

The Sustainability of Tilapia Fish Farming in Ghana

Divya Rao^{1,2}, Elizabeth S. Perrino¹, and Elizabeth Barreras*¹

¹Blue Kitabu Research Institute, Boston MA

²University of Southern California Dornsife, Los Angeles CA

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Abstract

Fish are a primary source of protein for the communities of the Central Region of Ghana. Fish farming occurs on a commercial level as well as on a home-based level and methods of farming vary widely. The sustainability of each of these methods was analyzed and compared to determine the most effective, environmentally sustainable farming methods available. Recommendations are also made to improve sustainability and to conduct future research.

1 Introduction

“Eaters must understand that eating takes place inescapably in the world—and that how we eat determines—how the world is used.” Wendell Berry, farmer and writer, crosses the ts and dots the is of a basic truth about food and how our relationship with food affects the

environment. The current problem is that when people procure food they often do so in a way that damages the environment, oftentimes inadvertently, in ways that may not be immediately evident. However, the long term cumulative effects of these damages can be catastrophic in the future.

During my time in Ghana, I studied the sustainability of tilapia farming, as tilapia is a main food source for Ghanaians.. According to the textbook used by students at the Asuansi Farm Institute, fish supplies about 60-70% of the protein in a typical coastal Ghanaian diet [15]. Aquaculture, or fish farming, also provides food security to small farmers because there is a constant supply of protein available [3]. Although there are a few subsistence farms in the Central region, in order to fill the demand of the village, fish is imported from Akosombo, which is where commercial fisheries are located in the Eastern region [17]. Each small to mid-size salted tilapia, called koobi, costs around 3 Ghana

*elizabeth@bluekitabu.org

Cedi, or \$1.86 American dollars, and there are no fresh tilapia available in these small villages [17]. In one mid-size village, there are 20 koobi vendors, however on market day there are 130 vendors, which demonstrates the demand for tilapia in Ghanaian communities [17].

My project has two important section-education and development. From an education standpoint, the problem of sustainability and maintaining the environment stems from a lack of knowledge concerning proper fish farming methods and the environment, so I decided to look at how aquaculture is taught in Ghana. From the development standpoint, knowledge is great as long as you can put it to use in developing the country, therefore I assessed both subsistence and commercial tilapia farms to study current practices and to determine what could be done more sustainably.

In order to determine what is a sustainable practice and what is not, it is imperative to first define sustainability for this study. My definition of sustainability is in the context of the environment. In this study sustainable means that there are low to no negative impacts on the environment as a result of producing a certain product, in this case tilapia, so that future tilapia farming may be continued without any disruptions due to a lack of natural resources or the destruction of a natural environment. A further indicator of sustainability is if a farm has the ability to produce the same results year after year without damaging the habitat or products. In looking at tilapia aquaculture there are certain factors that need to be taken into account when

determining the sustainability of farms. Simply put, these factors are: the type of farming (method), feed (use of marine resources), disease/parasites, pollution and habitat effects, management effectiveness, escapes (fish that escape the farm and infiltrate the local ecosystem), farming intensity, and in certain cases genetics [14]. In this study I focused on the method of farming, feed, pollution and habitat effects, escapes, and farming intensity.

Many of these factors are straight-forward, however I will review a few, as well as provide a general overview of the state of tilapia farming in Ghana before discussing my study in depth. Overall, I have found that tilapia has a lot of potential for development in Ghana. The commercial farms in the Eastern region have far more environmental risks than the small-scale subsistence farms found in other regions. From the research I conducted, I have found that it would be good for the Ghanaian government to put more effort into aquaculture education, funding, and regulation.

Tilapia Farming Overview Before I arrived in Ghana and conducted my field research, I first began with an extensive literature review covering the basics of tilapia aquaculture to specific studies looking at the possibilities for aquaculture in Ghana. In order to learn generally about how tilapia is farmed, and what factors to consider in determining sustainability of farms the Monterey Bay Aquariums Seafood Watch Seafood Report on Farmed Tilapia was a good guide.



Figure 1: A man-made, land-contained fish farming facility in the Central Region of Ghana.

While this study did not directly concern Ghanaian tilapia aquaculture, it provided general factors to consider when looking at tilapia farming in Ghana such as method of farming, feed, and pollution or habitat effects as well as explanations as to what is sustainable versus what is not sustainable [14]. Then to learn more about the state of aquaculture in Ghana, I looked at a review studying the potential for African aquaculture. This study

found that although there is a lot of potential for African aquaculture, development is being slowed down by government inefficiencies [3]. This study stated that fish is extremely important in the African diet, making up 17.4% of the protein intake overall in Africa [3]. Still, aquaculture is not well integrated into African governments, and there is a general lack of fisheries legislation. African governments are more focused and concerned

with critical social services such as health-care, and education [3]. However, market and economic growth models that would help development rely on government support [3]. If African food markets could develop synergies with aquaculture then a few of the benefits would include employment, food, infrastructure development, and economic growth.

In order to understand the type of farming that occurs in Ghana today, it is important to first gain perspective on the different types of tilapia farming. Farming can be either land based or water based. Land based systems are in the form of raceways, re-circulating systems, or ponds [7]. Raceways are systems where some water is diverted from a natural running body of water directed through channels with fish and then filtered before being directed back into a natural waterway. Re-circulating systems are enclosed tanks where water is filtered and re-circulated. Ponds enclose fish in a body of water, which can be man-made or natural. Water based systems are either net pens or cages [7]. Net pens and cages essentially work the same way they are located off shore in natural bodies of water. They are usually large, and weighted down. [See Appendix A]

Fish can be managed with different levels of intensity such as extensive, semi-intensive, and intensive with each of these farming methods. Extensive is the most natural method of farming fish are not fed anything supplementary. Increased intensification uses up more natural resources and causes greater environmental degradation [14]. Semi-intensive farming requires some supplementary feeds and fertilizer in-

puts. Intensive farming relies heavily on formulated pelleted feeds known as complete feeds, where a large amount of this feed remains uneaten as waste [14]. Additionally there is often direct discharge of food and other wastes into natural bodies of water, which is harmful for general water system health. With increased intensity comes more nitrogen and phosphorous from the excess feed and wastes causing eutrophication in natural bodies of water [14].

Thus, semi-intensive and intensive farming both are less sustainable than extensive farming. Intensive farming requires high input, high fish density, and results in high output—therefore this type of farming is often seen commercially. Therefore, small scale integrated pond cultures without access to natural bodies of water are generally considered sustainable. Meanwhile, semi-intensive to intensive cage cultures in natural bodies of water are generally considered unsustainable. In Ghana, there is significant commercial cage culturing in the Eastern and Volta regions; while throughout the rest of Ghana there is subsistence pond culture. In this study pond cultures from the Central region, and cage cultures from the Eastern region have been inspected [4].

2 Field Research

During this project I visited three subsistence farms and two commercial farms one of which was a specialized hatchery. Of these, some sustainable practices were evident in both types of farms, while other practices were



Figure 2: The inside of a Tilapia farming facility in the Volta Region.

found in one or the other. Some of the sections I reviewed in assessing farms were:

1: Method of Farming Generally, sustainable aquaculture practices tend to be land-based systems such as ponds, and recirculating systems. These systems are sustainable because they are separate from natural bodies of water, treat waste properly, and reduce the risk of escapes, diseases, and par-

asites [14]. Unsustainable practices tend to be net pens, and cage cultures that are in natural bodies of water, where there is little to no water quality control, or disease, escape, or parasite prevention [14]. Escaped fish from fisheries are unhealthy for ecosystems because most of the time the fish being farmed is a different species from the fish in the habitat and when released can wreak havoc by disrupting critical relationships in

the environment. Oftentimes, these introduced species can outcompete the original species and cause the extinction of that race, which in turn affects other organisms in the environment negatively [2].

In Ghana, many of the subsistence farms are pond cultures, which are land-based systems. These farms are also environmentally friendly because they are integrated with agricultural farms and can often be used to irrigate certain crops, such as plantains, during times of drought. Also, after harvesting all the fish, the nutrient rich sediment can be used as fertilizer for crops [9]. The scraps from the farm such as cassava peels and groundnut husks can then be used as supplementary feed for the tilapia farms. Ponds average 20m by 20m, but can be either bigger or smaller depending upon the respective farmers resources. These pond cultures make use of swampy, waterlogged areas where manmade depressions fill naturally with water from the water table [9]. Usually these areas are unusable for vegetable crops and other agricultural practices.

Inlets and outlets are incorporated into the pond design allowing for easy drainage and movement of water. These pipes generally are covered with netting to prevent fish escapes, which in natural bodies of water can have negative consequences. Additionally, before adding tilapia to the ponds they are often fertilized with sacks of poultry droppings to develop phytoplankton that the fish can feed upon [8]. One farm also made sure to Lyne the water before adding fish to reduce the milkiness of the water that had come from the natural underground source [1]. Oftentimes,

the tops of the ponds dykes are planted with grasses and other plants to prevent soil erosion during the rainy season when a majority of the land is flooded [9].

The commercial farms located in the Eastern Region of Ghana are primarily cage cultures. Currently, there are around forty farms on the Volta Lake. Both farms that I visited also had pond cultures for brood-stock which are the parents for the fish that will be farmed, and separate artificial hatcheries for eggs and fry. The pond cultures were connected to the natural water body, the Volta Lake, as was the hatchery for the commercial farm. The commercial hatchery, however, is a complete re-circulating system with a filter that is not connected to the Volta Lake [16]. Since the pond cultures were built on land that was not waterlogged but sandy, they have a lot of seepage and need to be filled continually, using up precious water resources [5]. Both fisheries use hapa-based systems, which are small 1m by 1m cages, in their ponds for the brood-stock.

The cage cultures are located directly in the Volta Lake, without much management concerning water quality, waste, and excess food. The commercial farm that I visited had fifty cages, each of which measured 5m by 5m. Currently they have a stocking density of 40-60 fish per cubic meter, however in the future they plan on maximizing the density to 70 per cubic meter [5]. As the stocking density is maximized so is the risk of escapes, parasites, and disease. The reason behind maximizing the volume of the cages is so that the commercial fisheries can attempt to harvest as many times a year as possible.



Figure 3: Tilapia hatchery at Malekha Farms, a commercial farm on the Volta

Currently, the fastest farms are able to grow fish to market size in around four months [5]. The farm I visited is currently able to harvest every 7-8 months [5]. The cage cultures require divers to first remove the weights tying the cage down, before using boats and iron pipes to haul the entire cage onto land to harvest [5]. This means that commercial farms are required to harvest a minimum of 1-2 tons due to the size of the nets because they cannot harvest sections of one cage they must either harvest it all or harvest nothing [5].

2: Feed The most environmentally friendly feed in aquaculture is no added feeds always more sustainable if the fish are raised on what is naturally available to them in the pond such as phytoplankton [14]. As soon as you place food from outside the natural habitat, it automatically becomes less sustainable because the input is not native to the environment. Unfortunately, it is almost impossible to feed a significant population without supplementing food for fish because it will take too long for them to grow to a marketable size. Furthermore, its difficult to encourage

phytoplankton to grow rapidly without placing other inputs such as fertilizer, which is considered less sustainable than letting the plankton grow naturally.

In subsistence farms there are some supplementary feeds. However, these feeds tend to be whatever food scraps or farm scraps that farmers have around. In one of the three farms I visited, these feedings were fairly irregular. The tilapia are fed cassava leaves and groundnut peels from the farm scraps whenever available [8]. The other two subsistence farms I visited had fairly more regular feeding schedules for the fish twice a day every day [9] [1]. However, in one farm the feed was natural and from the available resources: groundnut peels, maize, wheat bran, and cassava starch [9]. The other farm, which was a little more prosperous, fed fish kitchen scraps, wheat bran, and special pellets all blended together [1]. While supplementary feeding is not considered the most sustainable option, it is the most sustainable viable option when considering that this industry is supplying a good portion of the protein demand for a country. Still a line for environmental consciousness can be drawn with the type of supplementary feeds. Subsistence farms providing kitchen and farm scraps is more sustainable than feed from commercial fisheries, which is nutrient rich and pelleted.

The commercial fisheries both purchase imported pelleted feeds, also known as formulated or complete feeds for their fish. Also, when the fish are very young fry, they are fed a specially mixed hormone pelleted feed. They prepare the feed by mixing a little bit of hormone with alcohol, which they mix with

the formulated feed, and then allow to dry in the sun so that the alcohol evaporates [16]. This hormone feed is key for the hormone sex reversal that the commercial farms rely upon. By changing the sex of all the fish to male, commercial fisheries are able to speed up the growing process because all the food consumed will go towards growth in fish size rather than reproduction. This hormone feed is fed to the fry five times a day, every day, for 21 days [16].

3: Pollution and Habitat Effects The amount of pollution is mainly dependent upon the method of farming. The most environmentally friendly method of farming, primarily considering pollution, comes from using integrated systems, which are pond cultures that are merged with agricultural farms [14]. Those that have moderate risks are pond cultures and re-circulating systems. Methods that pose the highest risk of pollution to the environment are raceways, net pens, and cages.

The subsistence farms that I visited were all pond cultures. However, two of them were integrated rather nicely into the agricultural components of the farms. Poultry droppings from the farm are used to fertilize the ponds, and sediment from the pond can be used as a fertilizer for the ponds [9]. None of these farms were directly connected to a natural body of water, so there is no damage to external water sources. Additionally, these pond cultures prevent soil erosion due to all the plants and grasses that are planted into the dykes. One problem mentioned by one of the

fish farmers was that an oily substance accumulates on the top of the ponds due to the feed after a couple of weeks, and they have to use a net to remove that substance [13].

The commercial farms did have pond cultures, but most of the business is vested in the cage cultures. Because these farms also use pelleted feeds, there is a greater chance for pollution. When all of the pelleted feed is not eaten it sinks to the bottom of the cage, and the accumulation of this high protein will lead to ammonia buildup. This is dangerous because ammonia causes oxygen depletion, which can not only cause fish kills but also is bad for lake health [14]. Although the effects of this buildup are not evident yet, the farms are aware that there might be problems in the future so they monitor water quality on a monthly basis, and rely upon the turbines at a local dam to aerate the water [5].

However, there is a pollution issue beyond the food waste, which is the accumulation of fish wastes, which is left untreated and swept into other sections of the lake. This will only become a larger problem as the commercial farms expand and maximize their stocking density. Also, because both commercial farms are using hormone sex reversal, there is the danger of a mishap and some hormone getting into the environment, which could have negative consequences. However, it is important to note that the commercial hatchery, which is equipped with a re-circulating system, does have a filter for waste and excess feed [16].

4: Farming Intensity The risk of escapes is a serious threat to any environment where the species is not local because that species can expand and take over an ecosystem. The risk of escapes is large when it comes to cages, and net pens in large natural bodies of water, and low in farms that have no access to natural water [14]. In Ghana, the species of tilapia used is specially created to optimize growth by a private hatchery, therefore this species is a mix of several different types of tilapia[2]. If this genetically modified tilapia escaped from a farm then there would be a good chance it would outcompete the species native to the habitat, which would disrupt the food web and organism interactions.

The subsistence farms have no risk of escapes because they have no access to natural bodies of water. Furthermore, they are careful to line their inlet and outlet pipes with netting. However, the commercial farms are cage cultures that do have a high risk of escape. One of the commercial farms has installed underwater cameras so that they can monitor the fish. Still, it would be difficult to reclaim an escaped fish.

5: Pollution and Habitat Effects As discussed in the tilapia farming overview, extensive farming is the most sustainable method of farming. Semi-intensive farming is more environmentally friendly than intensive farming but still more harmful than extensive and integrated farming. Intensity increases with the use of fertilization, and supplementary feeds, and usually causes more nitrogen and phosphorous pollution [14].

Even though farms can be labeled as semi-intensive or intensive, this means very different things for each farm, which makes intensity an abstract quality of fish farming. Semi-intensive farming is a range of practices starting from throwing tilapia a piece of bread just once or twice during the entire farming process to providing cassava starch mixed with pellets and groundnut husks a few times a week. Therefore, there is also the issue of perspective when it comes to semi-intensity. Is it really so bad for the environment if one or two loaves of bread are thrown in a 10m by 10m pond? Some authorities such as the Monterey Bay Aquariums Seafood Watch program would say yes, but others would say no, especially not if you are trying to provide an entire country with fish. My stance is that semi-intensive farming is generally acceptable dependent upon the feed if it is natural and coming from scraps off the farm I do not believe there is too much harm done, however I do believe that intensive farming is harmful for the environment.

Subsistence farms in Ghana are generally a mix of integrated and semi-intensive farming practices. Two of the three I visited were integrated with agricultural components of the farms. However, they still use poultry droppings to fertilize the ponds and create phytoplankton rich water [8]. These farms also do semi-regular feedings of whatever is available from their farm or kitchen scraps [9]. The commercial farms in Ghana are a mix of semi-intensive and intensive farming practices [5]. They do fertilize the pond cultures that they have for brood-stock and fry, however they do not fertilize the cage cultures. What re-

ally increases the intensity of the farming is the feed. The commercial farms provide formulated complete feeds for the tilapia that are not as sustainable for the environment because these are nutrient rich, dense pellets that tend to sink to the bottom of the habitat when they are not consumed and cause eutrophication [14]. A portion of this feed is mixed with hormones to help the fry grow which is unnatural, and risky for the environment [16]. Additionally, the excess food and waste is not cleared by the farms but allowed to mix into the rest of the lake, somewhat polluting the waters.

6: Genders and Breeding While there are no specific environmental threats from raising fish that are one gender or the other, or similarly from breeding, there are consequences from raising mono-sex cultures versus mixed gender cultures. First of all to get a mono-sex culture hatcheries farmers either have to hand-sex fingerlings or perform hormone sex reversal [9]. Hand sexing, which is the separation of both genders of fish by hand is clearly the more sustainable method, however with commercial fisheries that have enough capital, they will choose the foolproof hormone reversal method. The risks from hormones come mainly from the risk of escape of treated fish or the risk of pollution from the hormone itself. Raising mono-sex cultures also allow for more harvests, since all male fish grow faster than mixed gender cultures. All of the growth is going towards gaining weight and not towards reproduction [9]. Subsistence farms often try to get mono-sex



Figure 4: Open-water Tilapia farming facilities used in the Volta River.

cultures but cannot afford the hormone sex reversal so they often receive a few females, causing spawning and natural reproduction in the pond [8]. This ultimately makes it more difficult to harvest the fish and assess the marketability of the stock.

7: Financial Stability Financial stability also does not have an immediate or direct effect on the health of the environ-

ment, however there is a strong indirect effect. Logically, it would be impossible to environmentally sustain anything if you cannot even financially sustain yourself. From my research, financial stability in Ghana goes perfectly hand in hand with government support. Many subsistence fish farmers began farming fish because the government had set aside some financial support for them [8]. Still today, fish farmers can procure a loan

from the ministry of agriculture, albeit with some difficulty, if they have some form of collateral and need the money [9]. The problem is that there are so many sectors in agriculture now, and the money has to be evenly allocated for each sector, making it difficult for the aquaculture sector to get enough money [12].

Another problem with government provisions for small-scale farmers is with the promise of all male fingerlings to begin fishponds. Due to the lack of money and human resources the government provided fingerlings that were hand-sexed, which unfortunately is not always accurate. All of the subsistence farmers I visited ended up with females in the original shipment. This has resulted in natural breeding and has made harvesting the fish rather difficult because there are continually new young fish in the pond, which cannot be taken to market.

However, there is interest in aquaculture because it is an economically viable industry that still has to be developed. The Kufuor government, elected in 2001, promoted aquaculture and sent people to Israel and Asia to study semi-intensive and intensive farming in order to develop a national policy on integrating rice and fish farming [6]. The government also provides extension services from the ministries to help farmers [12]. Extension service is essentially a group of people sent out by the ministry to work as intermediaries between the government and the farmer they check on policies and also make sure that the farmers are doing well. Additionally, the government holds aquaculture workshops every year. One of the farmers I interviewed was

able to go to a workshop in Kumasi in 2005, where he was able to learn new pond aquaculture techniques [8]. Another part of financial stability for small-scale subsistence farmers is the ability to retain land to work on. One problem I learned about was that the government and chiefs or traditional rulers of towns often fight over land and power by claiming land that belongs to citizens so that they can retain some wealth [9]. Without a clear distinction and respect for farmers land it will be nearly impossible to achieve sustainable integrated subsistence farms.

3 Education Research

In order to get an education in agriculture or aquaculture students have to progress to the upper levels of education undergraduate and graduate studies. Students need to either receive a degree from an accredited university or go to specific vocational schools that offer an agricultural degree. Even though students are pursuing an agricultural education at a higher level there are not that many resources available to students. Some of the sections I reviewed in assessing the aquaculture education system were:

1. What is environmental sustainability? Two of the teachers that I talked to discussed what environmental sustainability means to them as well as the capacity in which sustainable methodology is taught to students. Eric Nyamteh, teacher at the Asuansi Farm Institute, defined sustainability as the ability to balance forces of supply

and demand, in terms of balancing our demand of Earth's resources so that we can continue to use those resources indefinitely [9]. He noted that people must have the ability to maintain the scale of equilibrium between what resources they need and what resources they must replenish [9]. Another professor discussed environmental sustainability in terms of environmental degradation and the specific risks from agricultural and aquacultural practices such as pollution. He also discussed how students are taught about sustainability through the principles of aquaculture: making sure that the two are not mutually exclusive, but that sustainable tenets are incorporated into the aquaculture curriculum [11]. He noted that if Ghanaian farmers treat the environment properly, and manage resources sustainably then aquaculture would not need to be performed on a large scale in Ghana [11].

Two of the students I interviewed stated that environmental sustainability requires supporting ecosystems and the balance of nature in essence trying to protect the environment. They believe that the government and those in power should focus more on sustaining the environment, especially with farming because it is so important to Ghana. The students said that there need to be specific places for forests and for farming, in other words a proper allocation of land. Therefore, in their minds, a sustainable farms operations do not affect the environment negatively no destructive practices like using chemical pesticides instead of organic and natural pesticides [13]. Furthermore, farming should occur in appropriate places making use

of flooded lands, and preventing overflow that can cause the deterioration of vegetable beds as well as soil erosion [13]. Most importantly to them, a sustainable farm is one that has been managed and productive economically for many years because sustainable farming automatically makes people think about economics and not the environment.

2. Aquaculture Theory Students of aquaculture study the subject in two sections theory and practical. Aquaculture techniques and principles are of chief concern during the theory portion of study [10]. However, the professors that I talked to said that while some environmentally sustainable practices were impressed, being environmentally friendly is not focus of the study. They told me that many principles of aquaculture intrinsically involve principles of sustainability such as the prevention of escapes, although the motivation for this is linked to financial reasoning [11]. Also, the governments perspective on tilapia farming has an effect on the education that students receive. So far, tilapia farming has not been that well developed or provided for by the government, so there is more concern about how to achieve economic stability with farming than how to protect the environment while farming. Also, one professor I met with told me that he has not witnessed that great a change in the environment due to subsistence pond cultures because it is almost an organic method of farming compared to the commercial farms in the Volta region [9]. A better education therefore could be provided if there was more

development of fish farming in the central region, and if there was more attention on the overfishing issues happening on the coast of Ghana.

Many of the courses offered for students of aquaculture also have theories of environmental sustainability built into them. One university I visited offered courses on aquatic pollution, and integrated coastal zone management. One of the main concerns of these classes is trying to focus on managing the natural resources Ghana has available. This university tries to make sure that undergraduate students gain a holistic understanding of aquaculture and the environment [10].

At one agricultural institute I sat in on the class regarding Environmental Management and Aquaculture. In environmental management the class was focused upon the causes of environmental degradation. Environmental degradation is the gradual deterioration of the environment leading to the inability for resources to support life, because of the overexploitation of natural resources [9]. The class also discussed renewable and non-renewable natural resources, and how renewable resources can only be regenerated if there is enough time allowed for the resource to rest. The professor clearly stated that agriculture, human settlement, use of forest resources, mining, and use of water resources are the chief causes of degradation [9]. These practices, which can often include overgrazing, over-cultivation, and deforestation can lead to desertification. The class discussed Ghanas dependency on forests for everything, and therefore they have to be careful to maintain these precious natural resources.

Often the problem with an industry that requires natural resources is that after the process of farming or mining is carried out, nothing is done to reintegrate the land and restore it to its natural state. The Asuansi Farm Institute professor talked about how a fishmeal company in Tema was recently arrested for improperly disposing of waste [9]. Furthermore, he added that the Environmental Protection Agency, a branch of the government, gave certification to a company that is disposing of their industrial waste into a river, making it unusable for a village that relied upon it [9]. When businesses and the government cannot take the time to maintain the natural resources that the country relies upon, not only is this disastrous for future economic stability but it is also precarious for environmental health.

3. Academic Perspective on Current Tilapia Farming According to the professors that I met with most tilapia farms in Ghana today make use of semi-intensive culturing [11]. These farms are mainly semi-intensive because of the supplementary feeds farmers provide to the fish a mix of pelleted feeds imported from Asia and local farm scraps such as groundnut husks, wheat bran, and maize. There are, however, intensive farms along the Volta in the Eastern region. Foreigners, who have the capital to procure huge cages and many workers, run these farms. Due to the influx of commercial farms, industrial hatcheries have been set up to supply Ghanas farms with fry and fingerlings.

The professors also noted that starting

these farms requires a large capital because they need constant electricity and a lot of power for the re-circulating systems. However, this capital is turned over rather quickly because tilapia has a huge market in Ghana. Still, these farms are plagued by problems common to large commercial fisheries just last year there were fish kills due to a low oxygen level from the decomposition of plants and other organic material [11].

4. Resources In order to look at the resources available to students studying aquaculture, I visited the libraries at both of the institutions I visited. At the university, I found that the aquaculture section was not very large, around seventy books in total. Many of these books are outdated, and concerned with the fisheries management such as dealing with fish diseases. One book, *Fishery Science: Its Methods and Applications*, by George Rounsefell and W. Harry Everhart (year) discussed many environmental issues that are still prevalent today. These subjects included the effects of exploiting fish, the prevention of fish escapes, the effects of pollution, and habitat improvement. Other books also mention the maintenance of water quality from an ecological point of view with studies on the effects of pollution on fish. One continuous perspective that I noticed in reviewing the books was that all the biological considerations, hazards, and diseases are all addressed from a viewpoint where the fishery is attempting to get the highest economic yield and profit possible rather than looking at the quality of fish produced.

Still, many of the books advocated for intensive fish culturing, which is not as environmentally friendly as semi-intensive farming. There was discussion about supplementary feedings, mono-sex cultures, and gender treatments in this context. As well as books with chapters focused on genetics and reproduction with the intent of hybridizing tilapia for the fastest growing possible. Although there is the commercial farming aspect, there was also a lot of information on pond aquaculture. Furthermore, there were books mentioning that research needs to be done on the ecological niche of hybrid tilapias, which is a good, sustainably concerned point. Overall, this university did have a lot of resources compared to other institutions for aquaculture. Most of this information, however, was devoted to pursuing aquaculture from purely an economic standpoint. There were no books solely based on environmental sustainability. If there is more of an emphasis on sustainability it will become easier to maintain an environmentally friendly fishery and there will be long-term economic stability. Also, many of these books were from the 1980s or earlier and therefore need to be updated. One book mentioned using DDT as a pesticide or preventative aid in rearing fish. DDT is now well known as a toxic compound, illegal to use in the United States due to the severe damage it can cause both to the environment and to humans.

This was in many ways similar to and very different from the other institution that I visited. There were only three books on aquaculture, including the textbook for students to rely upon. One of these books was an out-

dated report discussing the status of aquaculture in Ghana. The other was a short guide to fish preservation, which did mention the overfishing problem along Ghanas coast, and some prevalent open water fishing practices such as trawling and purse-seining. There was nothing specifically on fish farming, which means there was really no chance of having material on aquaculture sustainability.

That being said, the textbook was newly put together by a past teacher of the institute and did contain a discussion of many environmentally sound policies [15]. The first of which promoted aquaculture for the very reason that it allows for the enormous pressure on the dwindling fish stocks in the ocean to be reduced. Additionally, pond cultures maximize the utilization of marshy landwaterlogged areas where no plants can be cultivated can be used [15]. The textbook also talked about biological considerations when making a fishpond, which includes keeping the population density low so that there is enough oxygen, and food for the fish [15]. Additionally, population density should not be high otherwise there would be cannibalism, and a higher risk of disease. This institution needs to provide more new resources for students in addition to the textbook in order to positively influence the next generation of fish farmers.

5. The Next Generation of Farmers

At the second institution that I visited, I was able to interview some students about what they would practice after they gradu-

ated from the school in terms of fish farming. Across the board, all the students said that they would start out small with one pond around 10m by 10m because fish farms are initially very laborious and cost intensive [13]. In this pond they would have 1000 fish. After achieving success they all said that they would want to expand, and get as many as six ponds, which would be a similar size to the first, for their respective farms [13]. All of the students said that before filling the ponds with fish they would fertilize the ponds with poultry and pig droppings to increase the amount of phytoplankton in the ponds [13].

The students all stated that they would have a monoculture of tilapia that is all male so that the fish can grow faster. However, because of hand sexing, which is what they would only be able to afford, they realize that there will potentially be females in their first batch of fingerlings. Having an all-male fishpond they would be able to harvest the fish every six months [13]. Two students said that they would prefer to feed fish the pelleted feed because they would be able to grow faster, but since it is so expensive and imported they would balance the costs with a maize and millet feed [13]. Two other students said that they would feed the fish a mix of wheat bran, cassava, maize, and farm scraps. All the students said that they would feed the fish twice a day, three times a week for best results. This would be considered semi-intensive fish farming, and is generally environmentally friendly.

One environmentally friendly practice that all the students want to incorporate into their fish farms is integration with the agricultural

components of their farms. The students also plan on surrounding the fishpond with trees so as to provide shade for the fish, because high temperatures make it harder for fish to rest and grow [13]. The heat causes fish to constantly move in search of colder waters, therefore all of the food the fish consume is used up as energy and growth is stunted. They hope to store the excess water in case of a drought. Furthermore, they would incorporate an overflow pond, and set up the ponds so that they could direct the excess water into other fishponds via inlets and outlets. These pipes would be covered with netting so that there would be no risk of escapes. In order to prevent pests from getting into the pond, they would spray pesticides around the pond as well as cover the pond with nets to prevent snakes and frogs from entering.

4 Recommendation

During my weeks of research, I have managed to gain what I believe is a fairly comprehensive review of tilapia farming in Ghana today. I was able to meet with several professors, who are experts in the field, as well as visit farms, and talk with teachers and students of aquaculture. In the future, Ghana needs to become more aware of its natural resources and focus on conserving them so that they can build stable and successful industries. From what I have learned, it is possible for individuals and NGOs to have an effect on farming; however, it is my belief that for any significant, long-lasting change it is the government that needs to first make the changes.

The Ghanaian Government ought to make more policies on regulating fish farming in an environmentally sustainable manner, for example monitoring the levels of nutrients at commercial fisheries that leak into the environment when pelleted feed is not consumed. Also policies regarding waste management, fertilizing, and pollution should be implemented. They also need to make correct bureaucratic decisions and should mandate a sustainable element to the curriculums of agricultural students.

However, I do think that there is opportunity for NGOs to get involved and make a significant difference in the aquaculture industry in Ghana. Right now, a major problem preventing the expansion and development of tilapia farming is that subsistence farmers cannot afford to build ponds. Therefore, if a microfinance operation was set up to provide that initial capital, around \$250 US dollars, required to build a fish pond for enough farmers then the unsustainable commercial farming dominating the Volta would be unnecessary because these subsistence farmers would be able to manage the demand. Along with the money, should come a set of guidelines that the farms should be run on such as integrating the fish pond with the agricultural crops, etc. Therefore, I recommend that microfinance operations specifically modified for subsistence farmers in rural areas be set up so as to develop and improve tilapia aquaculture in Ghana.

5 Conclusion

There is a lot of opportunity in Ghana for tilapia aquaculture the demand is high and therefore it can be a lucrative practice for subsistence farmers. Moreover, the expansion of tilapia farming can provide Ghanaians with greater food security. However, this development needs to be accomplished in an environmentally sound manner so that the future of the industry will remain economically stable. Therefore, in addition to working with the government to develop a more environmentally conscious set of policies and curriculum for agriculture students, a microfinance operation should be set up to provide subsistence farmers with the support they require for building sustainable fishponds. The reason that an environmentally conscious curriculum is necessary for future farmers is because the methods of farming which students learn is what they will implement. Furthermore, if they are conscious of the natural resources that they have and manage them correctly they will always be financially stable because those resources will then never be depleted. That being said, there is definitely room for further research in Ghanaian aquaculture for example more can be done on the science side of things by looking at the effects of commercial farming on the Volta with water quality, and waste management. I think more research can also be done on the feeds provided to fish looking at the environmental implications of using different feeds compared with what feeds optimize fish growth.

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7 Glossary of Aquaculture Terms

1. **Escapes:** Farmed fish that manage to escape their enclosure and enter the environment
2. **Extensive farming:** The most natural form of farming, no inputs
3. **Semi-intensive farming:** Some inputs such as fertilizer, and natural feeds
4. **Intensive farming:** Fertilizer used as well as manufactured pelleted feeds
5. **“Complete” feed:** Manufactured pelleted feed, often imported
6. **Integrated culture:** When a pond culture is incorporated with the agricultural components of the farm
7. **Re-circulating system:** Enclosed system where water is filtered, and recycled
8. **Hapa based system:** 1m by 1m pens that hold brood-stock, promote mating, and allow for the easy collection of fertilized eggs

9. **Fertilizer:** In input used by farmers to promote the growth of phytoplankton
 10. **Stocking Density:** The density of fish in nets, cages, or ponds
 11. **Hormone Sex Reversal:** A treatment used to turn all hatchlings into males so that they grow faster, and prevent reproduction
 12. **Mono-sex culture:** A culture of all male fish
 13. **Hand-sexing:** Sorting the genders of fish by hand instead of using hormones
 14. **Fingerlings:** Young fish
 15. **Brood-stock:** The parents of the fish that are being farmed
 16. **Supplementary Feeding** Feedings that are inputed by farmers, anything given to the fish that is more than the plankton available in the habitat
 17. **Trawling:** A drag net fishing method used in the ocean
 18. **Purse-seining:** A wall of netting, the bottom of which can be pulled close to capture a school of fish
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