this species of shrimp are much smaller than the giant prawn and since most freshwater species are scavengers, zooplankton blooms initiated by fertilizer, as well as some occasional supplemental nutrients added to the pond should be more than enough to increase the food supply and in turn increase carrying capacity.

The recipe I've devised for fertilizer that will induce zooplankton blooms in the pond as well as supply some "ready to eat food" was informed by Bill Mollison´s Permaculture Design Manual and the UN´s FAO manual on freshwater shrimp farming, and modified to take into account what is readily available at the reserve. The recipe I feel is best suited for this site consists of compost (from the regular compost bin), fresh leaves, any vegetable scrapings or ends available (carrots are the most recommended), and any bits of tuna left in the can when available. These can then be ground up using the hand blender, mixed with water, and sprayed evenly over the pond to ensure even distribution and easy uptake. Humanure was also considered since Bill Mollison recommends fertilizing with pig or chicken waste and second stage (human) sewage. However it was decided against since it did not come recommended by the UN´s FAO document and because using human waste can be dangerous if all of the outcomes aren't considered. Yet using animal manure (and more cautiously humanure) as fertilizer should definitely be considered in future aquaculture projects.

The type and amount of fertilizer used will need to be determined and will most likely change over time. As an initial estimate, I would propose around a half a cup of fertilizer per day for the first few weeks until a natural zooplankton population is established and then step down to lower amounts. Monitoring of the health of the pond will determine if too much fertilizer is being added. Signs of over fertilization include murky water and an overgrowth of algae and aquatic weeds. It will be important to record the type and amount of fertilizer being given and to develop a food management schedule over time. Despite the unknowns involved, Bill Mollison records increases of 2 to 10 times the yield of ponds that are fertilized versus ponds that are not, showing that fertilization is a great way to increase yield.

The water that flows out of the pond will most likely be harmless. If, due to fertilization, the water has a nutrient content that is potentially harmful, the natural stream and its weeds will sufficiently filter this out before it reaches the river, much like how the kitchen wastewater filter functions. But since the pond is so small scale and because no unnatural fertilizers will be used I do not foresee pollution being an issue.

Stocking Rate

Shrimp go through many stages of growth and shed their shells at each of these periods. Although I couldn't find any specific information for this native species, the giant Malaysian prawn (freshwater shrimp are usually referred to as prawn) have three different categories of males that are different sizes and colors and each have different roles (for example the Orange Claw (OC) may mate more often where the Blue Claw (BC) may defend a territory more vigorously). These prawns have a grow out period of 120-150 days from young juvenile to adult, and I suspect that the native species in the river would require the same, if not less, time.

The rate at which the pond should be stocked was difficult to determine in this project since we are using a native shrimp species (little information available), it is on such a small scale (commercial recommendations are in unit per hectare), and because theoretically we should be able to stock the shrimp at higher densities than you would find in the river due to increased habitat and food supply. These factors, however, did not appear to be a reason to not carry through with the project, since overstocking or under-stocking will not jeopardize the project and can be monitored and recorded so that the ideal stocking rates can be determined in the future. Overstocking is better than under-stocking in this situation, because if the pond is overstocked, some of the shrimp will simply die off leaving the rest to thrive at carrying capacity. Since freshwater shrimp can be cannibalistic when overstocked or underfed, the stronger shrimp will simply eat the weaker ones in a situation where space or food is limited. This will simply function as more food for those shrimp and won't be very detrimental. Changes in population will be noted and appropriate stocking rates, fertilization, and available habitat can be determined for the future through recorded observation.

Depending on the exact size of the final pond and opinions of other people involved with the reserve, I will probably shoot for a stocking rate of around 50 juvenile shrimp of various sizes. By stocking different sized juveniles we will be able to harvest shrimp that are ready to eat in more frequent periods than if we were to stock shrimp which appear to be at the same developmental/growth phase. The phenomenon HIG (Heterogeneous Individual Growth) means that juveniles grow at substantially different rates then one another and will also aid in the ability to continuously harvest adult shrimp, making the system appropriate for a house of 3-10 residents. Any adult shrimp harvested from the pond can be replaced by new juveniles from the river in order to continue the possibility of periodic harvest. Due to the possibility of drainage and removable habitat, the catchment of only the adult shrimp will be possible with nets. I have recently made two nets of appropriate size, which have proven successful in catching shrimp in the river. These nets will also be used to catch the juvenile shrimp used for stocking the pond. The juvenile shrimp are much smaller than the adults and easier to find and catch.

Polyculture

In the spirit of permaculture, the pond will be stalked with algae, mollusks, and aquatic insects to ensure the stability and resilience of the pond, to maintain a natural nutrient balance, as well as to provide a potential food source for the shrimp. This will be done a few days prior to the addition of juvenile shrimp to ensure their establishment in the pond. The addition of juveniles will be done once these organisms look relatively established (how they look in the river). It will be important to remove the algae and riverweeds when overgrowth is observed so as to give the shrimp enough room and to maintain a healthy nutrient content for them. The removed plant material can be used as a valuable source of nutritious mulch or added to the compost.

Aquatic Plants

I have included a design for an aquatic plant section (simple) that could be added at the beginning of the pond so that the water flows through the aquatic vegetables and into the pond. This makes it so that the same water that's used for the shrimp is used for the vegetables. Also the leaf-drop from the vegetable plants will flow through the water and fertilize the shrimp pond. Some aquatic plants that could potentially be grown are Chinese water chestnuts, Indian lotus, Indian water caltrop, water spinach, watercress, taro, and arrowhead. The addition of aquatic plants to the pond can be easily completed if the necessary seeds are acquired. This is highly recommended because it brings a new mode of vegetable cultivation to the reserve that could prove less susceptible to insect and/or fungal damage and provide more on-site food production making the reserve more self-sustainable. Uses for algae, mollusks, riverweeds, and aquatic insects should be explored since I have read that they can be used for plant fertilizer and/or mulch. Algae and weeds could be a potential source of biofuel if an on-site energy supply were ever pursued.

Time and Future Projects

If it seems to be the right decision, the construction of the pond and introduction of juveniles could be completed in less than a week due to its size and ease of installation. Since I am done with my internship in 13 days, the future of this project depends on the continued monitoring and maintenance of employees and future interns of the reserve. An observation and maintenance log will be accompanied with a revised version of this document so that there is a straightforward way of monitoring the health of the pond, recording data, and making necessary changes to the design and maintenance regimen. Like I mentioned earlier, this is mainly an experiment and should only be continued as long as it proves productive and informative for future aquaculture projects.

If, after a period of months, the pond proves productive and the ideal fertilization and stocking rates are determined, the pond could be expanded or built on a larger scale with the possibility of adding fish, ducks, or more aquatic plants. Catfish cultivation pairs very well with shrimp and should be considered if fish were to be added to the aquaculture system. Duck and/or chicken coops can be built over ponds so that their manure falls and fertilizes the pond. These are only a few of the ideas that could be implemented within a larger aquaculture operation.