Best Practices for Small to Medium Scale Tilapia Aquaculture

Incopesca

Instituto Costarricense de Pesca y Acuicultura

July 5, 2005

Sr. Álvaro Otárola Fallas
Instituto Costarricense de Pesca y Acuicultura
San Jose, Costa Rica

Dear Sr. Otárola:

Enclosed is our report entitled Best Practices for Small to Medium Scale Tilapia Aquaculture. It was written at Instituto Costarricense de Pesca y Aquaculture during the period January 13, 2005 through July 5, 2005. Preliminary work was completed in Worcester, Massachusetts, prior to our arrival in Costa Rica. Copies of this report are simultaneously being submitted to Prefessors Vernon-Gerstenfeld and Gerstenfeld for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We sincerely appreciate the time that you and Dr. Rolando Ramirez Villalobos have devoted to us.

Sincerely,

Megan Slonski

Adam Broders

Matt Douville

Title Page

Report submitted to:

Professor Susan Vernon-Gerstenfeld and Professor Arthur Gerstenfeld

Costa Rica, Project Center

By

Names:	Signatures:
Adam Broders	______________________________
Megan Slonski	______________________________
Matt Douville	______________________________

In Cooperation With

Álvaro Otáro Fallas, Head of the Department of Aquaculture

INCOPESCA, Department of Aquaculture

BEST PRACTICES FOR SMALL TO MEDIUM SCALE TILAPIA AQUACULTURE

Date:____________

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of INCOPESCA or Worcester Polytechnic Institute.

This report is the product of an education program, and is intended to serve as partial documentation for the evaluation of academic achievement. The report should not be construed as a working document by the reader.

ABSTRACT

The goal of our project was to inform INCOPESCA of the condition of small and medium scale tilapia farms throughout Costa Rica and to identify the best practices for this type of production. We conducted twenty interviews at tilapia farms, where we identified the current practices in use and aspects of aquaculture in which the producers require assistance. Then we determined a set of best practices for this type of production and created a pamphlet containing three important topics. We also made recommendations to INCOPESCA designed to encourage the implementation of our findings. Our project aims to improve tilapia production, which will then support job creation and provide a protein-rich source of nutrition to many in need.

AUTHORSHIP PAGE

This paper was written in entirety by all team members. Matt Douville, Adam Broders and Megan Slonski all made equal contributions. All of the sections can be construed as teamwork.

ACKNOWLEDGEMENTS

As we look back on the work we have just completed for our Interactive Qualifying Project, we realize that we are indebted to many people to their contribution to our project.

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While in the United States we interviewed Professor Michael Rice, a professor at The University of Rhode Island, and Mr. John Reid, president of Bioshelters, Inc. We would like to thank both of these individuals for their time, the information they provided to us, and the contacts they put us in touch with.

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EXECUTIVE SUMMARY

The goal of our project was to inform INCOPESCA of the current condition of small and medium scale tilapia farms throughout Costa Rica, to identify the best practices for this type of production, and to find ways for INCOPESCA to relay our findings to the farmers. It was very important to achieve this goal because when problems arise in a tilapia farm they can have a very large impact on a farm's production rate and ultimately the revenue that the producer will receive.

In Costa Rica, a developing nation of nearly 4,000,000 inhabitants, about 3,600 people are dependant on the tilapia aquaculture industry. Many of these people own small farms that are located in rural areas where there are very few sources of income. In the past banana and coffee farms used to provide many jobs in these areas, but as world prices fell, some people became unable to make a living working in these industries. Many turned to tilapia aquaculture in hopes of increasing their income and improving the quality of life for themselves and their families. The implications of our project apply not only to Costa Rica but also to many other countries around the world. These include Thailand, the Philippines, and Honduras as well as many other countries located in tropical areas that are near the equator because of their similar climates and economic situations.

We are aware that there is sufficient knowledge in available literature regarding the best practices for tilapia aquaculture. However, our project aimed to identify a set of best practices that are specific to small and medium scale production in the tropical country of Costa Rica where monetary resources and technology are limited. To accomplish this we initially conducted onsite interviews at twenty farms in the Atlantic

region of the country. From the interviews we were able to learn which topics farmers would like to know more about and which aspects of cultivation caused the most problems for the producers. These areas included management of the farm, proper stocking density of the tanks, feeding of the fish, diseases that affect the fish, and design of the tanks.

As a result of the interviews, we were able to learn about the level of management that is practiced by the producers. An important aspect of managing a farm is properly registering it. Costa Rican law requires that a producer register a farm in order to gain permission to use public water and to commercialize the product. Another aspect that is vital to properly managing a tilapia farm is that an owner keeps records of their production. One benefit of record keeping is that it provides for more accurate knowledge of the size and quantity of a producers crop. This leads to more precise feeding when a producer uses a feeding table. Additionally, when problems arise in production, records allow for a producer to see the circumstances that led to the incident. Another beneficial practice would be to form aquaculture clubs that could unite the farmers in an area. Larger groups could purchase feed, technical assistance and other supplies at lower prices. Also if the producers openly share concerns and solutions to problems, then everyone involved would benefit from the exchange of knowledge. Unfortunately the producers as a whole did not practice these management techniques and often encountered problems that could have been remedied through these simple practices.

We have observed that producers have difficulty determining how many fish to keep in each tank, yet proper stocking density is crucial in the efficient management of a tilapia farm. On the one hand, too many fish in a pond leads to low oxygen levels in the water. This causes the fish to become stressed and if levels fall too low the result can be fish mortality. On the other hand, too few fish in a pond is an inefficient use of the producer's resources because the same tank could be used to produce more fish. Through research we have found a simple procedure that the producers can use to determine the optimal stocking densities for each of their tanks.

Even though the feeding of a tilapia crop is one of the most important aspects of production, farmers have shown many problems implementing accurate feeding methods. Through our investigation, we discovered that there were huge differences from farm to farm in how much food the fish received per day. Although this is partially because there are varied amounts of natural feed present in the different tanks, the majority of the variation comes from the fact that the producers do not know the appropriate amount to feed their crops and also do not know how much they actually do feed their fish. This is a serious problem for two reasons. If the farmers are feeding their fish too much of the expensive feed, then they are wasting money. However, proper nutrition is vital to efficient tilapia growth, which can be stunted when the fish are not receiving enough food.

The majority of producers we interviewed have experienced problems with disease in their fish. There are harmful bacteria present in the natural water sources in Costa Rica at all times. Healthy fish have natural defenses that protect them against these bacteria. However, when fish become stressed for any reason, their defenses are lowered and they become susceptible to the effects of the bacteria. If not promptly treated, the disease can spread to the entire crop causing widespread mortality.

After observing the design of numerous tilapia tanks, we recognized two main flaws that can be easily remedied. The first area is in regards to the location of the water exit for the tank. The majority of the tanks we saw had tube style exits located at the top of the tank. In this setup the water that enters at the top only moves across the surface before it leaves the tank. This does not allow for proper circulation of the water located at the bottom of the tank. A better alternative is to locate the water exit at the bottom of the tank. With this type of exit the water is forced to circulate throughout the entire tank before leaving through the tube instead of merely skimming across the surface. This results in a much cleaner tank which is key in the prevention of disease.

The other design flaw is that many producers do not have nets set up over their tanks. A system of nets prevents birds from eating the farmer's fish. This threat is especially relevant for the fingerlings because their small size makes them easy targets for birds. Another benefit of using nets is that they prevent fish from jumping out of the tank and escaping into the natural water source. The frequent escapes have caused concern for environmentalists because tilapia breed at a faster rate than many species of fish and will eat a large portion of the natural feed in the water. This is a problem because the tilapia take away precious space and resources from the native fish.

After thorough analysis of our findings and determination of a set of best practices for tilapia aquaculture, our team has developed the following recommendations for INCOPESCA and for producers. The main goal of these recommendations is to encourage the producers to adopt the best practices that we have determined.

We recommend that INCOPESCA distribute "Manual de Buenas Practicas" to existing producers as well as people who are interested in starting a tilapia farm. Our team created that manual for small and medium producers, which focuses on proper feeding techniques, optimal stocking densities, and disease recognition and treatment. The distribution of that pamphlet can be accomplished in a number of ways. Copies should be kept at INCOPESCA offices throughout the country in waiting areas or other areas that are easily visible to a farmer. The manual can also be distributed when farmers buy fingerlings by attaching a copy to the shipments. Likewise when a person registers a farm or requests technical assistance, INCOPESCA should hand out the manual.

Our second recommendation is that INCOPESCA advertise in newspapers that circulate in areas where tilapia farms are common. This will allow more people to learn what INCOPESCA is and about the services they provide to the public. We recommend that INCOPESCA advertise discounts on technical assistance, nets, or fingerlings when a person registers a farm or when they request assistance in groups. It is very important for producers to properly register their farms and to form aquaculture groups, and this type of advertisement will help promote these practices.

The third recommendation is that INCOPESCA hold a seminar for employees that provide technical assistance to farmers. The focus of the seminar will be to relay our findings to the employees that can deliver the information to the public. This will update them on the current status of the farms, inform them of the type of information producers need and want to know, and also will allow them to see which practices we have deemed most appropriate for small and medium scale tilapia production. We recommend that the PowerPoint from our final presentation be used as a visual aid for this seminar because it clearly displays a lot of information pertaining to these areas.

CHAPTER ONE: INTRODUCTION

In developing nations, maintaining a balanced diet is a very serious problem for many people. It can be a daily struggle to receive an adequate amount of essential nutrients such as protein. As stated by the World Hunger Education Service (2004), approximately 850 million people living in developing nations suffer from protein-energy malnutrition, which is the most lethal form of malnourishment in those countries. Even though the situation is improving, lack of a reliable protein source is a huge concern for millions of people throughout the world (World Hunger Education Service, 2004).

Subsistence aquaculture can be a very beneficial industry to developing nations around the world. It can supply nutritious protein-rich food for families and sometimes even for whole communities to enjoy. A typical four ounce fillet of tilapia, a newly popular fish that is easily produced through aquaculture methods, contains about ninety milligrams of omega three fatty acid and twenty-one grams of protein (Fitzsimmons, 2002). For a person with a two thousand calorie diet, only fifty grams of protein a day is recommended. Omega three fatty acids have been proven to reduce inflammation throughout the body, keep blood from clotting excessively and maintain the fluidity of cell membranes.

Not only can subsistence aquaculture provide people with a reliable source of protein, when done correctly, it can also provide a reliable source of either primary or secondary income to its producers. The benefits from this added income can have a substantial impact on an individual in a developing nation. Edwards (1999) claims that it has the capability to bring people above the poverty level at a fast rate. According to the Food and Agriculture Organization of the United Nations (FAO), aquaculture has the potential to aid in poverty alleviation, food security and social well-being, and already does so in many developing countries. In fact, approximately 90 percent of the world's production of aquaculture is produced in developing countries by small scale producers.

The ideal situation for subsistence farmers in developing nations would be to have the small tilapia farmers successfully run and manage efficient, highly productive farms. Unfortunately, the reality is that many farmers produce low yields, pollute the environment of surrounding areas, or fail completely because they have insufficient knowledge as to what the best practices are when managing the processes involved in tilapia culture. It is possible to maintain a successful fish farm in such situations as encountered in a developing nation, but proper supervision and management techniques are crucial. Edwards (1999) claims that many of those people have not been given information that they are able to use partly because of technology restraints on people below the poverty line. Additionally, Richard Pretto (1996) of the FAO states that it is common for farmers to not know some of the basic techniques such as crop rotation, pest control, and proper use of nutrients.

In doing our preliminary research, we have discovered that there are very few resources that are readily available to a potential aquaculture producer in a developing nation. We have been able to locate many bodies of information pertaining to aquaculture, but many are severely outdated or unavailable. Others do not pertain to tilapia specifically or do not contain strategies that are feasible for someone in a developing country.

One country that has realized the possible benefits of subsistence aquaculture is Costa Rica. According to the Costa Rican Fisheries and Aquaculture Institute, the number of citizens that are dependant on the aquaculture industry in Costa Rica, a country of nearly four million people, increased 18.5 percent in just one year, from 772 in 1999 to 915 in 2000 (Alceste and Jory, 2002).

Instituto Costarricence de Pesca y Aquacultura, more commonly known as INCOPESCA, is a government organization responsible for developing the Costa Rican aquaculture industry. One of their tasks is to work with small and medium-sized farms, which includes educating the producers and providing them with technical assistance. For the duration of our stay in Costa Rica, we worked with INCOPESCA in an effort to help them achieve this part of their mission.

The goal of our project was to inform INCOPESCA of the current condition of small and medium scale tilapia farms throughout Costa Rica, to identify the best practices for this type of production, and to find ways for INCOPESCA to relay our findings to the farmers. The objectives to achieve our goal were to interview tilapia producers to investigate the current policies, analyze the data that we received during the interviews to determine the overall best practices to run a successful tilapia farm, and develop methods for distributing our findings. One of these methods was to create a best practices pamphlet covering three areas that producers were having problems with.

CHAPTER TWO: BACKGROUND INFORMATION

Tilapia are rapidly becoming one of the most popular and frequently cultured white fish throughout the world (Alceste & Jory, 2002). Due to the ease in which tilapia can be cultured and the high nutritional value they provide, many people in developing nations are culturing tilapia at the subsistence level. Seeing the positive results that industry can produce, many others in those areas are becoming interested in that developing industry. Farm management can prove to be very difficult for many new producers because information about proper management techniques is not readily available to many of the people.

After a brief discussion of aquaculture and tilapia history, this chapter will discuss the processes involved in the production of tilapia. The major aspects of tilapia aquaculture are broken down into the following sections: types of aquaculture systems, feeding, population control, environmental parameters, and fertilization. We feel that these sections contain pertinent information necessary for the understanding of the production of tilapia.

HISTORY OF AQUACULTURE

The United Nations Food and Agriculture Organization (FAO) defines aquaculture as "The farming of aquatic organisms including fish, mollusks, crustaceans and aquatic plants. Farming implies some sort of intervention in the process to enhance production such as regular stocking, feeding, protection of predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated." The concept of aquaculture and cultivating fish has been in practice since ancient times. It is unknown exactly which civilization was the first to begin the practice of aquaculture, but some of the oldest evidence has been found in Chinese manuscripts, originating from the fifth century B.C. In those manuscripts, it was stated that these early cultivators collected immature fish from surrounding water sources, and then placed them into an artificial environment that was to be controlled. Egyptian hieroglyphics have also been discovered containing evidence that some form of aquaculture was used (Pompa, 1999).

Pompa and Masser (1999) state that a large step in the transformation of aquaculture came in the year 1773, when a German farmer gathered eggs from a particular fish, fertilized them and proceeded to grow and raise them into mature fish. From that point in time, scientists began discovering more about the biology of the fish and the needs required for it to live and develop. Those discoveries were in the areas of the stimuli that encourage growth, sexual maturation and reproduction. The improvements allowed the cultivator to have greater control over the developmental stages of the fish.

Following World War II, aquaculture began to gain popularity. White, O'Neill & Tzankova (2004) explain that before that time, developed countries were putting all of their money towards the war effort, and the public were unable to spend money on such luxuries as expensive fish. Practices of aquaculture had not been refined and only fish that were considered to be delicacies were being produced. When the war ceased, economies of many nations began to grow, allowing the general population to have money to spend. That newly found demand allowed new techniques to be developed, which led to the cheaper cultivation of the fish. In the year 1970 aquaculture consisted of

3.9 percent of all the fish production in the world. Thirty years later, the total production grew to 27.3 percent.

HISTORY OF TILAPIA AQUACULTURE

Pompa and Masser(1999) declare that Oreochromis nicloticus, more commonly known as tilapia, is the third most commonly cultured freshwater fish in the world. Tilapia are a fish originally from the Nile River and are descendants of the Cichlid family. Their appearance is similar to that of a perch or snapper but is easily identifiable by an interrupted lateral line down its back which is a characteristic of the Cichlid family. Tilapia became well-liked by consumers because it offered a sweet flavor and contained few small bones. Producers were also pleased with the fish because it grew very fast, was resistant to disease, and was tolerant of stress incurred during handling.

Bardach, Ryther & Mclarney (1975) state that experiments involving the cultivation of tilapia have been undertaken, dating back as far as the 1920's. Over the last fifty years, interest has grown tremendously in the culturing of tilapia and has led to the world-wide distribution of this fish. In the 1960's many developing nations began practicing tilapia aquaculture because of the vast impact it was having on the world's food production. Originally, the mindset of these countries was that tilapia farming was a way of providing the owner of a small farm with a large amount of quality protein at a very low price. Countries were not using the industry to increase their economy through the trade of the fish. In the 1970's production was geared toward providing the local community that surrounded the farm with the fish, but this soon proved to be unsuccessful. Alceste and Jory (2002), writers for Aquaculture Magazine, have stated that a reason for the failure was the lack of knowledge the farmers had of the industry.

Many were not aware of the management that was required to successfully run an aquaculture farm and began to lose many of their fish. With those loses, the average farmer was not able to earn enough profit to stay in business. It was not until large corporations began to take over the industry and to develop new techniques that many of the problems these farmers were encountering were solved.

Tilapia was introduced to Costa Rica in the 1960's. Fitzsimmons (2000), a professor at the University of Arizona, explains that just as in many of the developing countries at this time, tilapia aquaculture in Costa Rica started with small rural production that produced the fish mainly for the individual. When corporations began taking the industry over, they brought a new form of cultivation with them from Taiwan. This technique became known as flow through systems. The first attempt to introduce tilapia into trade was in the form of canned Tilapia. The name of the product was called "Lomas de Tillapia". The first major farm was created in Cañas by the company Aquacorporacion Internacional. There the flow through systems were utilized and the farm has been developed into the largest commercial tilapia farm in the Americas.

Shiau (2002) asserts that tilapia is now the third largest farmed fish produced in the world. Its annual production rate makes up 11.5 percent of the total production of farmed fish. In many places it is becoming a substitute for the traditional types of whitefish species. With a global production increase from 186,544 metric tons in 1984 to 659,000 metric tons in 2003, tilapia is becoming one of the most popular forms of aquaculture in the world.

TYPES OF AQUACULTURE SYSTEMS

The type of aquaculture system that farmers will use is dependent on their geographic location, availability of resources and financial situation. Different types of systems perform well in certain environments but not in others. In the aquaculture industry, there are two distinct types of systems that are separated by the environment in which they keep the fish. They are water-based systems and land-based systems. Systems are also then categorized by the amount of technology used. The three categories are extensive, semi-intensive and intensive systems.

Water-Based

Funge-Smith and Phillips (2001) describe a water-based system as one that uses an already existing body of water as a containment structure for cultivation. The most common example of this is to use a nearby pond. Water-based systems are very useful when there is a body of water that is not drainable and tanks are not realizable at the site. An advantage to using water-based systems is that they are a very low cost investment for a farmer who is just starting out in the practice of aquaculture. It is not necessary to purchase permanent tank structures or raceways. This design also allows the fish to be grown in a situation mimicking their natural habitat. This practice produces an overall healthier looking fish (Massachusetts, 1995).

However, there are some disadvantages that are very prominent as well. There is a large risk of losing many of the harvest due to poachers, because the water source is open to the public. Having a water source open to the public and everyday environmental factors can also make the fish very susceptible to an outbreak of disease. In spite of these negative factors, water-based systems are increasing globally because of the previously mentioned benefits (Funge-Smith and Phillips, 2001).

Extensive Farms

Extensive farms are a type of aquaculture farm that uses the lowest level of technology. They are located in standing bodies of water that are unable to be drained. These farms depend on one type of feed without any supplements added. This type is the natural feed that will enter the system through the water flowing into the fish's environment from the main water source of the area. For example, a cage might be placed in a small pond that is fed by a stream that flows into it. The feed will be supplied to the fish by the entering water from the stream. By relying on natural feed however, it can be very hard to control harvests. Many farmers are forced to use this method because they do not have the money for commercial produced feed and fertilizers (Kumar, 1999).

Semi-intensive farms.

Semi-intensive farms are aquaculture farms located in standing bodies of water that are also largely dependent on the natural food that is produced by the water flow to the fish's environment. The major difference between an extensive farm and a semi-intensive farm is that the natural food in a semi-intensive farm is supplemented with an organic or inorganic type of fertilizer. Semi-intensive farms are also quite versatile. For example, the density in the tank may be increased or commercial grown products found in the area may be used. The major cost of maintaining a semi-intensive farm is the purchase of supplemental feed and fertilizer. Kumar (1999), states that 60-70 percent of the total cost of production comes from the purchase of feed.

Land-Based

Land-based systems can be used in many different environments, but most predominantly if a pond cannot be dug or there is no water source to be used. The two main types of holding systems are raceways and tanks. Raceways consist of a rectangular trough that has a length to width ratio of 4:1 that is created with a slope in order for the water to flow from one end to the other. They can be easily constructed and because of the steady water flow always replenishing the oxygen levels, they are able to maintain large densities of fish. However, a disadvantage to the raceway is that it requires a steady flow of highly oxygenated water that can be difficult to maintain (Massachusetts, 1995).

Tanks can be created very easily as well and are also very inexpensive to install. Tanks can be constructed out of concrete, fiber glass or wood. The preferred material however is fiberglass, because it is light and relatively inexpensive. The tanks are created in an oval shape with a water inlet near the surface which allows for a steady circulation of the water. This circulation draws the solids towards the center of the tank which allows the solids to be drained out. This increases the feed distribution and allows for easier maintenance of the tank. A tank should also have a depth of 1.5 meters or less. If a tank has a depth greater than 1.5 meters, than the water will not heat up and cool down uniformly, exposing the fish to sudden temperature changes (Massachusetts, 1995).

In each of the two holding systems there are different ways in which the water is distributed to and from the containment system. One type is called a flow-through system that discards the water after it has been used. Flow-through systems can be set up in two ways: parallel and series. These designs can be seen in Figure 1.

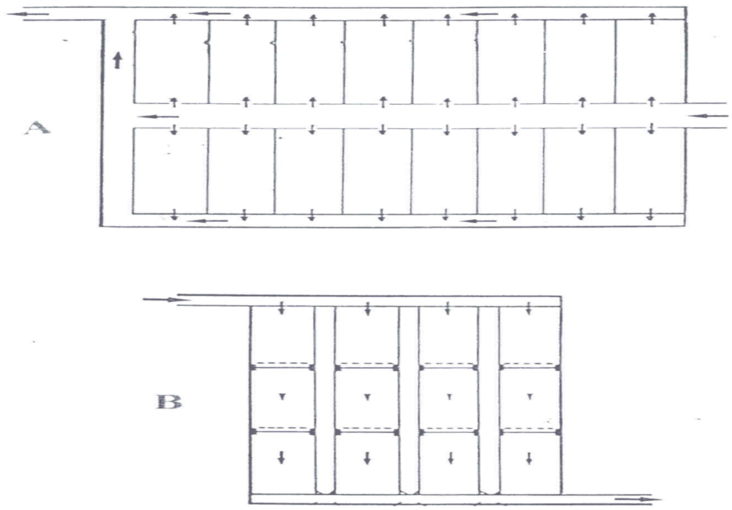


Figure 1: Series and Parallel Tank Designs (2005)

Part A shows a parallel system where the water comes in from the opening on the right and exits through the exit on the top left corner. In this system each tank receives fresh water. Part B provides an example of a tank in series. Here, the water enters the system at the top and then flows through the tanks in series and exits through the bottom right (INCOPESCA, n.d.). Because the water cycles through all of the tanks, the ones at the end of the system receive much dirtier water which can lead to problems with disease.

Once the water has cycled through the system there are two devices that allow the water to exit the tanks. The first drain mechanism is called a monje which is a vertical structure made of wood or concrete. A design of the monje forces water through the device, increasing the amount of water circulation in the tank. It also allows water to be released without letting any of the fish escape. The other type is called a tube. With this type the water is drained from the tank through a pipe, which can be made out of concrete as well as other materials, to areas outside of the tank.

An alternative to flow through systems, which does not pollute the environment, is known as recirculating systems. In those systems, the water is filtered and then used again in the holding system. The problem with that process is that it is expensive and harder to maintain than the flow-through process (Rakocy and McGinty, 1989).

The key advantage in having a land-based system is that it allows the farmer to implement ideal conditions on the harvest. The farmer is able to monitor the vital environmental factors and change the tank as they deem necessary. Of all the types of containment systems, the highest stocking densities can be achieved using tanks. High densities can be better sustained by aeration and a continuous water exchange to re-supply the water with new oxygen supplies. The problem with being supplied these unique conditions by an electrical source is that a power failure could destroy an entire harvest. This forces the producers to purchase expensive backup generators for use in case of an emergency. Harvests have also been found to contract disease more frequently if conditions become too stressful presented by the high density of fish in the water (Kumar, 1999).

Intensive Farms.

Intensive farms contain the most technology of all the types of farms. These farms are located on land that contains structures that were specifically designed for the purpose of aquaculture, such as tanks or raceways. For the feeding process, food is bought from a commercial producer in pellet form and altered for each stage of the fish's development. Filtration systems are used along with aeration systems to ensure the finest water quality. A typical intensive farm is owned by a corporation that has the money to maintain such an elaborate operation (Kumar, 1999).

POPULATION CONTROL

According to Rice (personal communication, April 2005), tilapia producers often run into problems because tilapia reproduce very quickly, and before long the producer is left with an extremely large crop of small fish that are not marketable. He notes two ways to deal with this problem. One solution is to use a polyculture system with predators to eat the young fish and another is to make a mono sex population by using a chemical known as Methyltestosterone (MT) (See Glossary). Popma and Masser(1999) state that a mono sex culture of males creates a larger yield due to a lack of energy used in reproduction and a faster male growth rate. Robinson (n.d.) adds that the fish in a dual sex culture will have an uneven growth rate.

This leaves only one problem in creating the best yield. How is a producer able to create an all male population? According to Popma and Masser (1999) there are three ways to produce an all male population. The simplest solution is to manually separate the fish by hand. They argue that this method is not optimal because mistakes are bound to be made mixing some females with the males and vice versa. A more interesting way of creating an all male population is to cross breed two species of tilapia that have exclusively male offspring. In order to do this, Popma and Masser (1999) recommend breeding a few Nile or Mozambique tilapia females with a few blue or zanzibar tilapia males. The most common solution, also mentioned by Robinson (n.d.), is to feed young tilapia a food that contains MT. This substance promotes male tilapia over females in younger growth stages and will convert most females to males. Popma and Masser (1999) also mentioned that a fourth solution may be available which entails the use of super males. These are males that only have y chromosomes therefore forcing the offspring to be all male. Recently these fish have become available commercially through distributors such as Til-Tech Aquafarm (http://www.til-tech.com/).

FEEDING

The feeding procedures of the tilapia crop in aquaculture systems have been researched in great detail. Much of this research pertains to the amount of feed per day, frequency of feedings, proportion of protein in feed, and variables that can affect these measurements.

The amount of food that should be fed to the tilapia fish is based on a percentage of their weight and the average fish's size. Robinson (n.d.) claims that 15 to 20 percent of the fish’s body weight should be provided daily for fish of .5 grams or less. He adds that 1.5 percent should be fed to fish of 400 grams. As would be expected many fish reside in between these two sizes and their rations can be determined from Table 1.

Table 1: Feeding Chart for Tilapia. Note. From “Feeding techniques, Conditions on Two Different Tilapia Faros,” Robinson, Bob (n.d.), Retrieved March 27th, 2005, from http://aquasales.com/techinfo/feed.pdf

Fish Weight (grams)	Daily Feeding Rate (% Biomass)
< 0.5	15-20
0.5	15-20
1	11.0
2	9.0
5	6.5
10	5.2
15	4.6
20	4.2
30	3.6
60	3.0
100	2.5
175	2.5
300	2.1
400	1.5

As a comparison to Robinson's feeding information, Riche and Gargling (2003) claim that small fish should be fed quantities of 10 to 30 percent of their body weight and fish in excess of one-hundred grams should be fed 1.5 percent to 3 percent of their body weight. Again many fish will inevitably reside in between these two sizes. For such fish Table 2 can provide the comparison food ration. When comparing these two tables it can be seen that the range provided by Riche and Gargling contains the range that Robinson lists.

Table 2: Feeding Table from "Feeding Tilapia in Intensive Recirculating Systems", Riche, M. & Gargling, D. (2003), *Northern Central Regional Aquaculture Center.* Retrieved March 24, 2005, from http://aquanic.org/publicat/usda_rac/efs/ncrac/ncrac114.pdf

Fish Weight (grams)	Daily Feeding Rate (% Biomass)
0-1	30-10
1-5	10-6
5-20	6-4
20-100	4-3
> 100	3-1.5

It is easily recognizable that the amount of food used in feeding procedures is not all that must be considered in a plan. The feeding intervals are also very important. Riche and Gargling (2003) claim that four to five hours in between feeding is more efficient than the two to three hours that is usually allotted for adult fish. Due to digestion habits of younger fish this number will change with varying size. For clarification, fry are younger than fingerlings. Riche and Gargling (2003) address this point stating that fry will grow best at eight to ten feedings per day or at a constant rate if the feeding is automated. Fingerlings will grow the fastest at approximately four feedings per day.

Overeating among tilapia can prove to be a very serious problem. According to Riche and Gargling (2003) a tilapia will eat more than what can fit in their stomachs, letting the extra food pass over and go directly to their intestines. They explain that this causes wasted energy on digestion and wastes food. To better increase yield tilapia should be fed slightly less than what they will eat to ensure full digestion of all the food. This also requires that the feeding intervals be slightly farther apart than a cultivator may expect. It can be hard to determine exactly when the fish have reached there maximum capacity for food. As a result it is hard to determine the appropriate time to stop feeding them. For this reason, fish are commonly slightly over fed in order to ensure that they get the adequate nutritional content. Overfeeding has been practiced before with negative results and therefore should be analyzed further. It is well known that in China, aquaculture has been used for many years as a method for obtaining a food source. As Tacon (n.d.) explains, commercialization started to degrade shrimp farms water quality in the early 1990's because of their over fertilization and overfeeding. This caused disease to kill the shrimp and reduce the production significantly. This is a prime example of why overfeeding of tilapia should be monitored carefully.

These feeding rates and feeding durations are variable and depend on the tilapia's environment. Robinson (n.d.) gives a comprehensive list of the major environmental changes that will affect the eating habits of a tilapia fish: water temperature, barometric pressure, fish density, fish size, the size mixture of the fish in the tank, water quality, and the fish's feeding behavior.

Besides research in how much to feed and how often to feed the tilapia, a good deal of research has also been done on what to feed the tilapia. Tilapia will eat a wide variety of food sources in the environment and each kind provides different benefits to the fish. For this reason a person is not able to guess what the best food content is because it is not intuitive. Due to this need Riche and Gargling (2003) have performed research and report that fingerling tilapia are best grown using a 32 to 36 percent protein content and fish of forty grams or larger do best at 28 to 32 percent protein content. However, Popma and Vasser (1999) report that typical feeds for fingerlings contain 50 percent protein, and for larger fish, 26 to 30 percent protein. The reason that the fingerling food contains such high levels of protein is that for convenience, food producers will typically design the food with 50 percent protein content in order to have a product marketable to both tilapia fingerlings and other fish that prefer the higher protein content such as catfish. In spite of the range in eating habits, tilapia have reportedly grown well with 50 percent protein content and therefore can be used in polyculture systems (see glossary) with this common protein content requirement.

Feeding of tilapia in developing countries often is done in an extensive or semi-intensive water based system with differing availability of food sources and therefore each location has different requirements. Unfortunately, most of the research that has been done in this field pertains to the more intensive systems in which food is very carefully monitored. These two approaches to aquaculture clash from a practice standpoint. Riche and Gargling (2003) imply that tilapia grow the best when both types of systems are understood by the producers in regards to how the natural environment and the farmers themselves control the tilapia's intake of food. They claim that when the natural food is present the fish will simply eat the food already present in the water supply so for a period of time no feeding is necessary. Cruz (1997) agrees with this claim and says that in the Philippines this type of practice is undertaken very often. The aquaculturist then must be able to determine when to start manually feeding the fish based on when these natural food supplies disappear.

As mentioned above, a large portion of the tilapia's diet consists of food found in their natural environment. Popma and Masser (1999) made a list which included the following food sources: plankton, aquatic macrophytes (See Glossary), planktonic and benthic aquatic invertebrates (See Glossary), larval fish (typically only as juveniles), detritus (See Glossary), decomposing matter, and algae (See Glossary). Cruz (1999) reports that in the Philippines farmers take advantage of this diet and let the natural environment feed their fish until the natural feed is depleted and can no longer sustain them. Once this point is reached additional food is added to the aquaculture in order to continue the fish's diet. Michael A. Rice (personal communication, April 2005) from the University of Rhode Island believes that supplemental feeding may not be required if proper water fertilization can sustain the natural food supply in the water.

FERTILIZATION

The purpose of fertilizing a culture pond is to create a food chain that will increase the productivity of the system. The added fertilizer provides a food source for plankton that quickly begin to reproduce at rapid rates. The presence of large populations of plankton can be very beneficial to the culture system. Rakocy and McGinty (1989) observe that the species of tilapia that are most appropriate for culture can feed on a diet of plankton and detritus, both of which are made more accessible to the fish through fertilization. According to Ludwig, Collins and Stone (1998), another benefit of fertilization is that it gives the water a turbid, green to brown color, caused by the phytoplankton and zooplankton, that provides shade to the bottom of the pond and aids in the prevention of aquatic weed growth. Rackocy and McGinty (1989) believe that inorganic fertilization or manuring can increase the natural productivity of a culture pond and can allow for significant tilapia production without supplemental feeds. They observe that supplemental feeds produce the highest yields but admit that they can be very costly. Instead, inorganic fertilizers and manure can provide an alternative that reduces the need for supplemental feeds and therefore can lower the production cost. The disadvantage of using fertilization to supplement the pond environment is that it can have adverse effects on the environment. This is particularly important when using a flow through system. Many times the area where the water is discharged after use can become contaminated. There are two main types of fertilizers: inorganic and manure. Both types produce the same results. The type of fertilizer an aquaculturist will use depends on the availability of resources and the farmer's budget.

Inorganic Fertilizers

The following information about inorganic fertilizers is mainly from Ludwig, Stone, and Collins (1998). Inorganic fertilizers are man-made and usually contain varying amounts of phosphorus (P_2O_5), nitrogen (N), and potassium (K_2O), with phosphorus being the most important. These fertilizers can be bought in three forms: granules, powders, and liquids. Each of these has specific application techniques. The liquid form should be applied by mixing it with ten parts water and then spraying the mixture over the pond surface. Granules also need to be mixed with water before going into the pond because they do not dissolve quickly. If added directly into the pond the granules will sink to the bottom and will be absorbed by the mud before they can completely dissolve into the water. The powdered form is the easiest to apply because of its high solubility and can be blown over the pond surface. The typical rate of application of inorganic fertilizer is six to eight pounds of phosphorous per acre per application. Rakocy and

McGinty (1989) note that inorganic fertilizers are a large expense, and if cost is a constraint, one large application can be made before stocking the fish. Inorganic fertilizers are an option if the aquaculturist can afford to purchase the inorganic material.

Manuring

Manuring is a good option for subsistence farmers with limited resources because in many cases manure is very cheap or even free. Rice (personal communication, April 2005) states that manuring alone, instead of using costly commercial high-protein feeds or inorganic fertilizers, can produce a healthy tilapia harvest. For complete interview details see appendix B.

Rakocy and McGinty (1989) set many guidelines for using manure as a fertilization method in their paper *Pond Culture of Tilapia*. They note that manure should be added daily in quantities varying from ninety to one hundred eighty pounds per acre per day. Because manure decays, it reduces the Dissolved Oxygen (DO) (See Glossary) concentration in the water, one should be cautious as to how much manure is added. If morning DO levels are lower than three to four ppm, manuring should be stopped until DO concentrations have reached safe levels (Rice, personal communication, April 2005). If DO levels cannot be measured manuring should be reduced to ninety pounds per acre per day (Rackocy and McGinty, 1989).

Racoky and McGinty (1989) write that the type of manure used is important. Pig, chicken and duck manure are more effective than cow and sheep manure. Animals fed grains rather than diets high in crude fiber produce better manure for fertilization.

One problem that arises from manuring is that the manure can clump on the bottom of the pond. Racoky and McGinty (1989) assert that this can result in the sudden release of toxic chemicals into the water. The two factors that can contribute to this problem are temperature and application techniques. At low temperatures, less than sixty-four degrees Fahrenheit, the rate of decomposition decreases and manure accumulates at the bottom. To avoid these problems when applying manure, the fertilizer should be evenly distributed on the water surface. They note that finely ground manure is more effective than large masses, because of its increased surface area.

WATER QUALITY AND ENVIRONMENTAL PARAMETERS

According to Aquasol, Inc. (2003), a global provider of technical assistance, expert opinions, technology transfer and comprehensive project management services to the aquaculture industry, a suitable living environment promotes growth and is strongly recommended for crops in any tilapia production system. They identify the critical environmental parameters to be the concentrations of dissolved oxygen, nitrite concentrations, and pH. Other important aspects are temperature, salinity, and ammonia concentrations. Aquasol, Inc. (2003) also states that during periods of rapid fish growth, proper levels of these variables must be maintained for cost effective production. The following sections provide background information for the understanding of these topics.

Temperature

The temperature of the water in a culture system is a very important factor in the production of tilapia. As they are a warm water fish, the optimal temperature range is eighty-five to eighty-eight degrees Fahrenheit. According to David Campbell of the FAO (1987), death occurs occasionally at higher temperatures. The more serious problem however is temperatures that fall below the optimal range. Thomas Popma and Michael

Masser (1999) agree with this information and say that temperatures of fifty to fifty-two degrees for a few days are lethal to most species of Tilapia. Problems also arise when there are sharp temperature changes because tilapia cannot adapt well to these changes. (Campbell 1987). Campbell notes that when water temperature falls from sixty-four to forty-six degrees and then remains constant for three hours, there is a 25 percent mortality rate. Popma and Masser (1999) have also noted other key temperature constraints that are important when culturing tilapia. They will stop feeding when temperatures drop below sixty-three degrees. Sampling, harvest and transport at temperatures below sixty-five degrees can lead to fatal diseases. They have determined that the optimal temperature for reproduction is about eighty degrees and stress that it will not occur below sixty-eight degrees.

Dissolved Oxygen

Dissolved oxygen concentrations are a critical aspect of water quality in any culture system and can have a large impact on the fishery crop (Rice 2000). The level of dissolved oxygen in the water needs to be high enough to support the respiratory needs of all of the species in the culture system. Although the experts agree that tilapia are more tolerant of low DO concentrations than most cultured fish, they cannot seem to agree on the lowest acceptable concentration. While Popma and Masser (1999) assert that DO concentrations should be maintained at levels above one mg/l, Pescod (1992) sets higher standards and believes that the DO concentration in a system should remain at a minimum of five mg/l. According to the Republic of the Phillippines Department of Argiculture (1999), DO levels should remain above three mg/l. Finally, Rice (2002) asserts that tilapia prefer levels above four g/L.

One fact is certain, low DO levels have serious effects on the fish. Popma and Masser (1999) observe that prolonged periods of low DO concentrations can result in the depression of metabolism, growth, and disease resistance. Rice (2000) also believes that this situation is stressful and increases the likelihood of disease.

Fish mortality often results from the depletion of oxygen during the night from the respiratory demands of a phytoplankton population that is too large and concentrated. A large portion of the mortality results because a major source of the system's oxygen, phytoplankton photosynthesis, cannot happen in the hours without sunlight, but the respiratory needs of the plankton are still present during these hours. The other factors that deplete oxygen levels are respiration by fish, respiration by benthic organisms, and diffusion of oxygen into the air (Rice, 2000).

DO concentrations are constantly changing throughout the day, making close observation that much more important. When levels fall below acceptable limits, there are ways for culturists to change the amount of DO in the system to avoid harming their crop. Fertilizing the pond with manure increases the density of phytoplankton in the system. Thus, DO concentrations are directly related to the amount and frequency of fertilization and can be manipulated through adjustment of fertilization routines. Popma and Masser (1999) remark that studies show aerators are a useful tool in preventing morning DO concentrations from falling below 0.7 mg/l. They also note that extra use of aerators to elevate morning DO levels to concentrations much higher than 0.7 mg/l, is not efficient because it does not further improve growth. Pescod (1992) says that it may seem like a wise solution to reduce the concentration of phytoplankton to achieve desired morning DO levels but it must be advised that this could result in the depression of fish growth.

Salinity and pH

Tilapia are more tolerant of brackish (See Glossary) water than are most types of cultured freshwater fish, according to Popma and Masser (1999). Even Nile tilapia, the least tolerant of the Tilapia species, still grow in salinities up to fifteen parts per ton (ppt). When the tilapia are reproducing a lower salinity concentration environment is required, five ppt is the optimal level, while ten to fifteen is acceptable. Although tilapia are tolerant of high salinities, Rice (2000) asserts that its levels should be monitored for two main reasons. One is that higher salinities result in lower oxygen solubility into the water. The result of high levels of salinity is low dissolved oxygen concentrations. The second is that fish adapt to a specific salinity regime and they become stressed when it is rapidly changed.

The general consensus among the experts is that the desirable pH range for tilapia culture is between six and nine (Popma and Masser, 1999; Phillippines, 1999; Rice 2000). However, David Campbell (1987) disagrees and feels that the desirable pH range for reproduction and growth is from 3.5 to 5.2. He has also determined that they lower lethal range is between 3.0 and 3.3. When the pH was held at this level for seven days there was a 50 percent mortality rate in the studied group. Rice (2000) notes that extreme pH measurements on either end of the spectrum are lethal to even the hardiest of fish. He advises that when choosing the location for a culture system, the pH that will result from the location should be considered. Acidic conditions usually result from soils with large amounts of decaying organic matter. Alkaline conditions usually result from soil with large amounts of carbonates from limestone or similar bedrock (See Glossary).

Ammonia

According to Marty Riche and Donald Gargling (2003), ammonia is a concern in intensive recirculation systems. For this reason management of the farm should entail close monitoring of ammonia levels in the water. Ammonia is a waste product from fish and is also a product of bacteria decomposing organic matter such as excess supplemental feeds (Rice 2002). Toxic unionized ammonia (See Glossary) typically exists in higher percentages when temperature and pH are higher. Due to the warm water conditions required for tilapia production, this gives increased importance to monitoring ammonia levels. Popma, Masser (1999), Riche and Gargling (2003) agree that unionized ammonia concentrations greater than two mg/l cause death in tilapia. Even levels of 0.2 mg/l over a prolonged period of time cause mortality and concentrations as low as 0.08 mg/l cause lowered food consumption. Feeding the crop increases ammonia production. The ammonia levels usually peak four to six hours after feeding. One way to remedy high ammonia levels or signs of stress in the fish, as prescribed by Riche and Gargling (2003), is to reduce or stop feeding until the ammonia levels attain a normal level.

Nitrite

Nitrite is a chemical compound that is toxic to many types of freshwater fish. Riche and Gargling (2003) assert that nitrite is a concern in intensive recirculating systems and its levels should be monitored closely. As indicated by Popma and Masser (1999), nitrite reduces the capability of the blood’s hemoglobin to transport oxygen to the fish's cells. In a culture system, they believe it is wise to keep chloride concentrations at one hundred to one hundred and fifty mg/l because chloride ions reduce the toxicity of the nitrite. They note that the general rule of thumb is that freshwater fish should be cultured in water with nitrite concentrations below twenty-seven mg/l.

CHAPTER THREE: METHODOLOGY

The main goals of our project were to determine the best practices for small to medium scale aquaculture of tilapia in Costa Rica and to create a pamphlet containing these methods that INCOPESCA will distribute to potential and existing farmers.

The objectives we used to achieve our goals were to conduct interviews with farmers which allowed us to learn about the techniques that are currently in practice and also to involve the producers in our research, have discussions and conferences with INCOPESCA technicians, research aquaculture material circulating through INCOPESCA, analyze the data collected during the interviews to determine the best practices, and finally develop methods for INCOPESCA to relay this information to potential and existing producers.

During our time in Costa Rica, we conducted qualitative research, mainly through on-site interviews. We conducted twenty interviews in three areas of the country. Out of the twenty farms sixteen were located in Limón, three in Heredia and one in Cartago. This area makes up much of the Atlantic area of Costa Rica. The sample of producers was chosen by our contact at INCOPESCA. The criteria for our project sample were directed at two types of people. The first were farmers who seemed to be managing their farms successfully and were producing high yields of healthy fish because we thought we would be able to learn a great deal from this type of producer. We would see first hand what goes into a successful farm in a given area and receive information about problems that can occur and how they can be eradicated. The second type of farmer included in our study was farmers who were not very successful and may have had problems. We thought this was important because it would provide information about the types of problems that frequently occur in tilapia production and the effects they can have on the harvest.

During each interview we had two objectives. We needed to gather pertinent information and gain the interest and confidence of the interviewee. Without the proper information, our research would have been incomplete. To obtain this information, we created a questionnaire and worksheet that can be seen in Appendix D. The questionnaire was filled out during our interviews with the farmers and helped to guide the interview. The main areas of focus in the interview were tank construction, water flow, feeding schedule, sickness and treatment, and areas of insufficient producer knowledge.

The worksheet was then filled out by a member of our group. It aided us in organizing key information. The information entered into this worksheet included the farm layout, entry and exit water points, water quality measures and a general notes section for interesting observations. This gave us insight into some of the less common practices.

During our interviews, one of our main goals was to get the producers interested in our project. In order to be successful in this endeavor, the many tilapia producers in Costa Rica need to be aware of what we are trying to accomplish and how it can benefit them. To accomplish this, at the beginning of each interview we made sure that we explained what our project was about, why we needed their help and what the final product would be. Later in the interview, we asked the individuals what information they would like to see included in the pamphlet. This was to make sure we included information that would be useful to the people who had helped us, ensuring the later use of our pamphlet.

As we conducted our interviews we analyzed and interpreted the data we obtained in order to discover what practices worked the best for tilapia farming in Costa Rica, and what aspects farmers needed the most information about. We examined our findings in between each interview session, and modified our questionnaire to better fit the interviews. Our reasoning behind many of these decisions came from the answers that producers continually gave and also from seeing new practices that we had never thought of. The purpose of this was that we wanted to be as flexible as possible with our interviewing, and not continue to use a questionnaire that was not sufficient. We did not want to conduct all of our interviews and find that we missed an important aspect that was vital to the success of our project.

After we had conducted our on-site interviews we were able to use our data to conclude what the best practices were. However the way in which we came to these conclusions changed over the course of the interviews. Before arriving on-site we chose variables such as size and quality of the fish, death rate and approximate number of fish sold in a year. The value of these variables would determine which farms were successful and which were not. We could then compare the practices of a farm that was considered successful to the practices at a farm that was not considered successful. However, we quickly realized that this type of analysis would not be possible because none of the farmers kept records of this information and we had no way of obtaining it in the short amount of time we had available in each visit. With this in mind there was no way to give a farm an overall rating and based on that rating determine which practices were better than others. Instead the determination of best practices had to come from recommendations from experienced farmers and from analysis and comparison of individual aspects of production.

The other way in which we gathered information was through meetings with professionals in the field of tilapia aquaculture in Costa Rica. The first person we met with was our farm guide German Arce Cerdas. One of his duties at INCOPESCA is to regularly visit existing farms and to give technical advice to the producers. From his experience he has obtained a vast knowledge of the practices in Costa Rica and the problems that are often encountered. We had many conversations with him that were unstructured and arose from observations that we made at the visited farms. We also had two conferences with our liaison Alvaro Otárola. These unstructured meetings were able to provide us with valuable information regarding various aspects of tilapia aquaculture that we had not been able to find elsewhere.

The last strategy our team used to gather information for our project was to conduct archival research. We used the INCOPESCA library extensively to research information regarding disease detection and treatment, the species of tilapia and their biology, water intake and outtake systems, and farm layout.

Once we determined what the best practices were, we then needed to find ways for INCOPESCA to relay this information to the people who needed it most, the producers. Initially this was going to be accomplished solely through the creation of a best practices pamphlet that would contain all of our recommendations to the farmers. However, upon INCOPESCA's request only three topics were to be included in the pamphlet. The purpose of the pamphlet was to give information to farmers on areas in which they were having the most trouble. After we created our first draft of the pamphlet we then translated it into Spanish and had it reviewed by Alvaro Otárola. After receiving his revisions, we finalized our pamphlet. The pamphlet was handed out at our final presentation to producers and then was given to INCOPESCA to be distributed to the already existing farms and to prospective farmers that want to start their own tilapia farm. Because the new pamphlet was limited to three subjects we devised other methods for INCOPESCA to pass on the rest of our information to the farmers, which have been included in the Recommendations section of our paper.

CHAPTER FOUR: FINDINGS, ANALYSIS AND BEST PRACTICES

In addition to the background information we gathered in the United States through aquaculture documents and interviews with experts and professionals, we were able to acquire key knowledge through on-site interviews and observations at existing tilapia farms in Costa Rica. We visited twenty farms that were located throughout Limon, Cartago and Heredia. The distribution of the locations can be seen in Figure 2.

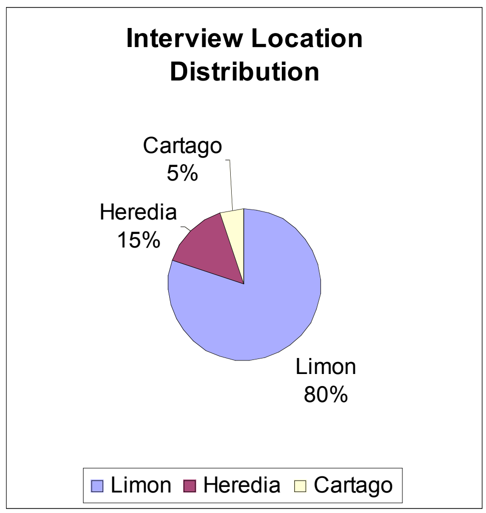


Figure 2: Interview Location Distribution

The knowledge we gained falls into four major categories: Current practices in use at small and medium size farms, the types of problems that are frequently encountered, innovative techniques that have been developed through years of experience, and areas in which the farmers would like more information.

CURRENT PRACTICES AT SMALL TO MEDIUM FARMS

Visiting the farms provided us with invaluable information that we would not have been able to obtain anywhere else. We were able to observe exactly which practices are being used in Costa Rica. We were also able to learn about the current status of the farms and the technological and financial constraints that the farmers encounter.

On-site farm interviews gave us valuable knowledge about the feeding of the tilapia. The first important fact that became obvious was that eighteen out of twenty producers used a feed known as concentrado. It contains high levels of protein and all other nutrients required for efficient tilapia growth. It can be purchased at various local stores throughout the country. Typical concentrado can be seen in Figure 1.

Figure 3: Concentrado

In addition to a diet of concentrado, we observed that some farmers fed their fish fruits and vegetables that they grew in their yard such as papaya. A mixed diet can be a good alternative for a small producer that has lots of fruits and vegetables on their farm because it can reduce the cost of the feed. However, when fruits and vegetables are included in the diet it leads to slower growth because it does not provide enough protein and other vital nutrients. Another disadvantage is that the uneaten fruits and vegetables often collect on the tank floor, which increases bacteria growth in the tank and can cause disease.

A part of the feeding process that is not as obvious, is how much and how often to feed the tilapia. Table 3 shows the average number of feedings per day and the total kilograms of feed that one hundred fish receive per day. However, these averages were very difficult to obtain because many of the farmers simply gave us estimates and did not have rigid feeding guidelines. Additionally, as seen in Table 3, the standard deviations for the amount of feed per day are very large in comparison to the corresponding averages.

Table 3: Feeding Results and Calculations

	Average Feedings per Day	Average Kilograms per Day per 100 fish	Standard Deviation
Fingerlings	3.2	38.59	29.61
Juveniles	2.43	221.43	132.48
Adults	2.3	318.65	279.76

Although this is partially because there are varied amounts of natural feed present in the different tanks, the majority of the variation comes from the fact that the producers do not know the appropriate amount to feed their crops and also do not know how much they actually do feed their fish. We view this as a serious problem for two reasons. On the one hand, if the farmers are feeding their fish too much of the expensive concentrado, then they are wasting money. On the other hand, proper nutrition is vital to efficient tilapia growth, which can be stunted when the fish are not receiving enough food.

Among the observations we noted, we were able to observe the quality of water present at the farms. Initially we determined that nineteen out of twenty farms had a pH level of seven. According to the literature we previously gathered, a safe pH range for tilapia production is six to nine. Experts at INCOPESCA agree and have stated that a pH of 7 is optimal but is acceptable within a range of 6.5 to 8.5. Because pH is a vital aspect of water quality and is very difficult to alter without the use of expensive chemicals, this is very positive feedback to receive.   The other water quality measure that we were able to observe is temperature. The temperatures of the water in twenty-seven tanks can be seen in Figure 4.

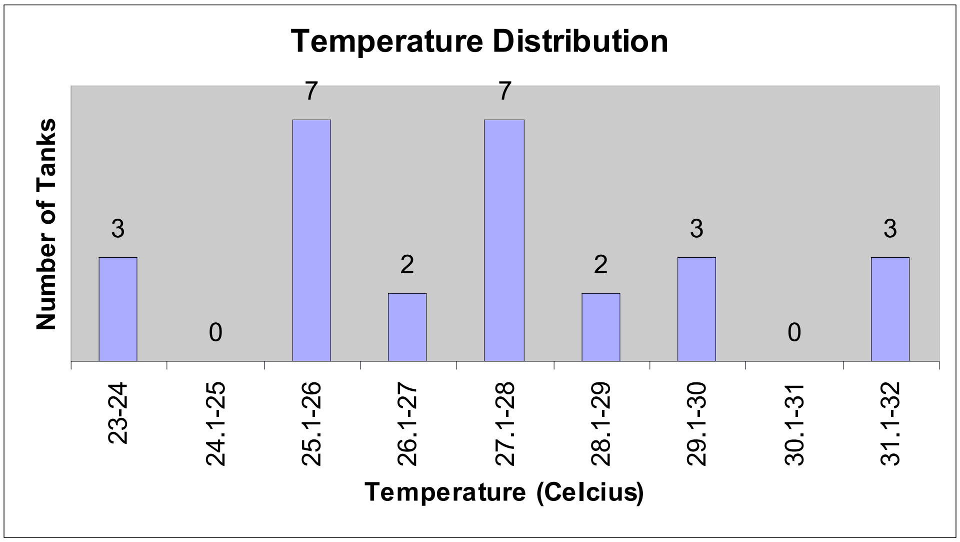


Figure 4: Temperature Distribution

The two most commonly cultivated species of tilapia in Costa Rica are the Nilotica and the Aurea. The desirable temperature range for Nilotica is between twenty-five and thirty degrees Celsius and is twenty to twenty-five for the Aurea. Figure 4 shows that twenty-four of twenty-seven tanks that were tested fell into this range. A producer should choose the species for production based on the temperature of their natural water source.

Upon conducting the interviews we were able to learn about the level of management that is practiced by the producers. Overall the producers we spoke with had poor management. This is mainly because they have not been convinced of the importance of many management procedures. For example, only seven out of twenty producers kept any sort of record on their production. One point that we would like to emphasize is the importance of record keeping. This practice has been recommended in the past, but apparently the majority of producers have not followed this advice. One benefit of record keeping is that it provides for more accurate knowledge of the size and quantity of a producers crop. This leads to more precise feeding when a producer uses a feeding table. Additionally, when problems arise production records allow for a producer to see the circumstances that led to the incident. Secondly, it became evident that management is a difficult aspect of production for many farmers. Yet, this task could be made easier through the formation of small aquacultural organizations that could unite the farmers. Unfortunately, as is shown in Figure 5 only two producers belonged to an organization and fourteen out of the eighteen that did not belong had no interest in joining one.

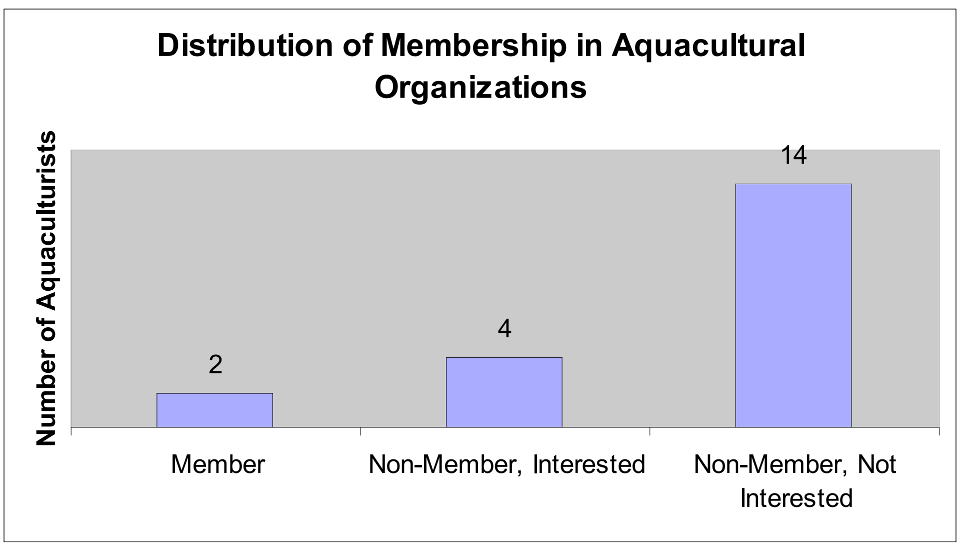


Figure 5: Distribution of Membership in Organizations

Despite the lack of interest in such organizations, we feel that it can provide numerous benefits to the producers. Larger groups could purchase feed at lower prices. Transportation costs are significantly lowered when producers travel together. They could receive cheaper rates on technical assistance if they received it while in a group. Lastly when they openly share concerns and solutions to problems everyone involved will benefit from the exchange of knowledge. The third fact is that only one out of twenty producers has permission to operate their tilapia farm. It is required by law to contact the Ministerio de Ambiente y Energia (MINAE) and complete three forms. To initiate the farm a form known as the Formulario de Evaluacion Ambiental Preliminar needs to be completed. Another that can be received from the department of water at MINAE for the use of the government's water. Finally, a producer needs to obtain authorization from INCOPESCA. In addition to this, only three out of twenty farms have permission from INCOPESCA to transport their product which is also required by law.

Another observation we were able to make is that sixteen producers purchased their fingerling from Incopesca, three owners produce their own fingerlings and one buys their fingerling from Coopebatan. This information can be seen in Figure 6.

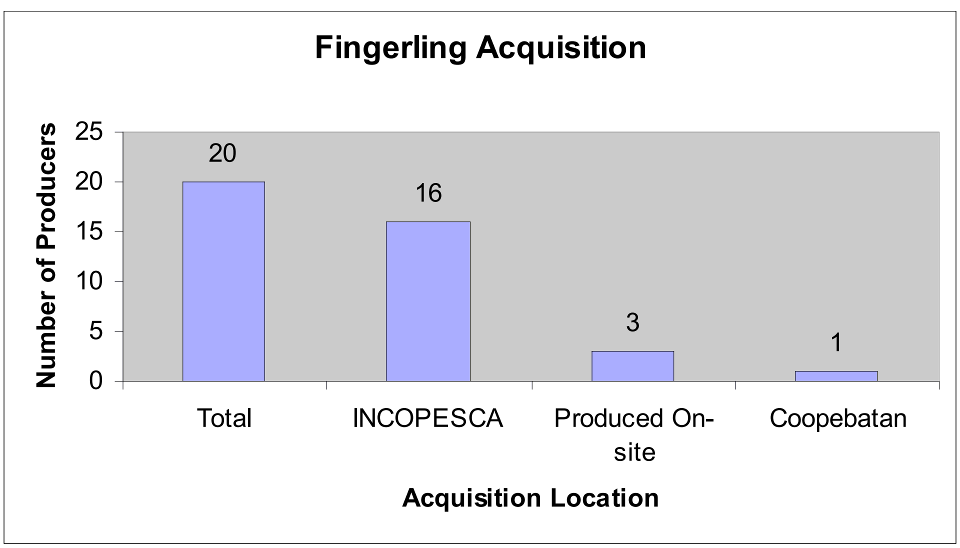


Figure 6: Fingerling Acquisition

It was positive feedback to learn that 80 percent of producers purchased their fingerlings from INCOPESCA. INCOPESCA adds hormones to the concentrado that is fed to the fingerlings starting at birth. This results in a 98 percent male population and very little reproduction in the tanks. This is also beneficial when the fish escape into the natural water sources because it does not allow for the rapid reproduction and over population that is characteristic of tilapia.

COMMON PROBLEMS

During the interview process, we noted that there is room for improvement in every farm that we visited. We have discovered five recurring problems that were apparent in multiple farms. The first is fish mortality caused by disease, the second is insufficient water flow, the third is improper water exit design, the fourth is problems with the fingerlings purchased from INCOPESCA, and the fifth is dissolved oxygen outside the appropriate range. There are harmful bacteria present in the natural water sources in Costa Rica at all times. Healthy fish have natural defenses that protect them against these bacteria. However, when fish become stressed for any reason, their defenses are lowered and they become susceptible to the effects of the bacteria. When this occurs producers have noticed that the fish lose their appetite, their movement becomes drastically slowed, their gills become white, and if the fish is dissected one can notice that the fish's pancreas has lost its bright red color. If not promptly treated, the disease can spread to the entire crop causing widespread mortality. Eleven out of twenty farms have experienced problems with disease. This is especially true in the Guapiles area where eight out of fourteen farms have experienced the previously mentioned problem. In fact we were able to experience first hand the drastic effects this crisis can have on a farm. At one farm the owner was experiencing these symptoms in his fish and was dealing with mortality rates of six fish per day. Figure 7 shows the effects this disease can have on the fish. The picture on the top left shows the coloration of a healthy gill, where the picture on the top right shows the discoloration present in a sick fish. In the bottom picture you can see that the pancreas is white and spotted while it should be bright red.

Figure 7: Fish Symptoms and Comparisons.

Another serious flaw present in the majority of farms is insufficient water flow through the system. Proper water flow is very important to maintaining a healthy water supply for the fish. The circulation of the water supply cleans the tank and aerates the water giving more oxygen to the fish. A water change is defined as the complete replacement of the water in the tank. Every producer’s goal is to have as many water changes as possible. Unfortunately small scale producers do not have the luxury of altering the flow of water that enters their tanks. The most common method of bringing water into a system is to have a pipe set on a decline that carries the water from its natural source to the tanks. Since the only force moving the water into the system is gravity, the farmers have no way of altering the water flow from its natural rate. This has a serious impact on the number of fish that a producer is able to put in their tanks. When the water source is a fast flowing river, producers do not have a problem maintaining an acceptable water flow. However, the reality for many is that their water source is a much smaller river or stream and for some there is no external body of water to be used as a source. They simply use a standing body of water to house their fish. For these people water flow has presented them with many hardships in their cultivation of tilapia.

A common flaw in the design of the majority of aquaculture tanks that we have seen lies in the system used for the removal of water from the tanks. The majority of the tanks we saw had tube style exits located at the top of the tank. In this setup the water that enters at the top only moves across the surface before it leaves the tank. This does not allow for proper circulation of the water located at the bottom of the tank. We were very concerned to learn this fact because this often leads to very dirty water and outbreaks of disease. A more effective alternative can be seen in Figure 8.

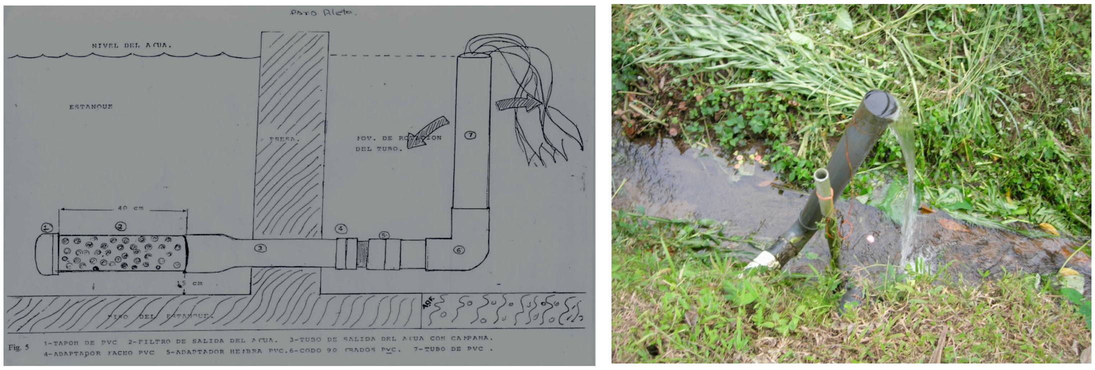


Figure 8: Standard Tube Exit Located at the Bottom

This device is situated at the bottom of the tank. With this type of exit the water is forced to circulate throughout the entire tank before leaving through the tube instead of merely skimming across the surface. According to experts at INCOPESCA, this is the best method for tanks that are smaller than one-hundred square meters. For larger tanks they recommend the use of a monje which cleans the water better than the system that is used at the majority of the farms. An example of a monje can be seen in Figure 9.

Figure 9: Monje

As noted above sixteen producers purchase their fingerling from INCOPESCA. Although this is a majority, people are not always happy with the quality of the fingerlings that they receive. Some producers reported that there was severe mortality in some of the batches they have received. For example, one producer complained that every other fingerling batch he purchased experienced widespread sickness. Similarly, a producer we interviewed said that the current harvest of three month old fingerlings he was raising had been experiencing disease since they were delivered. Another producer noted that in one shipment of fingerlings there were many females, which led to excessive reproduction. There was not enough food for the fish to receive adequate nutrition and the result was a large population of very small fish that were not appropriate for market.

Dissolved oxygen is a very important aspect of water quality because the fish need the oxygen in the water to breath and live. The recommended dissolved oxygen content in a tank is three to five g/l. The dissolved oxygen readings from the twenty-nine tanks that were measured can be seen in Figure 10.

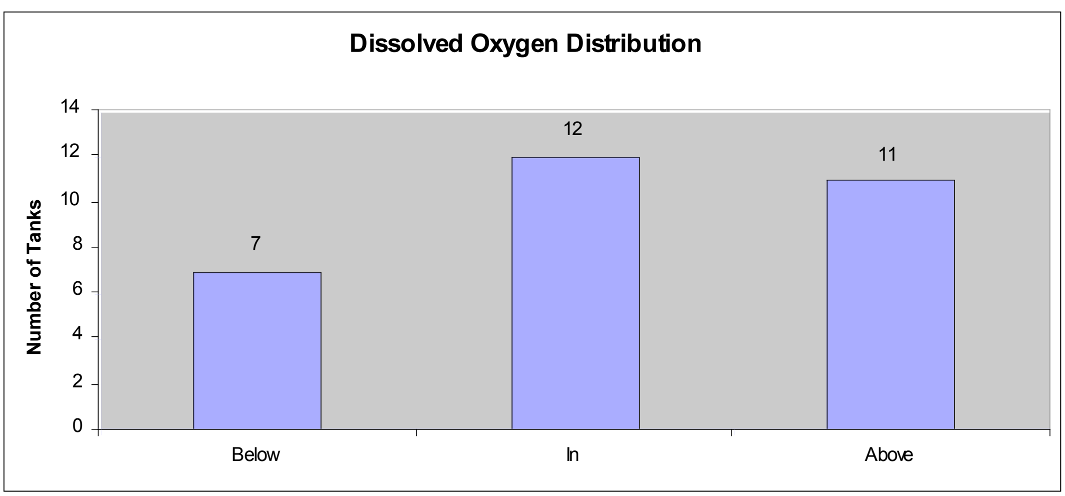


Figure 10: Dissolved Oxygen Distribution

As shown above, seven tanks had a dissolved oxygen content that was lower than the suggested range. This can result from insufficient water flow or a stocking density that is too high. On the other end of the spectrum, eleven of the twenty-nine tanks had higher dissolved oxygen than is recommended. This is not harmful to the fish, but the problem arises from the fact that this is an inefficient use of the producer's resources because the tank should be filled at a higher density.

With the imperfections that are present at the farms come problems that are specific to a single farm's surroundings and the procedures that are in place. Another problem plaguing some producers is that their fish are being eaten by birds. For many, a netting system can be placed over the tanks to protect the fish from attacks. However, some producers have much larger tanks used for sport fishing that cannot be covered. Therefore the problem still persists for these producers. Soil composition has also shown to be a problem for some. At one farm in particular, the soil was too soft causing the bottom of the pond to become very mucky. Additionally, the geographic location of the river and land forced the entrance and exit of the tank to be on the top. This setup prevents proper circulation of the water. The combination of these two circumstances created a serious problem because the water became extremely dirty and even trapped the fish towards the bottom of the pond. Although these problems are serious for the few they affect, they are not widespread throughout the tilapia farms in Costa Rica.

INNOVATIVE TECHNIQUES

Although some of the farms are relatively new, there are many others that have been in existence for a number of years. Through years of experience, some producers have developed creative techniques to adapt to the specific environmental conditions of their land.   As mentioned above, a large concern for producers is the threat of birds eating their harvest. This is especially relevant for the fingerlings because their small size makes them easy targets for any size bird. To combat this problem, nine producers have set up netting over their tanks. A typical netting system can be seen in Figure 11.

Figure 11: Netting in Protection of Bird Attacks.

It is most common to see nets over the fingerling tanks because this tank is usually the smallest in size and the fingerlings are the most susceptible to attacks. This technique has not been adopted by some of the producers with large tanks because they think it is impractical. Nevertheless, we feel that setting up a set of nets is a very beneficial practice and we have actually seen it in use over some very large tanks. Another benefit of using nets is that they prevent fish from jumping out of the tank and escaping into the natural water source. The frequent escapes have caused much concern for environmentalists because tilapia breed at a faster rate than many species of fish and will eat a large portion of the natural feed in the water. This is a problem because the tilapia take away precious space and resources from the native fish. For the same reasons it is wise to put a screen over the tube leading to the water exit which prevents the fish from escaping through it.

Another technique, which has been developed by some producers, is put into practice after each harvesting. Before receiving new fingerlings, the tank is completely drained and a treatment of Calcium Carbonate and Salt is added to the bottom of the tank. The sun then dries out the tank floor for eight days during which time the chemicals kill bacteria that could potentially cause disease in the new harvest. After this period the tank is ready for the new batch of fingerlings. This is not the only technique that has been developed to try to prevent outbreaks of disease. One producer noticed that every other batch of fingerlings he received from INCOPESCA would become sick at approximately three months, causing high mortality rates and a large loss of profit. Rather than wait for his harvest to become ill, he decided that he would take preventative measures and treat every batch at two months with Oxytetracycline, Calcium Carbonate, and Salt. He applies ten kilograms of Salt and three kilograms of Calcium Carbonate to the tanks for five days. To apply the Oxytetracycline, he makes a mixture of regular household oil, the fish's regular food and fifty grams of Oxytetracycline per kilogram of fish. According to Mr. Alforo, these chemicals are relatively inexpensive making the benefits of these measures worth the expense.

High quality water is vital to the success of a tilapia culture project. Although many producers are aware that clean water is important, financial restrictions force the majority of producers to use untreated water of whatever quality is present in the natural source. However, we did encounter one producer who created a water filtration system that was able to rid the water of the disease causing bacteria that is naturally present in the water source. The water entering the system from the river was immediately filtered and the clean water was then stored in a large tank before entering the system. The producer told us that she has not encountered any diseases since implementing the filtration system, which can be seen in Figure 12.

Figure 12: Water Filtration System at Proyecto Tilapia AMUCHI

Implementing a filtration system is an optimal practice for a tilapia culture project. However, it is not a feasible investment for the majority of producers that we have encountered because it is very expensive. The farm that has put the filtration system into practice was able to do so because it was collectively owned by Asociación Mujeres Unidas de Chirripo with a larger budget than a single producer.

REQUESTED INFORMATION

One area of information that was particularly important to us during the interview process was to determine which type of information people would like to see in our pamphlet. The results of this inquiry can be seen in Figure 13.

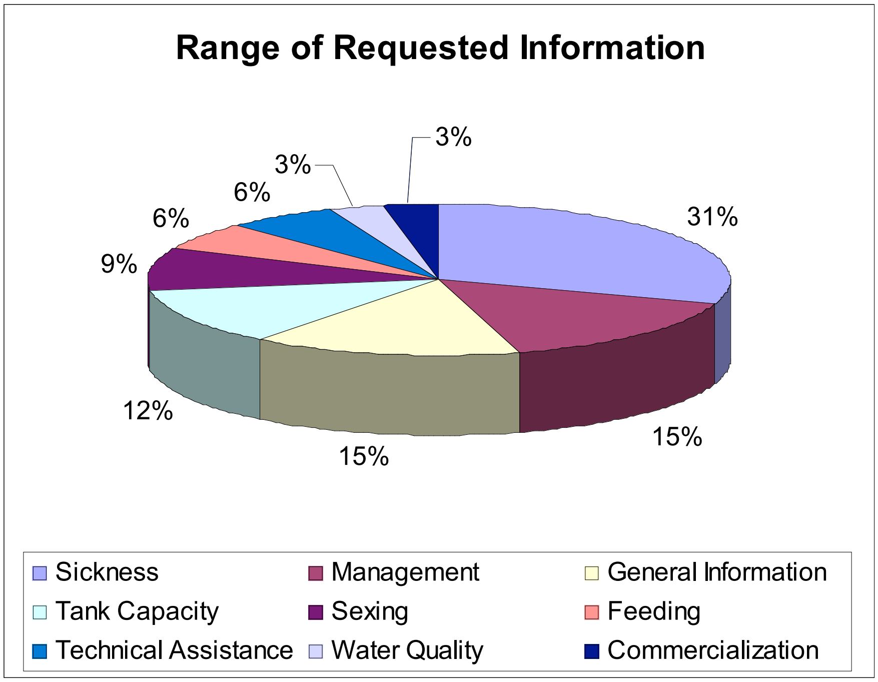


Figure 13: Range of Requested Information

As you can see the most sought after information regards sicknesses that can infect and possibly kill large percentages of a producer's crop. There is also a lot of interest in the sex reversal that is necessary when growing fingerlings. This is because purchasing fingerlings from INCOPESCA is expensive. Another reason is that many producers have experienced widespread disease in the fingerlings and many producers live in such remote locations that many fingerlings die in transit. The last area that is important to note is tank capacity. It is very difficult for a producer to know how many fish should be kept in each tank, yet proper stocking density is crucial in the efficient management of a tilapia farm.

After organizing and analyzing the findings of our fieldwork, our team was able to develop the following best practices for small to medium scale tilapia aquaculture. For a full explanation of these practices and instructions on how to implement many of them, please refer to Appendix F.

1. Before Starting a Farm
    - Test water temperature and pH of the proposed water source
    - Register farm with MINAE and INCOPESCA
2. Design of the Tanks
    - Decide on type of water exit
        - For tanks larger than one hundred cubic meters use a monje
        - For tanks smaller than one hundred cubic meter use a tube located at the bottom of the tank
    - Construct a system of protective netting over all tanks
3. Receiving Fingerlings
    - Buy fingerlings from INCOPESCA
    - Properly acclimate fingerlings to tank water
    - If high reproduction rates are observed, separate males from females
4. Management
    - Keep production records of information gained through sampling fifteen percent of the harvest every twenty-two days, using the example record in Appendix E.
    - Form aquaculture clubs or organizations to receive lower rates on supplies and to allow for an exchange of knowledge and expertise
    - Determine optimal stocking density for each tank
5. Feeding
    - Use Concentrado to feed the tilapia
    - Employ proper storage techniques of the feed to ensure quality
    - Determine the proper amount of feed to provide to the fish in each tank

CHAPTER FIVE: SOCIAL IMPLICATIONS

Our project worked to reveal the problems that producers commonly encounter in their aquaculture farms, to determine the best ways for the producers to combat these problems while taking into consideration financial and technological limitations, and to find ways for INCOPESCA to get this information to the producers. We know based upon our research that these tasks are very important because when problems arise in a tilapia culture system they can have a very large impact on a farm's production rate and ultimately the revenue that the producer will receive. For example, Costa Rica's largest tilapia producer is a company known as Aquacorporation International located in Cañas, Guanacaste. During May and June of 2005 this company experienced widespread disease in their tilapia. The ramifications of this unexpected crisis were losses of 1.2 million colones and 110 jobless people. (Rojas, 2005)

In Costa Rica, a developing nation of nearly 4,000,000 inhabitants, about 3,600 people are dependant on the tilapia aquaculture industry. Large production companies such as Aquacorporation International employs roughly fifteen hundred of these people. The other 2,100 is the result of multiplying the 700 small and medium sized tilapia farms in Costa Rica by the average family size of 3 people. The areas where these small farms are located are quite rural and there are very few sources of income. Many of the people used to farm bananas or coffee but as world prices lowered they became unable to make a living off these industries. Many turned to tilapia aquaculture in hopes of increasing their income and improving the quality of life for themselves and their families. Not only does tilapia production help the people of Costa Rica by generating employment in rural areas, but it also helps the country as a whole by contributing to the economy. In 2004 Costa

Rica's large production companies exported twenty-three million dollars of fresh tilapia filets to the United States. Our project could have similar implications in many other developing nations around the world including Thailand, the Philippines, and Honduras (Otarola, personal communication, June 2005). This also includes many other countries located in tropical areas that are near the equator because of their similar climates and economic situations.

CHAPTER SIX: RECOMMENDATIONS

After thorough analysis of our findings and determination of a set of best practices for tilapia aquaculture in Costa Rica, our team has developed the following recommendations for INCOPESCA and for producers. The main goal of these recommendations is to encourage the producers to adopt the best practices that we have determined.

One of the outputs of our project is a manual for small and medium producers that focuses on proper feeding techniques, optimal stocking densities, and disease recognition and treatment. We recommend that INCOPESCA distribute this manual to existing producers as well as people who are interested in starting a tilapia farm. This can be accomplished in a number of ways. Copies should be kept at INCOPESCA offices throughout the country in waiting areas or other areas that are easily visible to a farmer. The manual can also be distributed when farmers buy fingerlings by attaching a copy to the shipments. Likewise when a person registers a farm or requests technical assistance, INCOPESCA should hand out the manual.

Our second recommendation is that INCOPESCA advertises in newspapers that circulate in areas where tilapia farms are common. This will allow more people to learn what INCOPESCA is and about the services they provide to the public. We recommend that INCOPESCA advertises lower rates on technical assistance, nets, or fingerlings when a person registers a farm or when they request assistance in groups. It is very important for producers to properly register their farms and to form aquaculture groups, and this type of advertisement will help promote these practices.

The third recommendation that we would like to make is that INCOPESCA hold a seminar for employees that provide technical assistance to farmers. The focus of the seminar will be to relay our findings to the employees that can deliver the information to the public. This will update them on the current status of the farms, inform them of the type of information producers need and want to know, and also will allow them to see which practices we have deemed most appropriate for small and medium scale tilapia production. We recommend that the PowerPoint from our final presentation be used as a visual aid for this seminar because it clearly displays a lot of information pertaining to these areas.

Although we have aimed these recommendations at INCOPESCA, they can be applied to other organizations that work to improve small and medium scale tilapia aquaculture around the world. Some of these recommendations could also be implemented at organizations that promote the aquaculture of other species of fish.

After analysis of the data that we received from our interviews, we have determined a set of best practices for small to medium scale tilapia aquaculture in Costa Rica. We have also made recommendations to the producers as to how to implement these best practices in their farms. This work can be seen in the Best Practices section of Chapter Four of our paper.

GLOSSARY

Algae: a plant or plantlike organism of any of several phyla, divisions, or classes of chiefly aquatic usually chlorophyll-containing nonvascular organisms of polyphyletic origin that usually include the green, yellow-green, brown, and red algae in the eukaryotes and the blue-green algae in the prokaryotes. (Merriam-Webster Online Dictionary) Tilapia digest blue-green algae better than green algae. (Popma and Masser, 1999)

Bedrock: the solid rock underlying unconsolidated surface materials (as soil). (Merriam-Webster Online Dictionary)

Benthic aquatic invertebrates: Creatures at the bottom of the body of water without a spine. ((Merriam-Webster Online Dictionary)

Brackish: somewhat salty (Merriam-Webster Online Dictionary)

Detritus: Loose material that results directly from disintegration (Merriam-Webster Online Dictionary)

Macrophytes: A member of the macroscopic plant life especially of a body of water. (Merriam-Webster Online Dictionary)

Methyltestosterone: Androgenic compound used to enhance male characteristics.

Planktonic aquatic invertebrates: The passively floating or weakly swimming usually minute animal and plant life of a body of water without a spine. (Merriam-Webster Online Dictionary)

Polyculture: pertaining to many types of creatures on various levels of the food web all in one culture.

Unionized Ammonia: The chemical formula is $NH_{3.}$ Unionized ammonia its counterpart ammonium, NH_4, are both present in the water at all times but the concentrations of each are affected by temperature and pH. NH_3 is much more toxic to the fish than $NH_{4.}$
(Riche and Gargling 2003)

APPENDIX A: MISSION AND ORGANIZATION OF INCOPESCA

BASIC INFORMATION

The Instituto Costarricense de Pesca y Acuicultura, commonly known as INCOPESCA, was created on March 16, 1994 by the Legislative Assembly of the Republic of Costa Rica as a replacement for the insufficiently resourced organization called La Dirección de Pesca. INCOPESCA currently has thirteen offices located throughout the nation that dedicate themselves to the control and improvement of the aquaculture industry of Costa Rica. Additionally, INCOPESCA sells fingerlings to the small and medium tilapia producers. The yearly budget of INCOPESCA is 1 billion colones (~2.3 million dollars); 75 percent of this is funded by the government, and the other 25 percent comes from the tilapia fingerling sales.

ORGANIZATIONAL STRUCTURE

The organizational structure of INCOPESCA is shown in Figure 14.

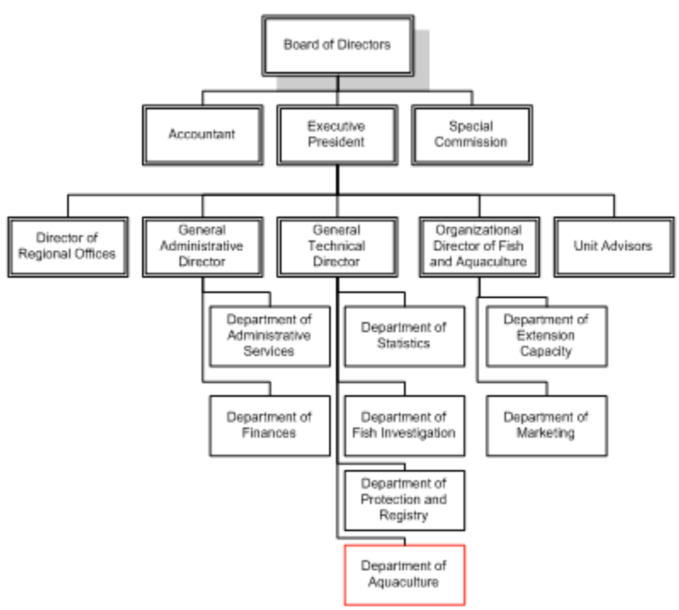


Figure 14: The organizational structure of INCOPESCA

This government institution has three main objectives (INCOPESCA, 2005).

1) To coordinate the fishing sector through the organization and improvements in the development of fishing using scientific and biological resources of the sea and aquaculture.
2) To protect marine species that may be in high demand to avoid risk of endangerment.
3) To monitor and regulate the contamination created by aquaculture and fishing that threatens natural resources.

Our liaison for this project is Álvaro Otáro Fallas. He is the Head of the Department of Aquaculture. His position within the organization is highlighted by the red box in Figure A.1. Our other contact in INCOPESCA is Dr. Rolando Ramirez Villalobos. His position within the company is Jefe Departamento Mercado INCOPESCA and Coordinador Programa Nacional de cumplimiento de Buenas Practicas de Manejo de Productos Pesqueros y Acuicolas.

MISSION

As stated by INCOPESCA (2005), the mission of the organization is to promote fishing and aquatic development in Costa Rica. The organization regulates, protects and administrates marine and aquaculture resources, providing a sustainable contribution to the economic development of the country.

APPENDIX B: INTERVIEW WITH PROFESSOR MICHAEL RICE

On Saturday April 9, 2005, Matt and Megan went to the University Of Rhode Island to meet with Professor Rice of the aquaculture department. We first asked Prof. Rice to describe what type of work he has done with tilapia. He explained that he spent several months working in the Philippines with small and medium sized tilapia farmers. He helped these farmers to create the most efficient farms possible, given the geography of the region. We then asked him if there were any new type of technologies that we should be aware of. He said that there were new techniques in regards to the recirculation of the water and materials used in the construction of tanks, but we would not have to worry about these new improvements because they will not be used in the small farms in Costa Rica. He stated that the concept of pond cultivation has not changed over the years, and that sources dating back to the 1970's would be just as useful to us. He told us of books that we would be able to use and also photocopied a large section out of one of his books that will help us greatly in determining the best practices. An interesting idea we gained from the interview was in terms of the soil composition. Prof. Rice told us of work he had done where a pond was created but the soil was too thin and the water kept seeping through into the ground. He told us that soil must be at least 40 to 50 percent clay in order for it to hold the water in. He also discussed how fertilization should be a large part of our studies and that fertilization alone, without any food added to the tank, is a sufficient source of food for the fish.

APPENDIX C: INTERVIEW AND TOUR WITH JOHN RIED, PRESIDENT OF BIOSHELTERS

INTERVIEW

On April 11th, 2005 we interviewed John Reid over the phone. Due to time requirements, Reid proposed that he explain as much pertinent information as he could to us regarding our project to save time. The resulting information was gained from such correspondence.

Initially he described the fish species he was culturing at his farm. He used a unique cross breed to avoid the use of the controversial hormone MT. This particular cross breed of Victoria Blue and Nile Tilapia produces a high percentage of males in the resulting population.

Following the fish species the interrelations of fertilization, feeding, and stocking of fish were discussed. Initially he made clear that tilapia produce their own fertilizer, a often overlooked fact. This is important because it affects dissolved oxygen, stocking density, natural feed, and feeding schedules. To discuss this topic, John first explained eutrophication. This is the reaction a body of water will undergo when an algae bloom receives less than adequate light. The light can't penetrate deep enough for all the algae to survive and thus some dies off. Once this has occurred, it begins to decay which consumes dissolved oxygen in the tank. If enough decay occurs the dissolved oxygen will reach dangerous levels and many deaths can occur. He explained that there is a danger of eutrophication if the pond water turns slightly green because cloud cover can reduce the available light, thus triggering the death and decay of algae.

Algae blooms occur due to over-nutrient rich water, often attributed to runoff or over-fertilization. As mentioned previously fish fertilize their own water and as such too many fish or overfeeding of fish will inevitably cause an algae bloom. This is where John's theory comes into play. He explained that a light algae bloom can be sustained rather easily and will create a larger yield of fish by balancing the feed and stocking density. Unfortunately, if the algae bloom is too thick, the instant clouds appear eurtophication will begin. This implies that a very light algae bloom or none at all will work best because the light can still penetrate the water in reduced light in order to sustain the algae.

He explains that in many cases, to attain a higher yield, individuals have used systems that flush the water into the environment. To avoid environmental damage a simple solution would be to drain the tanks through a crop field that will use the fertilizer. A downhill slope from the tanks to the crops could easily distribute this waste water through a simple gravity driven distribution system.

Finally, in a direct request regarding feeding practices he gave a suggestion for farmers in Costa Rica. Purchasing food can be a large expense but in the surrounding environment many sources of food could be present. To alleviate the purchase costs these natural foods could be utilized with few or no affects on the growth of the fish.

TOUR

During the tour much information was attained however three aspects stood out from the rest. These include the problem of reproduction, feed type issues, and a marketing tactic termed perging.

It was initially very clear that reproduction used up extra energy and therefore was unwanted. The fact that the rearing of young caused uneven fish sizes in a tank was the added information that clarified our understanding. By letting young fish grow they use food, dissolved oxygen, and just general space in the tank slowing the growth of the parents while at the same time during a harvest will need to be separated for market.

The feeding aspect of tilapia was rather different than expected. Apparently there are two types of fish feed, ones that include fish meal and ones that do not. Fish meal is ground fish caught in the ocean which depletes the natural fish in the environment. In many cases aquaculture is used in order to help balance the fishing of the oceans however this directly contradicts it, and as such should be avoided.

Finally a marketing tactic was discussed termed purging. Yeast is typically present in most living creatures, but is especially concentrated in the fat. This produces a "dirt" taste and should be avoided. To avoid this taste the yeast must be burned off with the fat. The simplest way to accomplish this is to starve the fish for a set period of time. Once the fish is sufficiently starved, the yeast and fat will be gone from the fish yielding a better product.

APPENDIX D: INTERVIEW QUESTIONNAIRE

ENCUESTA DE PROYECTOS ACUÍCOLAS REGIÓN ATLANTICA.

WPI

1- Nombre del propietario:____

Teléfono: ________________ Fax: _______________ Celular: ______________

Correo electrónico: _______________________________ Beeper: ____________

2- Nombre del proyecto: ____

3- Ubicación del proyecto: ______________________ ______________________

Cantón **Distrito**

____

Dirección exacta

4- Ubicación coordenadas geográficas: ____________________________________

5- Altitud: _____________ msnm

6- Fuente de toma de agua: ____

7- Capacidad de la toma en litros/ segundo en época seca: ______________l/seg.

8- Realiza monitoreo de la calidad de agua en su finca (pH y oxigena). Si si, cuales son los métodos
____
____
____

9- Uso del agua:

- Cuenta con concesión de agua ______litros/seg _________
- Permiso en trámite __________
- No ha realizado ninguna gestión ___________

10- Procedencia de los alevines: ____

11- Cual tipo de enfermedades he experimentado en su proyecto?

____

____

12- Que puede notar en sus peces cuando están enfermos?

____

____

____

13- Qué tipo de tratamiento usa cuando hay una presencia de enfermedades

____

____

____

14- Destino de la producción: ____

- Proyecto turístico: ___________________
- En la comunidad :__________________
- Mercado local (cantón): ___________________
- Mercado regional: ________________
- Restaurante: _____________________
- Otro: ____________

15- Como vende el producto

- Vivo _________________
- Eviscerado ______________________
- Congelado ______________________
- Filet __________________
- Otro ____________________________

16- Posee permisos para comercializar el producto

- Incopecsa ________________
- Ministerio Salud _________________
- Feria de Agricultor ________________
- Otro_________________

17- Cuales instalaciones posee por procesar y comercializar el producto

____

____

18- Como transporte el producto

____

____

19- Tipo de alimentación empleada: ____________________________________

20- Principales problemas que enfrenta el proyecto. Como los resolvió:

____

____

____

¿Cuenta con asesoría técnica? Si _____ (pase a 17) No ______ (pase a 19)

21- Si la respuesta es afirmativa ¿paga por esta? Si ______ No ______

22- ¿Quién brinda esa asesoría? ____

23- Si la respuesta es No, estaría dispuesto a pagar: Si _______ No_________

24- ¿Lleva registros de la actividad? Si _________ No __________

25- ¿Pertenece a alguna organización acuícola? Si ______ No_______

26- Si su respuesta es afirmativa a cual: _____________________________________

27- Si su respuesta es No, estaría interesado(a) en pertenecer a alguna organización de esta naturaleza: Si _____ No _____

28- Ha cambiado sus métodos de producción desde que empezó la finca
____
____
____

29- ¿En que área necesita capacitación?_______________________________________
____
____

30- Tiene algunos recomendaciones por una persona que quiere empezar un proyecto?
____
____
____

Estanque	Area de Cultivo en m^2	Cantidad Actual (peces)	pH	Temp	DO	Tipo de peces	Tipo de Entrada	Tipo de Sailida	Flujo de Agua (l/s)	Recambios por Dia
1										
2										
3										
4										
5										
6										

Tipo de Peces	Alimentos por dia	Cantidad de Alimento por dia (kg/dia)
Alevines (1-1.5 GR)		
Juveniles (15.1-250 GR)		
Adultos (> 251 GR)		

APPENDIX E: EXAMPLE RECORD

Numero de Estanque	Fecha de Muestreo	Numero de Peses	Peso Promedio	Mortalidad	Biomass en el Estanque (kilo)	Alimento por Dia (kilo)	Observaciones

APPENDIX F: BEST PRACTICES

Our team has determined a set of best practices for small to medium scale tilapia aquaculture in Costa Rica. This is a complete description of our set of best practices. We have included explanations for why we consider these to be best practices and also instructions on how to implement some of these practices.

Before Starting a Farm

When someone decides that they would like to start a tilapia aquaculture farm, there are many things that need to be considered before production can begin. One of the most important aspects to consider is that the farm needs to be located near an acceptable water source. The water that will circulate through the farm will be taken directly from this source and needs to be appropriate for tilapia aquaculture. The pH should be tested and should fall within the range of 6.5 to 8.5. If the water falls outside this range, it should not be used to supply the farm because costly chemicals are the only way to alter the pH of the water. The temperature of the water source should also be tested. The acceptable range for tilapia aquaculture is twenty to thirty degrees Celsius. Usually the higher end of this range is preferred, however if the water falls in the lower end, Aurea tilapia should be produced at the farm. Table 4 shows the optimal temperature range for the two most commonly cultured species of tilapia in Costa Rica. The species chosen for culture should be based on these temperature specifications.

Table 4: Optimal Temperature Range for Two Species of Tilapia

Temperature Range	Species of Tilapia
20° - 25° C	Aurea Tilapia
25° - 30° C	Nile Tilapia

After the site is chosen, the next step is to properly register the farm. It is required by Costa Rican law that a potential producer completes three forms to properly register the project. The first is called the Formulario de Evaluacion Ambiental Preliminar. The second allows for the use of the government's water and can be received from the Department of Water at the Minesterio de Ambiente y Energia (MINAE). Finally, new legislation requires that the person contact INCOPESCA to receive authorization for the farm and also to transport the fish to market.

Design of the tanks

The design of the tanks at a farm can have a large impact on the production yields. Therefore, proper tank design should guide the construction of the farm. We would like to make two recommendations concerning the design of the tanks. In regards to the location and type of water exit, we believe that a monje is ideal for tanks larger than one hundred cubic meters. It allows for the best circulation of water, and its design prevents fish from escaping through the device. According to professionals at INCOPESCA, a monje typically costs one hundred dollars to install. For tanks smaller than one hundred cubic meters a cheaper, simpler tube system can be built and located at the bottom of the tank. The team would like to emphasize the importance of constructing the exit at the bottom of the tank. It allows for much better circulation of water which results in a cleaner tank and less disease outbreaks among the fish.

Producers should set up a system of nets above the tanks to prevent birds from attacking the harvest and to also prevent the fish from escaping into other water sources. Because there are many restrictions on the type of nets that can be used, producers should contact INCOPESCA. INCOPESCA has agreed that with proper permission they will donate nets to producers and dispose of any that do not meet current standards.

Receiving Fingerlings

Fingerlings should be purchased at INCOPESCA to ensure a 98 percent male population that has efficient tilapia growth. Males grow faster and with less females there is less reproduction in the tanks. When a producer arrives at the farm with the fingerlings they should put the bags of fingerlings in the tank for ten to fifteen minutes to reduce the temperature difference. Next the farmer should open the bag and add water from the tank to allow the fish to become accustomed to the new water conditions. Slowly over the next ten to fifteen minutes more water should be allowed into the bag until it is eventually empty of fingerlings.

If a farmer receives a batch of fingerlings that seems to be reproducing rapidly, it is a good idea to separate the males from the females. This procedure is best done in the morning on fingerlings that are at least three inches. Hold the fish as shown in Figure 14.

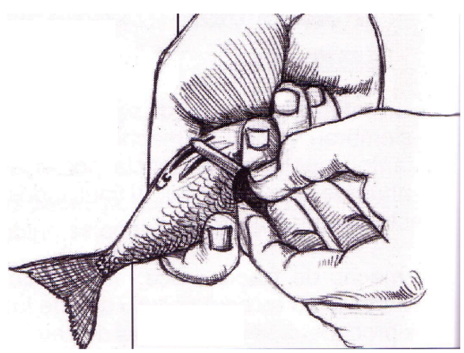


Figure 15: Proper way to Hold a Tilapia for Sexing

Then apply a drop of dye or iodine to the genital area. This helps to mark the orifices of the fish for easier sex recognition. The female genitals can be seen in Figure 15.

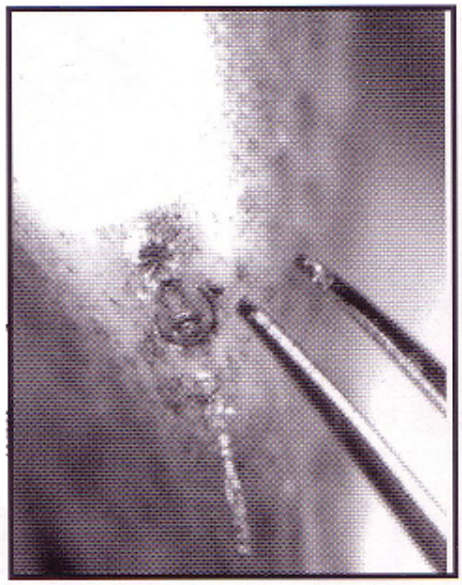


Figure 16: Female Genitalia

If the farmer can see the genital pore, then the fingerling is a female. The male genitals are shown in Figure 16.

Figure 17: Male Genitalia

The females can still be cultivated but will not grow as quickly and should always remain separated from the males.

Management

To properly manage a tilapia farm a producer should implement the following practices. Every twenty-two days a sample of 15 percent of the fish in each tank should be evaluated to determine the average weight and general health of the fish. This information should be entered into the chart shown in Appendix E. Appendix E is a sample record that can be used in order to monitor a tank's density, mortality rates, fish size, feed amount, and general health of the system. The other practice that we recommend is that producers come together to form tilapia aquaculture clubs or organizations. A farmer can accomplish this by contacting INCOPESCA to receive a list of tilapia producers in his or her area.

Stocking Density

Our group would like to recommend that producers use the following process to determine the proper stocking density of a tank. First, the number of changes per day must be determined by using the water flow into the tank, the tank's volume, and the equation shown in Equation 1.

$$\frac{WF * 86400}{TV * 1000} = CPD$$

WF: Water Flow (l/s)
TV: Tank Volume (m^3)
CPD: Changes Per Day
86400: Seconds in a Day
1000: Changes Liters to Cubic Meters

Equation 1: Changes Per Day

The result from this equation is the number of water changes per day. INCOPESCA has provided a table with approximate stocking densities based on the number of changes per day. This can be seen in Table 5.

Table 5: Fish per Cubic Meter for Given Changes Per Day

Changes Per Day	Fish Per m^3
< 0.3	2
0.3 – 1	5
1	10
3	15
5	20
10	50
50	100

After a producer determines the appropriate number of fish per cubic meter the tank can hold, there is only one simple last calculation to perform. The volume of the tank in cubic meters must be multiplied by the number of fish per cubic meter, yielding the total number of fish that can be safely grown in the tank. The equation for this can be seen in Equation 2.

$$FPCM * TV = NF$$

FPCM: Fish Per m^3
TV: Tank Volume (m^3)
NF: Number of Fish

Equation 2: Total Number of Fish

Feeding

We recommend that producers feed their fish a type of feed that is known as Concentrado. The advantage of using Concentrado is that it is specifically designed for the feeding of tilapia and provides the fish with nutrients that allow for the most efficient growth. The disadvantage to Concentrado is that it is expensive. Nevertheless we feel that the increase in growth and overall health of the fish is enough of a benefit to purchase the Concentrado. If the farmer does not have the money to buy Concentrado, fruits and vegetables may also be used. However, this should not be a common practice. The first reason is that fruits and vegetables do not contain the necessary nutrient levels that allows for the fast growth of tilapia. The other problem that arises is that the uneaten food can sink to the bottom and cause an increase in bacteria growth.

Producers should use the following procedure to determine how much food to give their fish per day. The first step is to determine the average weight of the fish in a tank. A farmer should partially fill a bucket with water and place it on a scale. The farmer should then note the weight of the bucket with the water. The next step is to add a number of fish equivalent to 15 percent of the total number of fish in the tank and to note the new weight. The average fish weight can be calculated by using the equation in Equation 3.

$$\frac{FBW - BW}{\#\, fish}$$

FBW: Fish, Bucket, and Water
BW: Bucket and Water
 # fish: Number of Fish in the Bucket

Equation 3: Average Fish Mass Equation

As fish grow they should be fed a smaller percentage of their body weight. Because of this a producer should use the average weight of the fish and Table 6 provided by INCOPESCA to determine the correct percentage of body weight to feed their fish.

Table 6: Feeding Table

Weight Interval (grams)	´ % of Body Weight
1-5	10
5.1-10	6.3
10.1-20	5.2
20.1-50	4.6
50.1-70	3.3
70.1-100	2.8
100.1-150	2.2
150.1-200	1.7
200.1-300	1.5
300.1-400	1.3
Mayor de 400.	1.2

The final equation uses the average fish weight, the number of fish in the tank, and the percentage acquired from Table 6. The result is the amount of feed a producer should provide to the fish in that tank per day. This equation can be seen in Equation 4.

$$FEED = \frac{AFM * FIT * P}{100}$$

FEED: Amount of Feed per Day
AFM: Average Fish Weight
FIT: Number of Fish in Tank
P: Percentage from Table

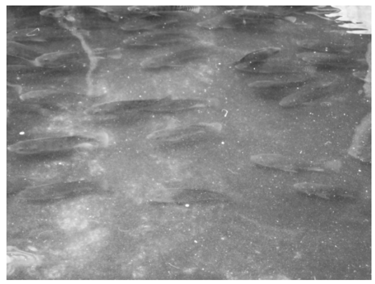
Equation 4: Mass of Food to Feed Fish Equation

Another important aspect of feeding for a farmer to consider is how they should store their feed. The storage area should be high off the ground on a platform in order to prevent insects and other rodents from getting into the feed. We also recommend that the feed be kept in a cool, dry place with proper ventilation. The reason is that at elevated temperatures and high levels of humidity, the deterioration of the feed is accelerated. When this occurs, it stimulates the growth of many disease causing microorganisms that could be very harmful to the tilapia. A producer should also use their feed within twenty-two days of purchasing. After twenty-two days has passed many of the fats and oils in the feed break down and cause poor growth and an overall health decline in the fish. A producer should also wash their hands before handling the feed so the feed does not become contaminated.

APPENDIX G: BEST PRACTICES MANUAL

Manual de Buenas Practicas

Alimentación, Densidad de Siembra y Enfermedades


Por Megan Slonski, Matt Douville,
Adam Broders y Álvaro Otárola Fallas
INCOPESCA con Worcester Polytechnic Institute

2005

INDICIE

Alimentación

Tipo de alimento

El mejor tipo de alimento para el cultivo de tilapia en Costa Rica es el alimento concentrado nutricionalmente balanceado para esta especie. Este concentrado fue diseñado específicamente para las tilapias y contiene los nutrientes correctos lo que favorece el adecuado crecimiento de las tilapias. Viene en forma de extrusado y es de fácil adquisición en tiendas de suministro de insumos para animales. Una desventaja del concentrado es que representa un alto costo de producción (mayor a 60%). No obstante, su alto costo si es de buena calidad esto implica peces saludables y con tallas de comercialización entre los 9 y 10 meses. Si un productor no tiene suficiente dinero para comprar el concentrado, puede usar frutas y verduras, como fuente sustituta, además algunos productores usan como complemento las frutas y verduras para reducir la cantidad de concentrado y reducir costos. Sin embargo hay desventajas en usar este método. Primero, las frutas y verduras no contienen un buen nivel de nutrientes para un adecuado crecimiento y una buena salud del pez. Otro problema es que la comida que los peces no comen se hunde al fondo del estanque y esto causa un aumento en el proceso de descomposición realizado por bacterias aeróbicas, lo cual resta oxigeno al agua, elemento determinante en el crecimiento.

Raciones de alimentación

Un buen raciones de alimentación es muy importante para un buen crecimiento de los peces, por su alto costo es importante ***“alimentar a los peces y no al estanque”*** y para optimizar las ganancias. Hay tres pasos fáciles para calcular la correcta cantidad de alimento a dar a los peces cada día.

1. Primero, se necesita encontrar el peso promedio del pez. Para esto, se llena un balde a la mitad con agua y se pesa (se anota el peso), luego se colocan quince peces en el balde con agua y se pesa de nuevo peso (se anota el peso final). Para realizar el calculo de peso promedio se usa la siguiente formula:

$$P\bar{x} = \frac{PBA - BA}{\#PEZ}$$

PBA: Pez, Balde y Agua
BA: Balde y Agua
#PEZ: Numero del Peses en el Balde

Reste el peso del balde y agua (BA) del peso del balde con peces y agua (PBA). Entonces divida este número por el número de peces en el balde.
Con la operación anterior usted obtiene el peso promedio.

2. Los alevines necesitan comer un gran porcentaje de alimento con respecto a su peso corporal, cuando la tilapia crece, necesita comer un porcentaje menor con

relación a su peso corporal. Mire la tabla abajo y use el promedio peso del pez para encontrar el porcentaje de ración de alimento por día.

Peso Promedio (gramos)	% de Ración de Alimento por Día
1-5	10
5.1-10	6.3
10.1-20	5.2
20.1-50	4.6
50.1-70	3.3
70.1-100	2.8
100.1-150	2.2
150.1-200	1.7
200.1-300	1.5
300.1-400	1.3
Mayor de 400.	1.2

3. Ahora use el peso promedio del pez, el número de peces en el estanque, el porcentaje del tabla y esta fórmula para calcular el correcto número de kilogramos de alimento a suministrar a los peces por día.

$$\text{Alimento} = \frac{P\bar{x} * NPE * P}{100}$$

Alimento: Cantidad de alimento por dia
P$\bar{x}$: Promedio peso del pez
NPE: Numero del pez en la estanque
P: Porcentaje del tabla

La primera meta de esta formula es a encontrar la biomasa de peces en el estanque. La biomasa es el total de peso de todos los peces en el estanque. Multiplique el numero de peces en el estanque por el peso promedio del pez y eso es la biomasa. Siguiente, multiplique la biomasa por el porcentaje. El paso final es dividir este número por cien porque es un porcentaje. El nuevo número es el número de kilogramos por día que es necesario suministrar a los peces en el estanque.

Almacenamiento del alimento

Es importante que el almacenaje del alimento de los peces se haga de una buena manera.
Siguiente hay una lista de recomendaciones:

- Guarde el alimento en un área seca y bien ventilada.
- Gaste primero el alimento más viejo.
- No almacene alimento por más de 22 días porque alimento viejo tiene los siguientes problemas:

- Perdida de nutrientes:
    - Altas temperaturas y humedad aceleran el deterioro.
    - Perdida de vitamina C
- Rancidez:
    - Deterioro de grasas y aceites.
    - Rechazo del alimento
    - Deficiencia de vitamina E
    - Pobre crecimiento y salud deficiente.
- Mantenga el alimento en pilas sobre tarimas, para evitar que esté en contacto directo con el suelo.
- Los sacos deben ser apilados de tal forma que haya 18 pulgadas entre las paredes y las tarimas
- Si recibe sacos de alimento en bolsas de plástico quite la bolsa para permitir un mejor flujo de aire alrededor del producto.
- No manipule el alimento del saco con las manos mojadas.
- Verifique la fecha de fabricación.
- Realice control de insectos y roedores porque son vectores de transmisión de enfermedades y hongos.
- No maneje más sacos de los necesarios.

Densidad de Siembra

La densidad de siembra es un aspecto muy importante del manejo de un proyecto de tilapias. Es muy común que un productor ponga demasiados peces en un estanque. Cuando esto ocurre, si no hay un buen recambio de agua en el estanque se presentan deficiencias en los niveles de oxigeno en el agua, hecho que disminuye el porcentaje de crecimiento, además que mantiene al pez en una situación de estrés que lo hace susceptible al ataque de diferentes patógenos. Por otra parte muchos productores usan una densidad de siembra muy baja. Cuando esta situación ocurre, el productor pierde dinero porque puede cultivar más peces en el mismo espacio. Hay cuatro pasos fáciles para determinar la mejor densidad de siembra en un estanque.

1. El primer paso es calcular el flujo de agua de la fuente.
   Los materiales que se necesitan son:
    - Un recipiente como una "Pinchinga" o un estañón pequeño, que previamente, se le haya medido su capacidad en litros.
    - Un reloj preferiblemente digital o un cronometro

   La forma de realizar la medición es:
    - Recoger mediante una canoa, un tubo, o cualquier otro sistema, el agua de la fuente.
    - Llenar el recipiente
    - Medir el tiempo que tarda en llenarse
    - Hacer 4 o más varias lecturas y secar el promedio del tiempo de las lecturas.

2. La segunda cosa es a calcular el número de recambios por día. El numero de recambios por día es el numero de veces que toda el agua en un estanque se esta reemplazando. Para calcular este número se usa esta formula.

$$\frac{FA*86400}{V*1000} = RPD$$

FA: Flujo de Agua (l/s)
V: Volumen del estanque (m^3)
RPD: Recambios por Día

En esta formula se necesita saber el flujo de litros por segundo al día, para lo cual se multiplica los litros por segundo por 86400. Entonces divida este numero por 1000, el numero de litros en un metro cúbico. El resultado se divide por el volumen del estanque en metros cúbicos. Lo cual nos da el número de recambios por día.

3. La importancia de los recambios es mantener la calidad del agua, ya que esta ingresando oxigeno, además de que una buena circulación del agua en el estanque favorece la salida de desechos (restos de alimento y heces). O sea entre mayor sea el numero de recambios mayor es el numero de peces por unidad diaria (metro cuadrado)

Recambios por Día	Peces por m^3
< 0.3	2
0.3 – 1	5
1	10
3	15
5	20
10	50
50	100

4. El último paso es muy fácil. Se usa la siguiente formula para calcular el mejor numero de peces por estanque.

$$PPCM*V = NP$$

PPCM: Peces por m^3
V: Volumen del estanque m^3
NP: Numero de peces

Multiplique el volumen del estanque en metros cúbicos por el número de peces por metro cúbico de la tabla. El resultado es el número de peces que deben vivir en el estanque.

Enfermedades

Es muy común por los productores experimentar problemas con enfermedades en los peces. Enfermedades pueden causar mortalidad extendido y perdidas grandes de beneficios. Una lista de enfermedades en peces cultivados esta abajo. También hay características de las enfermedades y tratamientos.

Septicemia hemorrágica por Aeromonas mótiles

Características de la enfermedad: Es una de las enfermedades más comunes en los cultivos de peces y sus signos clínicos son variables; los más comunes son erosión de aletas con hemorragias, ulceraciones en la piel, erizamiento de escamas e inflamación abdominal. También puede observarse en los animales infectados exoftalmia. Internamente se encuentran inflamados el hígado, bazo y riñón. y el intestino presenta un líquido amarillo sanguinolento, el cual puede también hallarse en la cavidad abdominal.

Prevención y control: Tratamiento de los peces infectados con antibióticos, desinfección de toda la unidad con formalina 4% y mejoramiento de las condiciones de cultivo.

Columnaris

Características de la enfermedad: Es causada por una myxobacteria y su manifestación clínica más común es la erosión de las aletas, presencia de ulceraciones en la piel, necrosis de filamentos branquiales, donde puede observarse crecimiento micótico secundario. Es una infección secundaria a condiciones adversas de nutrición o ambientales, por lo que es común encontrar también en los peces signos de avitaminosis u otros.

Prevención y control: Buenas condiciones de cultivo, dieta balanceada y tratamiento con antibióticos a los peces infectados. Los estanques deben ser desinfectados.

Enfermedad corinebactérica de la tiiapia (ECT)

Características de la enfermedad: es una enfermedad septicémica que se manifiesta en forma aguda, con altas mortalidades en poco tiempo. Los animales infectados presentan exoftalmia, debido a la afectación de su mecanismo osmorregulador, oscurecimiento de la coloración; hemorragias en la piel y aletas; y edema en la base de las aletas. Su comportamiento natatorio es anormal, con pérdida del equilibrio; se observan largos hilos fecales blanquecinos en el animal y en el agua.

Prevención y control: Se debe mantener a los animales en condiciones de cultivo no estresantes. En caso de surgimiento de un brote, aplicar formalina 5% como desinfectante, eliminar los peces muertos de los estanques para evitar la ingestión de vísceras contaminadas por parte del resto de la población, incinerar los animales muertos, y tratar a los peces con antibióticos, por vía oral o mediante inyecciones. Cuando se detecte esta enfermedad, la estación o proyecto de engorde debe ser declarada en cuarentena.

Enfermedades Micoticas

Características de la enfermedad: Presencia de crecimiento algodonoso en huevos o sobre heridas en la piel de los peces.

Prevención y control: Desinfección de incubadoras y canaletas con verde malaquita antes de su empleo. Tratamiento de los adultos con verde malaquita o permanganato de potasio y de los huevos con verde malaquita. Los huevos no deben tratarse durante las 24 horas previas a la eclosión, ni las larvas con el saco vitelino.

Ictioftiriasis

Características de la enfermedad: Las branquias y la piel de los peces muestran puntos blancos, fácilmente observables; los peces nadan intranquilos y se frotan contra las paredes y el fondo de los estanques; también suben a las capas superiores y se acercan a la entrada del agua, dada la falta de oxígeno provocada por una mala función de sus filamentos branquiales parasitados.

Prevención y control: Buenas condiciones de cultivo; someter a cuarentena de 72 horas a todos los peces, antes de unirlos con otras poblaciones residentes. El tratamiento de los peces infectados se hace con una mezcla de formalina y verde malaquita.

Tricodiniasis

Características de la enfermedad: El pez enfermo sube a las capas superficiales del agua, reacciona débilmente a los estímulos del exterior y se concentra cerca de la entrada del agua. Su cuerpo se cubre de un velo azuloso, debido al exceso de mucus. Nada frotando el cuerpo contra el fondo y las paredes del estanque.

Prevención y control: Mantenimiento de las larvas y alevines en estanques separados de los reproductores, desinfección en forma rutinaria de los estanques, artes de pesca e instrumentos de muestreo; tratamiento de los peces enfermos con verde malaquita, formalina, acriflavina, sal común o agua amoniacal.

Scyidiasis

Características de la enfermedad: Los signos clínicos de la enfermedad son los mismos que los señalados para la tricodiniasis; suele encontrarse conjuntamente con enfermedades ocasionadas por otros parásitos, como la tricodina

Prevención y control: En este caso son válidos los mismos métodos de prevención y control dados para la tricodiniasis.

Chilodonelosis

Características de la enfermedad: La piel de los peces enfermos presenta una opacidad blanco azulosa, principalmente perceptible en la mitad superior de la cabeza, la que es el resultado de la irritación de la piel por el parasitismo y secreción excesiva de mucus. Los peces se observan intranquilos, nadan hacia la superficie, efectúan movimientos de rotación, y se frotan contra el fondo y las paredes.

Prevención y control: La *Chilodonella* es un parásito obligado, pero se multiplica específicamente en peces debilitados, por lo que es considerado "el parásito de la debilidad"; de ahí que la medida de prevención fundamental es una alimentación adecuada; se requiere, asimismo, de buenas condiciones sanitarias en los tanques. Los peces parasitados se tratan con acriflavina y sal común.

Dactylogyrosis

Características de la enfermedad: Los peces infectados muestran signos de asfixia, debido a la localización branquial de los parásitos y su efecto negativo en la respiración. Los peces están intranquilos: se acercan a las entradas de agua, nadan hacia las paredes y el fondo, y suben hacía la superficie, donde se mantienen con movimientos operculares intensos. Las branquias se encuentran con exceso de mucus y pueden aparecer ya sea de coloración rojo intenso, decoloradas o necróticas.

Prevención y control: Evitar la importación de peces parasitados y su traslado entre unidades de producción. Mantenimiento de reproductores, larvas y alevines en estanques separados, y tratamiento de los ejemplares enfermos con agua amoniacal, formalina o dípterex

Gyrodactylosis

Características de la enfermedad: Las aletas de los peces infestados se encuentran deshilachadas, dada la localización del parásito en la piel; no se manifiesta en las branquias. Se observan zonas hemorrágicas en la piel y producción excesiva de mucus; ocasionalmente se observan también infecciones nicóticas secundarias.

Prevenci6n y control: La infección sólo puede prevenirse empleando aguas libres de parásitos y manteniendo a las larvas y alevines separados de los reproductores.

Los peces enfermos pueden ser tratados con los fármacos indicados para otros monogéneos.

Diplostomatosis

Características de la enfermedad: La enfermedad es producida por la presencia en el humor vítreo de metacercarias de ***Diplostomum*** por ello, su signo clínico es la presencia de abundantes metascercarias en los ojos de los individuos afectados, produciendo ceguera.

Prevención y control: Hasta el momento no se conoce terapia efectiva, por lo que las medidas a tomar deben estar encaminadas a la prevención para ello, se debe evitar la penetración de moluscos a los estanques y es necesario emplear controladores biológicos de los mismos, como la carpa fanguera.

Botriocefalosis

Características de la enfermedad: Es una enfermedad ocasionada por un helminto que penetra al intestino de los peces, localizándose en la primera asa intestinal; traumatiza su pared, produciendo inflamación de la mucosa y anemia severa. El pez enfermo se torna flácido, su vientre se inflama, nada junto a la superficie, rechaza el alimento y adelgaza considerablemente.

Prevención y control: Desinfección de los estanques donde se hayan detectado animales enfermos y tratamiento por vía oral a los peces con niclosamida, acompañado de tratamiento del agua de los estanques con Dipterex, para eliminar los copepoditos con estadios infectivos de los parásitos.

Neoergasilosis

Características de la enfermedad: La enfermedad es producida por un crustáceo de la Familia Ergasilidae, el que se localiza en piel y branquias, por lo que en los peces infectados se observan numerosos puntos azulosos moviéndose (los parásitos) y producción excesiva de mucus. También hay signos de asfixia y natación hacia las paredes y fondo de los estanques, donde se frotan.

Prevención y control: Buenas condiciones sanitarias en los estanques y tratamiento de los peces enfermos con permanganato de potasio.

Lerneosis

Características de la enfermedad: El parásito penetra con la cabeza en la piel del pez y se fija en el músculo; en el lugar de fijación se forma una úlcera, cuyos bordes se ven hemorrágicos; en ocasiones es posible observar emblanquecimiento de éstos. Es común observar los parásitos como colgando del pez. En la zona ulcerada se presentan signos de infección secundaria por bacterias u hongos.

Prevención y control: Evitar el contagio de las poblaciones sanas mediante su separación de las enfermas. Tratamiento de estas últimas con Dipterex.

Argulosis

Características de la enfermedad: La enfermedad es ocasionada por un parasito chupador, conocido como piojo de los peces; produce irritación de la piel y úlceras en la zona de succión, las que se ponen hemorrágicas. Hay necrosis en dicha zona. Es posible observar los parásitos sobre la piel de los animales infectados.

Prevención y control: Cultivo separado de adultos y alevines y tratamiento de los peces enfermos con permanganato de potasio y Dipterex .

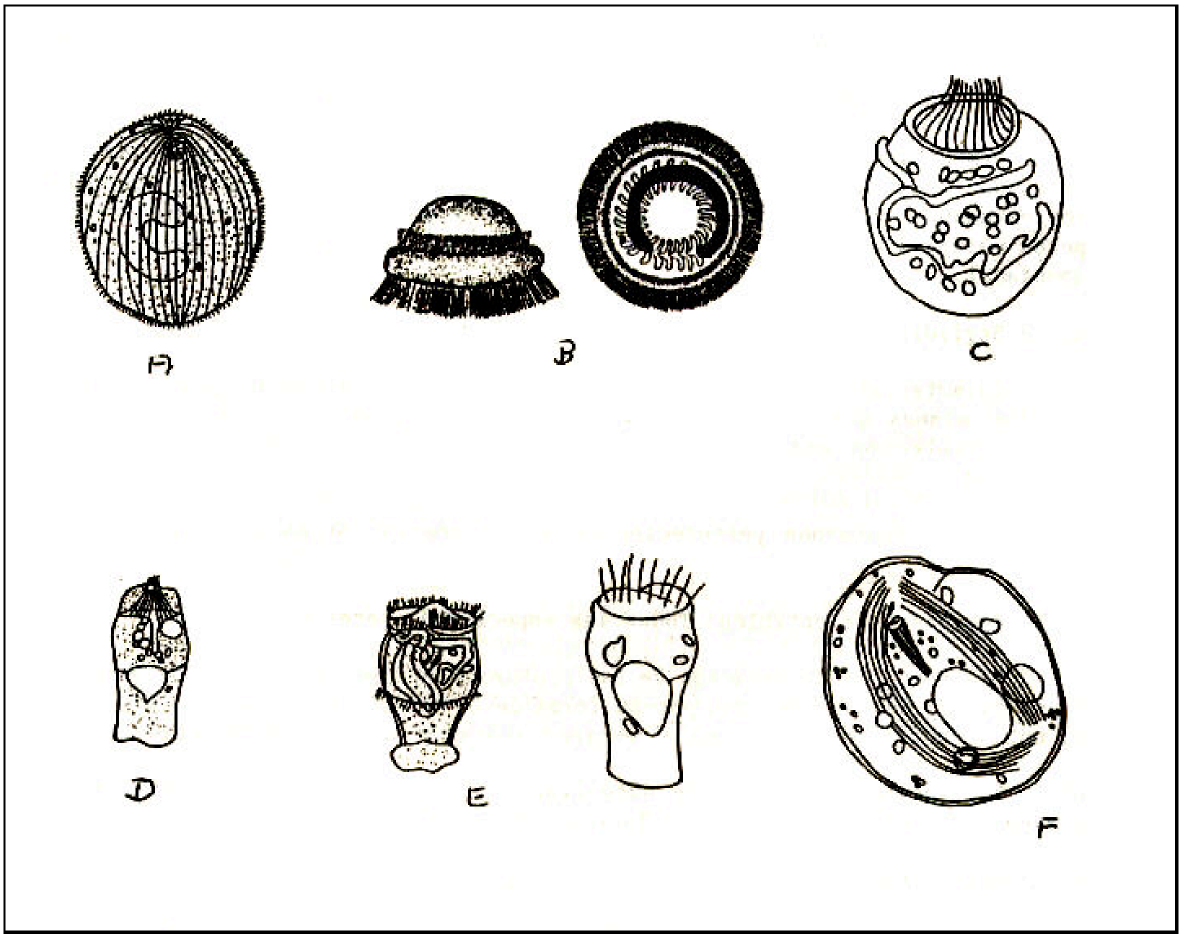


FIGURA 1. ***A: Ichthyophthirius multifilis. B: Trichodina sp C: Scyphidia sp D: Apiosoma sp E: Ambiphrya sp F: Chilodonella sp***

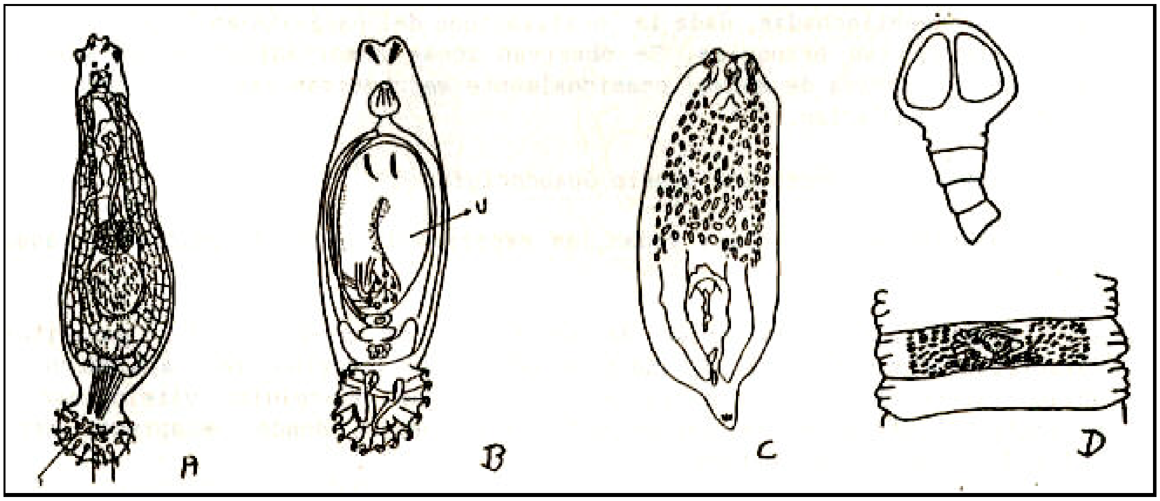


FIGURA 2. ***Helmintos A: Helminto típico monogéneo B. Gyrodactilus C: Diplostomun D: Botriocephalus***

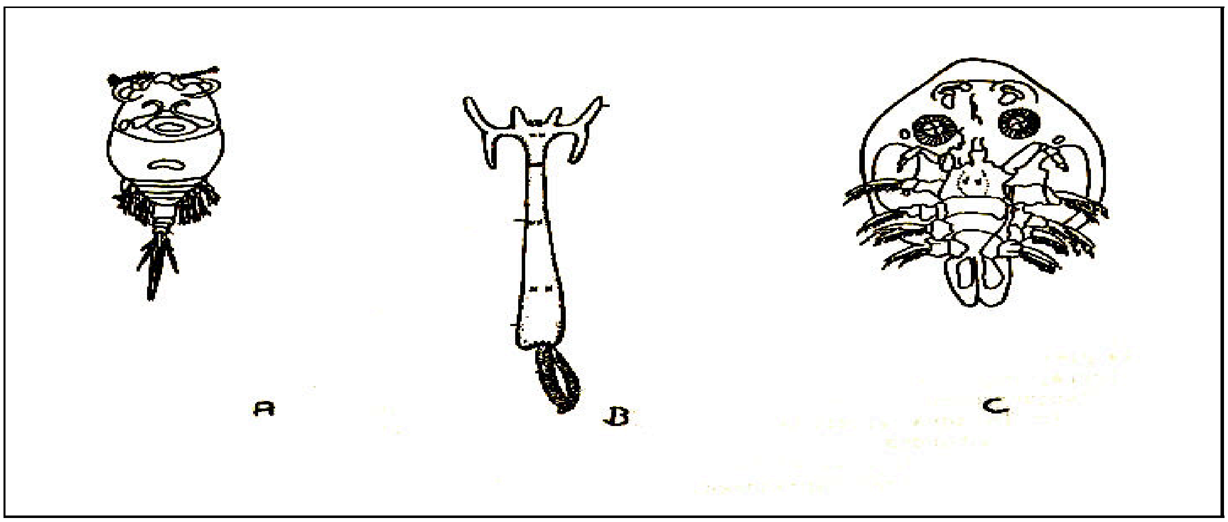


FIGURA 3. ***Copépodos. A: Neoergasilus japonicus B:Learnea cyprinacea C: Argulus***

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