Operators Manual for 880 - Recycle System

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Table of Contents

INTRODUCTION 3

STOCKING/ HARVESTING SEQUENCE 4

WATER QUALITY MANAGEMENT 7

Temperature 7
Dissolved Oxygen 7
Carbon Dioxide 7
pH 8
Total Ammonia-Nitrogen 8
Toxic Ammonia 8
Nitrites 9
Total Alkalinity 9
Turbidity 9
Chlorine 9

FEED MANAGEMENT 10

Fish Feeds 10
Feeding Rate 10
Feed Size 11
Frequency of Feeding 11
Feed Delivery Systems 11
Feed Conversion Ratio (FCR) 12

SAMPLING FISH 13

GRADING FISH 14

RECORDKEEPING 16

Water Quality 16
Feeding Data 16
Sampling Data 16
Stocking Data 16
Harvest Data 16

SETTING UP A HATCHERY 18

Spawning Tank 18
Hatching Jar/Aquarium 19
Phase I - Nursery Tanks 19
Phase II – Nursery Tanks 19
Phase III - Fry Growout Tank 19

OPERATING A HATCHERY 21

Spawning 21
Sexing Tilapia 21
Broodfish 22
The Spawning Tank 22
The Hatchery Jars 23
The Fry Trough 23

GROWTH 24
Temperature *25*
Water Quality *25*
Density *25*
HANDLING FISH 26
Acclimating Fish *26*
Stocking Fish *26*
Harvesting Fish *27*
Shipping Fish *27*
Transporting Fish *27*
HOW THE BIOFILTER WORKS 29
Acclimating the Biofilter *30*
FISH HEALTH MANAGEMENT 31
Stress *31*
Temperature *31*
Water Quality *31*
Spawning Activities *31*
Handling *31*
Nutrition *32*
Genetics *32*
Recognizing Sick Fish *32*
Severity of Infections *32*
Prevention of Disease *32*
Treating Diseases *32*
TROUBLESHOOTING 34
Low DO Levels *34*
High NH_3 *Levels* *34*
High NO_2^- *Levels* *34*
Reduced Flow *35*
Low pH *35*
High pH *35*
Power Outage *35*
EQUIPMENT MAINTENANCE 36
DEFINITIONS 37

Introduction

The operators manual was written for the 880 gallon recycle aquaculture system designed by The Conservation Fund's Freshwater Institute for use in high schools as an educational tool. The purpose of this operator's manual is to provide those interested in using aquaculture in the classroom as a teaching tool a technical description of the design and operation of the 880 gallon recycle aquaculture system.

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Stocking/ Harvesting Sequence

This sequence is designed to produce about 85 one-pound plus fish every month as a maximum yield (over 1000 pounds of fish per year). Your success at achieving this maximum yield will depend upon your ability to manage the system. At first the tanks will not have a heavy load of fish, allowing you time to learn and experiment with the system, but as the fish begin to grow and the tanks begin to fill, more demand will be put on both the system and the managers.

You will be producing fish using a multiple cohort system (a continuous or sequential fish rearing system). This simply means that you will have several different-sized fish in each tank. The fish will range in size from 50 to 450 grams. As the largest group of fish are harvested, you will stock another batch of 50-gram fish to replace them. This system allows you to maintain a fairly constant load of fish in the tanks at all times. Since the feeding rates determine the nutrient levels for the plants, it is important that feeding levels remain somewhat constant.

Example:

TANK 1			TANK 2		
# fish	avg weight (g)	total wt (kg)	# fish	Ave weight (g)	total wt (kg)
120	50	6	93	300	27.9
108	90	9.7	90	400	36.0
98	150	14.7	88	454	39.9*
95	225	21.4			
	Total weight of fish:	51.8 kg		Total weight of fish:	63.9 kg

* - These fish are harvested from the system or put into another tank to increase weight.

You are trying to maintain the standing crop of fish between 1/3 and 1/2 pound of fish per gallon of water.

TANK 1 51.9kg x 2.2 lbs/kg = 114.18 lbs of fish
114.18 lbs/420 gallons = 0.27 lbs/gallon or about 1/4 lbs per gallon

TANK 2 63.9kg x 2.2 lbs/gal = 140.58 lbs of fish
140.58lbs/420 gallons = 0.33 lbs/gallon or about 1/3 lbs per gallon

One month from stocking the tanks this way, it will be time to harvest the largest group of fish that should have an average weight of about 525 grams each. The tanks would now look like this:

TANK 1			TANK 2		
# fish	Ave weight (g)	Total wt (kg)	# fish	Ave weight (g)	total wt (kg)
108	90	9.7	90	400	36.0
98	150	14.7	88	454	39.9
95	225	21.4	86	525	45.2
93	300	27.9			
Total weight of fish:		73.7 kg		Total weight of fish	121.1 kg

TANK 1 73.7kg x 2.2 lbs/gal = 162.14 lbs of fish
162.1lbs/420 gallons = 0.38 lbs/gallon or about 3/8 lbs per gallon

TANK 2 121.1kg x 2.2 lbs/kg = 266.4 lbs of fish
266.4 lbs/420 gallons = 0.63 lbs/gallon or about 1/2 lbs per gallon

Both tanks hold 428.5 lbs of fish in 880 gallons of water to have a maximum load of about ½ lb of fish per gallon of water. Notice that the load is not exactly balanced (tank 2 has more weight than tank 1). The imbalance means that tank 2 contains more than its carrying capacity of fish. You may experience problems such as low dissolved oxygen just after feeding or other associated water quality problems. This could be compensated for by running a little more water through tank 2 than tank 1. You might start harvesting 1 lb + fish throughout the month so you can keep the weight of fish in tank 2 below ½ lb/gal.

Stocking/ harvesting sequences often must be modified when the fish don't perform as expected. In order to adequately plan a stocking/harvest sequence, the following information is needed:

1) An accurate estimate of growth rates for various sized fish.
2) An estimate of survival for various sized fish.
3) The maximum safe feeding rates for the tanks.
4) An understanding of the following relationships:
    - Stocking density versus average harvest weight
    - Standing crop versus time for different stocking densities

Growth and survival rates can be found in extension literature or journals but the best reference is your own practical experience once you have had the fish growing for a while (keep accurate records!).

Table 1 - Estimated stocking, growth and feeding rates for Tilapia*

Stocking Rate (#/cu meter)	Beginning Weight (grams)	Final Weight (grams)	Growth Rate (grams/day)	Growth Period (days)	Feeding Rate (% of body weight)
1,600	5	20	0.5	30	10 - 7
1,000	20	50	1.0	30	7 - 4
500	50	100	1.5	30	4 -3.5
200	100	250	2.5	30	3.5 - 1.5
100	250	450	3.0	70	1.5 - 1.0

* - From SRAC pub SP 374-P

You have control over the numbers of fish stocked and the size of fish stocked. These decisions will determine how long until the tank reaches carrying capacity and what size the fish will be when it reaches carrying capacity.

Water Quality Management

Providing the fish with an environment conducive to optimal growth is the objective of a good water quality management program. Managers have a great number of tools at their disposal to predict, detect and resolve water quality problems in closed, recirculating systems. Careful monitoring and organized recording of vital water quality parameters is essential.

Many water quality variables fluctuate throughout the day. It is a good practice to take the measurements in the same place and at about the same time each day to make comparisons of data more valid. You may occasionally want to check the water quality in each tank to establish that the variables change little between tanks in the same system (since they all share the same water). Tank flow rates and turnover times should be checked periodically (lower overall flow rates may indicate the need for a backwash of the bead filter). Tanks with heavy loads of fish or unusual coloration may warrant individual water quality testing with increased frequency.

Temperature

The temperature should be monitored about every other day. Tilapia grow best between 77 and 95°F. Tilapia become stressed and may die when water temperatures drop below 65°F. Try to keep the temperature as constant as possible at around 85°F.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations are measured with a dissolved oxygen meter and should be checked every day. There may be a chemical test for this in your water quality kit, but the meters are much more efficient and accurate. DO measurements are reported in milligrams per liter (mg/l) or parts per million (ppm). Your meter should also report temperature (degree F or degree C). This is because the amount of oxygen the water can hold is influenced greatly by its temperature.

The greatest demands on the amount of oxygen in your tanks is dictated by the amounts of food fed. Shortly after feeding DO levels begin to drop. Try to measure DO about an hour after feeding. When you are feeding near maximum feeding levels, the DO should be checked twice a day.

Carbon Dioxide

Carbon Dioxide (CO_2) is a waste product released into the water by fish. It is significant in water quality management for two reasons. First, at high concentrations (>10 mg/l), it tends to interfere with a fish's ability to utilize oxygen. And secondly, its buildup will reduce the water's pH. Only rarely will the CO_2 levels be a problem in your system. High levels will result from poor circulation or inadequate aeration during high feeding periods. Some test kits are equipped with a CO_2 test. Usually, it is unnecessary to measure CO_2 because of the system's ability to maintain it at acceptable levels. You should simply be aware of its presence and potential effects.

pH

pH is defined as the negative logarithm of the hydrogen ion activity: $pH = -\log(H^+)$. In simpler terms, it is the measure of whether something is acidic or basic. A pH of 7 is considered "neutral" with all values less than 7 being acidic and values greater than 7 being basic. It is important to understand that a pH of 7 represents 10 times the (H^+) as a pH of 8.

The pH of the water in your system should be maintained between 6.5 and 7.5. It should be measured about every other day. Several factors contribute to the general tendency for the pH in your system to steadily decline (see How the Biofilter Works). Low or high pH values can stress fish causing decreased feeding activity and growth. The pH of your system will also affect the biofilter's ability to remove wastes.

Total Ammonia-Nitrogen

The amount of total ammonia-nitrogen in the system should be measured at least every other day. This test measures both NH_3 (called toxic or un-ionized ammonia) and NH_4^+ (called ionized ammonia or ammonium), and is reported in terms of an equivalent nitrogen concentration. The ultimate source of all nitrogenous compounds, such as total ammonia-nitrogen, is the feed administered to the fish (for more information on transformations of nitrogen see "How the Biofilter Works"). Fish metabolize the feed and excrete ammonia as a waste product. The equilibrium equation is: $NH_3 + H_2O = NH_4^+ + H_2O$. Total ammonia exists in two forms. The bulk of the total ammonia exists as the ammonium ion (NH_4^+), which is only toxic to fish at high concentrations. A small amount of the total ammonia present will be in the form of NH_3, which is toxic to fish at fairly low concentrations (it is this form that is often called "toxic ammonia"). The amount of total ammonia that exists as un-ionized ammonia depends on the pH and temperature of the water.   The lower the pH, the greater the percentage of un-ionized ammonia. The higher the temperature, the greater the percentage of un-ionized ammonia. Since there is no direct way to measure the amount of un-ionized ammonia, we must measure the amount of total ammonia and use pH and temperature to help us determine what percentage of the total ammonia will be in the toxic, un-ionized form.

Toxic Ammonia

Once the concentration of total ammonia-nitrogen is known, the amount of toxic, un-ionized ammonia can be calculated and reported in mg/l. Simply refer to a table (provided with your water quality kit) that gives the percentage of un-ionized ammonia for different pH and temperatures. Find the percentage value for your pH and temperature, and multiply this by the total ammonia-nitrogen value (see the instructions in your water quality test kit for examples). Un-ionized ammonia levels of 0.2 to 2.0 mg/l will stress your fish and may cause depressed feeding activity. Levels higher than 2.0 mg/l can result in death.

You should note that a small change in pH can have a profound effect on the amount of un-ionized ammonia. At 77°F (25°C) and a pH of 7.0, only 0.40% of the total ammonia will be un-ionized. While at 77°F (25°C) and a pH of 8.0, almost 4% of the total ammonia will be in the form of toxic, un-ionized ammonia.

Nitrites

Nitrites (NO_2^-) occur as an intermediate stage in the biological decomposition of ammonia to nitrates (NO_3^-). Nitrites are readily oxidized to nitrates under the aerobic conditions of your biofilter. Occasionally there may be an interruption in the biological processes that convert nitrites to nitrates, and nitrites will begin to accumulate in the water.

Nitrites should be checked every 2-3 days and should generally be very low (0-2 mg/l). You may notice an increase in nitrites 5-7 days after a "spike" in the ammonia levels. Nitrite concentrations of 2-10 mg/l stress fish. High nitrites (10-20 mg/l) cause "brown blood disease" in fish and can result in death (the fish will appear to be gasping for air at the surface and their blood will appear chocolate in color). Nitrite toxicity can be alleviated using low concentrations of salt, but since salt cannot be used in systems that are integrated with hydroponics, water exchanges will have to be used when nitrite concentrations become dangerously high. Reducing the feeding rate may give you some relief.

Total Alkalinity

Total alkalinity is a measure of the HCO_3^- (bicarbonate) and the $CO_3^=$ (carbonate) in the water expressed as mg/l $CaCO_3$. The presence of these compounds in water minimizes pH fluctuations by acting as a buffer. Common household baking soda ($NaHCO_3$) may be added to buffer the water in the systems and to raise pH. Sodium (Na^+) may tend to buildup in the water and interfere with hydroponics. Total alkalinity should be checked about once a month. Measured values should exceed 20 mg/l.

Turbidity

This is a measure of water clarity. Usually a secchi disc (an eight-inch white and black disc) is lowered into the water until it disappears and then brought back up until it becomes faintly visible. The depth at which it becomes visible (measured in inches) is a measure of the turbidity. A light colored coffee cup or other small object can be substituted. The turbidity should be checked each week. It is important to notice changes in turbidity. Sudden changes can indicate problems with the system. The water in tanks with high standing crops of fish will be brown in color with a secchi visibility of only 5-8 inches.

Chlorine

Tap water contains chlorine that will suffocate fish in high concentrations. Changing more than 40 % of the water in a system at one time with chlorinated tap water could stress your fish (the more organic material you have in your water, the more chlorinated water the system can tolerate). Allowing tap water to stand overnight will allow the chlorine levels to drop significantly.

Feed Management

In recirculating systems, feeding is the most important management tool because it sets the level at which all of the working components must function. If tanks are overfed, the filtration system may not be able to keep up and the system may "crash". If the tanks are underfed, the fish will take too long to reach market size and costs of production will be too great. In integrated hydroponic systems, the feeding rate establishes nutrient levels for the plants. They should not fluctuate widely. A good feed management program requires diligent recordkeeping. Feed amounts must be carefully weighed, administered and adjusted as the fish grow in size.

Feeding has been equated to an art form. Training the fish to your feeding regime and getting feed to all of the fish so that they all grow uniformly is difficult. It requires keen observation and a little intuition on the part of the feeder. Being able to read the fish's level of feeding activity takes some practice. As a general rule, if administered feed is not eaten within 15 minutes, you should cut back on the ration. The importance of this management activity cannot be stressed enough. The growth rate of the fish and the health of the system are primarily dictated by the feeding program.

Fish Feeds

For Tilapia, you should buy 28%-32% protein, nutritionally complete feeds for your fish. The fish are entirely dependent on the feed for meeting their nutritional requirements. Floating feeds are desirable since they allow you to better monitor fish feeding activity. Feeds that are held longer than 30-40 days should be refrigerated since they can spoil. "Fines" (the powdered feed in the bottom of the feed bags) should be saved and fed to small fry. This material is too small for larger fish to utilize and would only foul the water.

Feeding Rate

Feed amounts are determined based on a percentage of the fishes' body weight. Small fish require 15-20% of their body weight each day (because of higher metabolisms), and large fish require only 2.5% of their body weight each day for optimum growth. Fish are willing to eat more than this, but additional feed does not significantly increase growth rates and will cause deteriorating water quality.

Weight of fish (grams)	Feeding Rate (% body weight)
0 – 1	20 - 15
1 – 5	15 - 10
5 – 20	10 - 7
20 – 50	7 - 4
50 – 100	4 - 3.5
100 – 250	3.5 - 1.5
250 – 454	1.5 - 1.0

Therefore, if a tank of fish contains 45 kg of 50-gram fish, it should be fed 45 kg x 0.04 (4%) or 1.8 kg of feed a day. Each tank has a maximum feed amount of 5.0 lbs/day.

Feed Size

For fish to grow at optimum rates, the size of the pellet fed needs to be changed as the fish grow. You should feed a pellet that is as large as the fish are able to eat. This is dictated by their mouth size. Feeding pellets that are too small results in fish wasting energy and effort chasing small pellets around the tank trying to get enough to eat. Feeding pellets that are too large results in the fish having to repeatedly grab and spit out pellets while they wait for them to break up or soften so they can be swallowed. The following are general guidelines for feed sizes.

Fish size (inches)	Feed size (mm)	Sieve #
< 0.5	fines	30
0.5 - 1	crumbles	20
1 - 2	1 - 1.5	16
2 - 4	2 - 3	12
4 - 6	3 - 5	8
> 6	5	6

Try keeping two different sizes of floating pellets in inventory (1/16" and 3/16" pellets) and grinding the pellets to the appropriate size. Sieves can help sort the particle size. Usually, only a very small amount of the smaller feed sizes needs to be kept in inventory.

Frequency of Feeding

Studies have consistently shown that fish that are fed several times a day grow faster than fish that are fed the same ration only once or twice a day. This is especially true for Tilapia. Tilapia are “grazers,” and feed throughout the day in natural environments. They have no well defined stomach or “gut” that allows them to store food for later use. Therefore, a day’s ration should be split into as many feeding sessions as possible. Smaller fish tend to have higher metabolic rates, and must have regular access to feed. Frequent feeding not only improves growth, but contributes to improved water quality. It is important to spread out ammonia production and utilization of oxygen throughout the day.

Feed Delivery Systems

Demand Feeders - These feeders allow fish to feed whenever they want. They are usually loaded with a day’s ration and fish administer the feed to themselves (see drawing). Demand feeders save on feeding labor but have several problems and should therefore be used cautiously. Some of the problems are: 1) there may be a differential growth advantage to individuals that learn to use the feeder more efficiently; 2) fish may trigger the release of more food than they will actually eat thereby wasting feed and damaging water quality; and 3) the fish may eat all of the feed early in the day and not spread out their feeding activity.

Automatic Feeders - These feeders are activated by a timer and will feed a set amount many times a day. They are good laborsaving devices, but are no substitute for hand feeding with observation of feeding activity. Automatic feeders will continue to administer feed even if the fish aren't eating it.

Belt Feeders - Belt feeders are particularly suited for small fry since they only handle small amounts of feed, can handle fines and small crumbles, and will feed continuously.

Feed Conversion Ratio (FCR)

An important measure of a feed management plan's effectiveness is it's feed conversion ratio or FCR. The success of a feeding program can be measured by both the fishes' growth rate and FCR. It is important to have the fish reach the one-pound harvest weight on schedule, but how much feed did it take to produce the harvest? The FCR may be calculated as follows:

$$FCR = \frac{\text{total weight of feed fed during time period (kg)}}{\text{weight of fish at end of time period (kg) minus weight of fish at beginning of time period (kg)}}$$

Feed conversion ratios can be estimated over time periods as short as two weeks but tend to be more accurate over longer time periods. Samples of fish can be used to estimate how the weight of fish in a tank has changed over any given time period (see sampling fish). More accurate tank weights can be determined during harvests (all of the fish can be weighed). Feeding records can be used to determine the weight of feed administered to any group of fish.

Tilapia are known for their good feed conversion rates. They can gain about one pound of flesh for every 1 ½ pounds of feed administered or have an FCR of 1.5. Note that fish mortalities will increase the FCR since the weight of mortalities will be excluded from the calculation.

Sampling Fish

Each tank should be sampled every two weeks to adjust feed amounts and to determine if growth has been adequate. Periods of unsatisfactory growth will not only postpone the tentative harvest date but may indicate environmental conditions that need attention (see growth). Sampling about 10% of all of the fish in the tank will provide an adequate sample size. If a tank holds 200 fish, you should randomly net about 20 of the fish and determine their average weight as follows:

$$\text{average weight (g) of the sample} = \frac{\text{total weight of fish in sample (kg) x 1000}}{\text{numberof fish in sample}}$$

It is important to take care of the fish during this process. Stressing the fish during sampling will only result in lost growth or mortality. Fish can be weighed in a bucket of water if the tared weight is recorded before adding fish. Larger fish may be weighed in a net if they are not kept out of the water too long. If the fish are held in a container for any period of time, they will require aeration. Fish will not feed well for a few hours after sampling and should not be sampled just after feeding.

Once the average weight of the sample has been determined, the total weight of fish in the tank can be estimated as follows:

$$\text{total weight of fish in the tank (kg)} = \frac{\text{number of fish in the tank } x \text{ average weight of sample (g)}}{1000}$$

Now that you have an estimate of the total weight of fish in the tank, you can calculate a new daily feed amount for that tank. You can also calculate the standing crop or fish density for that tank.

standing crop (kg/m^3) = total weight of fish in the tank (kg)/ volume of tank (m^3)

fish density (#/m^3) = total number of fish in the tank/ volume of tank (m^3)

Grading Fish

For centuries, fish culturists have known that every fish responds differently to the stresses of captivity. Some fish grow exceedingly well (jumpers) and some will do poorly (culls) in the crowded environment. Eliminating the fish that grow poorly and maintaining uniform-sized groups of fish in each tank will improve yields if you are using a batch production system. A tank with fish that are uniform in size tends to gain weight more quickly than a tank of fish that has a wide size variation. Large fish tend to eat more feed than they need, and size differences tend to increase if left unattended. One of the great benefits of closed recirculating systems is that the fish stocks are completely accessible at all times. We use this accessibility to precisely control numbers and sizes of fish in each tank. Grading (sorting fish by size) insures regular harvests, more efficient utilization of feeds, and produces a more uniform harvestable fish.

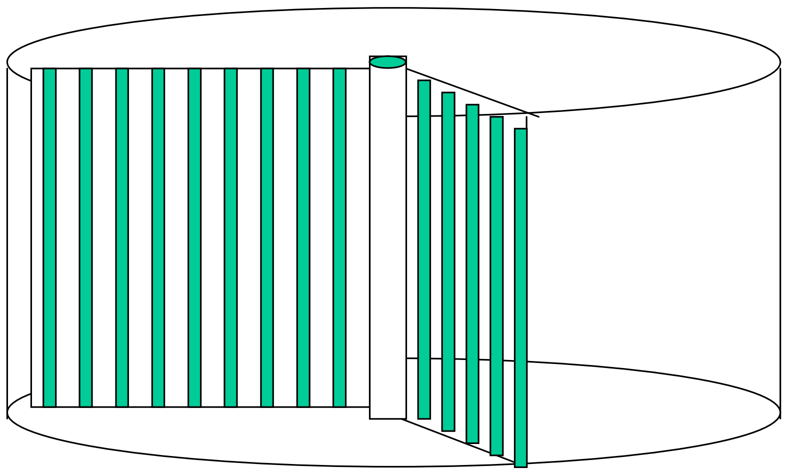

Figure 1 – Bar grader for harvesting fish out of a tank.

Make sure that you carefully record relocations so that you always know how many fish are in each tank. Grading is especially important for smaller fish. Cannibalism is a major cause of mortality of very small fish.

If you are using a multiple cohort production system, you will have to deal with the problems associated with having many different sized fish in each tank. Your best degree of control is when you first stock the tanks, and then when groups of fingerlings are stocked each month. Starting with uniform sized fish will help. The longer you operate using a multiple cohort production system, the more control over the size and numbers of fish in each tank is lost. It may be prudent to occasionally remove all of the fish in a tank and restart the production scheme with known numbers and sizes.

Grading of fish may take place within a tank or between tanks and the procedure is summarized as follows. Grading of fish within a tank means that the small fish from a tank remain in that tank and the large fish are moved to another tank. A bar grader as shown in Figure 1 can be used to grade harvestable size fish from a tank with a fish of different sizes. This would involve crowding the fish to one side of the tank using the bar grader and allowing the smaller fish to pass through the bars.

Recordkeeping

The importance of good recordkeeping cannot be overemphasized. Good records will allow you to anticipate problems before they start, increase yields, decrease costs, and predict harvest dates more accurately. Being able to accurately record, organize, and evaluate data is an invaluable skill for students.

Each system needs its own set of water quality records and each tank will need feeding, sampling, stocking and harvesting records. These records must be easily accessible and kept current at all times. Everyone involved with the lab should know where they need to go to look up or record vital information such as how many fish are in tank #2, or when (and who) fed the fish last.

Water Quality

Plotting this data on graph paper allows easier identification of water quality trends. Plot each system's total ammonia-nitrogen, toxic ammonia, pH, and nitrates on the same piece of graph paper or prepare overlays that allow the interrelationships to be observed. Dissolved oxygen and water temperature can be plotted on another graph. It is always useful to be able to determine who collected the data.

Feeding Data

Daily feed amounts and an evaluation of the feeding activity need to be recorded for each tank (poor, fair, good, excellent). Being able to look at the past week's records of feeding activity allows you to feed more efficiently. Here too, it is useful to know who did the feeding.

Sampling Data

The average weight of each sample may be graphed to provide a growth curve that will expose periods of slow growth for each group of fish and let you accurately anticipate harvest dates. The total weight of fish in each tank can be used to determine the standing crop of fish (kg/m^3) which can be graphed over time to determine the system's carrying capacity.

Stocking Data

It is important to know what weight and how many fish were put into each tank. You should keep a running census of the numbers of fish and total weight of fish in each tank that accounts for mortalities and relocations.

Harvest Data

It is important to know what weight and how many fish are removed from each tank. When tanks are emptied, all the fish should be counted and weighed. This establishes baselines of production that can serve as goals for later crops of fish. You should know how many pounds of harvestable fish were produced by your system each year and what the survival rate was for each group of fish.

Setting up a Hatchery

A simple hatchery can be set up that should augment your supply of fingerlings. It will require a few aquaria or possibly a small tank with a filtration system depending on how many fingerlings you would like to produce. The tank requirements depend on the numbers of fish you want to produce. Batches of fry need to be initially separated and then spread out into larger volumes to allow them to grow rapidly. If they are overcrowded, poor water quality and cannibalism will cause excessive losses. This first phase of growth is the slowest. It will take about three months to produce a batch of 20 gram fingerlings. That means there is a significant commitment of time and space when producing fingerlings.

It will be difficult to consistently produce all the fingerlings you will need. Producing fry can provide an excellent learning opportunity. The following components are required to establish a hatchery.

Spawning Tank

This could be a 20 gallon aquarium or a 200 gallon tank. This tank=s size will limit how many broodfish the tank will hold and therefore, will limit the number of eggs you are able to produce each month. This in turn will determine how many hatching jars and nursery tanks you will need. An aquaria may hold a pair of 200 gram fish or possibly four, 100-gram fish. It is important not to overcrowd the spawning tank or there will be little results. The ability of the aquaria or tank to hold a weight of fish depends on the capacity of the filtration/aeration system. The spawning tank must also be well heated. Maintaining a consistent temperature is very important. All of the tanks associated with fingerling production will require heaters sized to maintain adequate temperatures.

Hatching Jar/Aquarium

A hatching jar can be made from a plastic soft drink bottle (any bottle with smooth round base) (See Figure 2). The water flow going into the bottle needs to be controlled so the eggs in the bottle are not agitated too much or too little. It needs to sit in an aquaria or something that will catch the overflow (which will contain hatched fry) and recirculate the water.

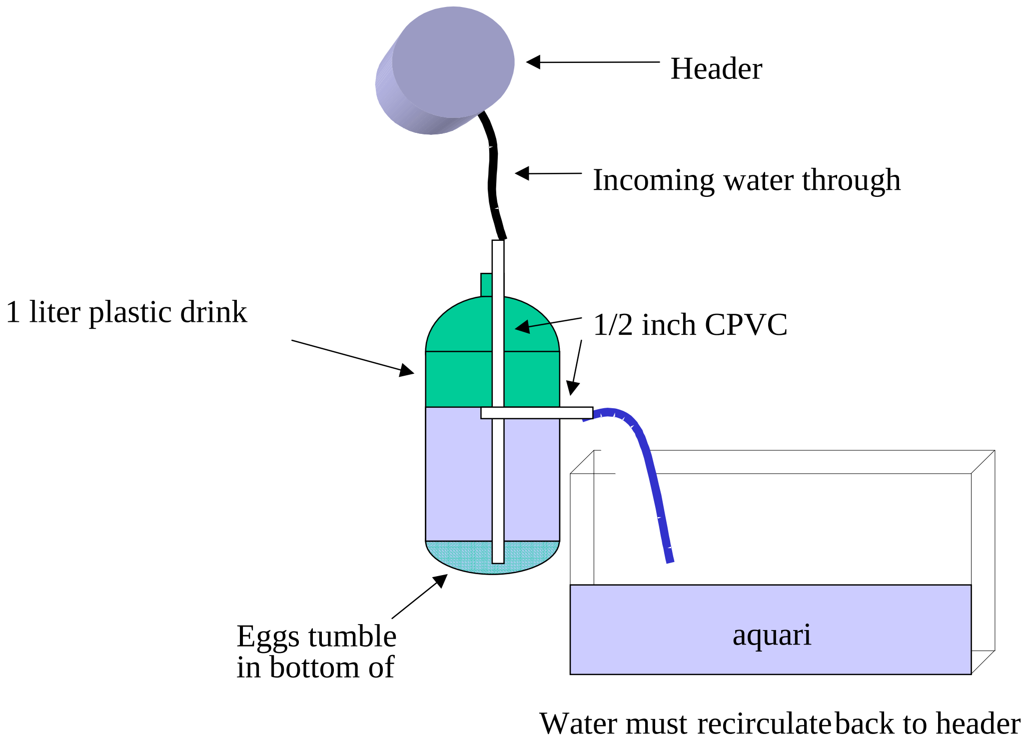

Figure 2 - Hatchery/Jar – aquarium.

Phase I - Nursery Tanks

A small aquarium - The fry are moved into this tank for the first 4 weeks of life. Here they are first introduced to feed. They should weigh about 0.02 grams when they are first stocked into this tank and will weigh about 0.4 grams when they are moved to Phase II tanks.

Phase II – Nursery Tanks

Small aquaria will be suitable for this phase of fry production. Fry are collected from the phase I nursery tank and kept here for further growth. They will weigh about 3-5 grams when they are moved from this tank to the fry growout tank.

Phase III - Fry Growout Tank

This should be a fairly large tank (50 gal +) where fry are held and grown out to stocking size.

You might be able to use a hapa that sits on top of a production tank to growout the fry. The size greatly depends on how many fry you plan to produce each month and the stocking size.

Operating a Hatchery

There are many environmental factors that induce spawning behavior in fish: temperature, photoperiod, water quality, water transparency, lunar cycle, substrate availability, density and the presence of mature males or females. The condition and predisposition of the broodfish can greatly affect spawning success. With so many factors to consider, it can be a process of elimination to get the fish to spawn satisfactorily.

Fortunately, Tilapia are known to be prolific spawners. They become sexually mature at a very young age and a single fish can spawn 8+ times each year! They exhibit buccal incubation (the female holds the eggs in her mouth) and are an excellent species for genetic/reproductive studies. You should work at developing a good broodfish management program and try to produce more fish than you require.

Spawning

Tilapia will spawn when water temperatures are maintained between 77 and 90°F. The female releases anywhere from 50-500 eggs while the male fertilizes them (males are polygamous). The female picks up the eggs and incubates them in her mouth until they hatch (about 3 days). She keeps the fish in her mouth for another 3 or 4 days until they can swim. After they can swim, they may spend as much as another 7 days in and out of the female's mouth. The female will not eat while eggs or fry are in her mouth. This, plus the loss of the energy she expends on egg production, causes the females to grow more slowly than males.

Sexing Tilapia

Tilapia may be sexed when they weigh about 50-60 grams. Larger fish are easier to sex. It is helpful to apply a little dark food coloring to the genitals with a q-tip swab. This will highlight the details of the genitals. The females have more rounded genitals with a characteristic crescent shaped slit posterior to the anus (See Figure 3). Practice will make you proficient at sexing Tilapia.

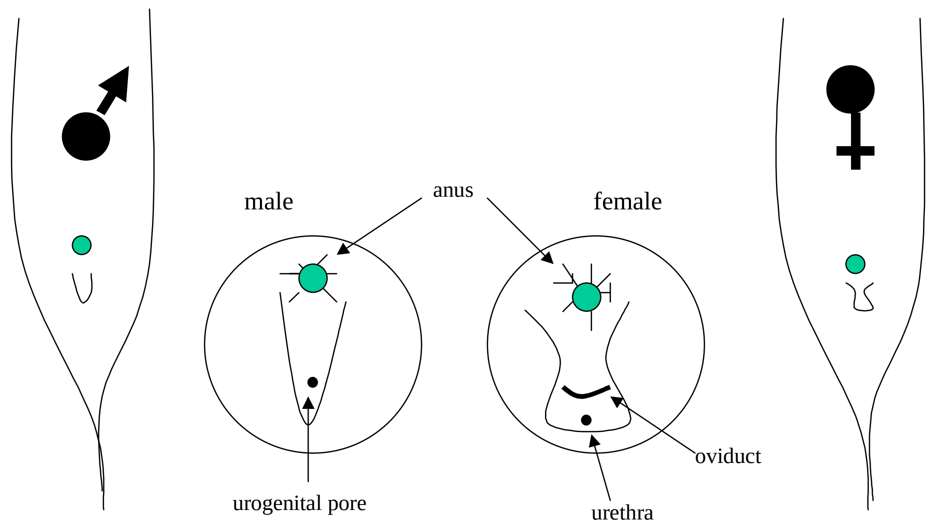

Figure 3 – Identifying male and female Tilapia.

Broodfish

Broodfish should be selected carefully. You may purchase strains suitable for specialized genetic studies or you can simply select them from among your crop of fish. Broodfish should be free of deformities, have a healthy appearance, exhibit good growth and be in good condition. Tilapia do not become sexually mature until they weigh 50-60 grams (4-6 months old). Female broodfish weighing between 150 and 250 grams will produce the most eggs per pound of fish (have the highest relative fecundity). Males and females should be kept separate prior to being placed in the spawning tank and should be fed well (2% body weight). Clipping notches on the dorsal fin or the tail of the broodfish with scissors will allow easy identification (for about a month) of selected males and females. Spawned females will not be ready to spawn again for another 6-8 weeks.

The Spawning Tank

The spawning tank should be stocked with broodfish that indicate they are close to spawning. The fish should have a well-rounded abdomen, the genital opening should be slightly swollen and reddish. A gentle squeeze along the belly may elicit eggs or milt. Stocking 2 or 3 females to each male gives the best results. The spawning tank should probably hold no more than 6-8 fish at a time. Broodfish should be fed lightly (1% body weight) and should not be unnecessarily disturbed while in the spawning tank. Females should be checked about every 3-4 days for eggs. If the broodfish stocked into the spawning tank have not produced within two weeks, they should be replaced with alternate broodfish. When the female broodfish are netted, they may spit out eggs or fry, so be sure to hold them over a container. Eggs may be removed from the females mouth by washing them out with water. Simply hold the female head down over a container and pour water through the back of the gills. Eggs should be immediately transferred into the hatching jars. Males are very rough on the females during spawning and may actually damage or kill them. Overaggressive males can have their upper lip removed with a sharp pair of scissors to prevent them from damaging females.

The Hatchery Jars

Groups of eggs that are collected at about the same time can be put into the same hatching jar. The flow through the hatching jar should be sufficient to gently roll the eggs around in the bottom of the jar. The time it takes for the eggs to hatch is directly related to the water temperature. Often hatching times are recorded in degree-hours (number of hours till hatch x temperature °C). After the eggs hatch, the fry will stay in the jar until they can swim, at which time they will be swept out of the jar and into the fry trough. Eggs that are damaged or have fungus on them (a furry coating) should be removed from the jars. Hatchery jars should be kept clean and may be sterilized with a weak bleach solution before use (make sure you thoroughly rinse all bleach off before using).

The Fry Trough

As the "swim up" fry spill out of the hatchery jar, they will fall into the fry trough. They can be caught in a modified milk jug. Simply cut the top 1/3 off of a one gallon plastic milk jug. Cut a small hole in the side of the jug (about 1"x 2") and glue or silicon window screen over the hole. Place the milk jug in the fry trough under the flow of water. The fry trough may be divided into smaller compartments using screens to allow grading of fry. The fish suffer their highest mortalities (mostly due to cannibalism) at this stage of the production cycle (over 20%). It is important to keep batches of fish separate (you will keep each batch of fish in the fry trough for about 40 days or until they weigh 2 grams).

These fish need constant access to appropriate-sized feed (the fry will begin to feed when they are 6-7 mm in size), but overfeeding will hurt water quality and could kill them. All screens need to be cleaned regularly to provide adequate water circulation. Old feed should be siphoned from the bottom of the trough (using a section of airstone tubing) twice a day. These fish are delicate and will not tolerate frequent handling.

Growth

Several factors affect the growth of fish. It is important to learn to manipulate these factors to encourage maximum fish growth. Temperature, age, water quality, feed quality, feed quantity, feeding frequency, genetics, disease, density, sex, and size all affect fish growth rates.

Growth can be measured two ways. Relative growth is a measure of a fish's growth as a percentage of body weight. Small fish have higher relative growth rates than larger fish. If a 10-gram fish is weighed 10 days later and found to weigh 14 grams, it has an relative growth of 40% ((14 g- 10g) / 10g), and an absolute growth (growth measured in grams per day) of only 0.4 g/day (the fish gained 4 grams/10 days). A 182-gram fish which weighs 204 grams 10 days later, has only a 12% relative growth (22/182), but an absolute growth rate of 2.2 g/day ((204g-182g) /10 days). Larger fish tend to grow at higher absolute growth rates than smaller fish. It is important to recognize that when fish are small, they are doubling their size frequently but are actually increasing in weight (g/day) very little. Therefore, it is important to get the fish through this stage of the production cycle as quickly as possible.

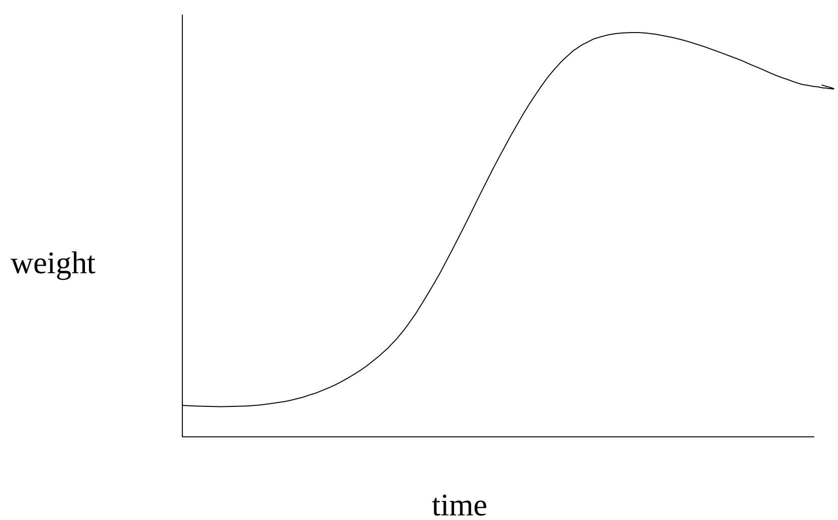

Figure 4 – Standard growth curve.

The typical growth curve (Figure 4) can represent the growth of a single fish (g) or the growth of an entire group of fish (kg) over time. The growth curve for an individual fish begins with slow absolute growth during larval and juvenile stages of development. This is followed by a phase of rapid absolute growth (the steepest part of the growth curve) as the fish becomes an adult. Eventually growth slows (the fish can even lose weight) because the fish has reached it's maximum size or because of senescence (old age).

The same growth curve can represent the increase in total weight of a group of fish over time. A group of young fish starts off adding weight slowly and then enters a stage of exponential growth as they become adults. It is during this period that the weight of fish in a tank can increase very rapidly. Growth begins to slow at the inflection point called the critical standing crop. The critical standing crop is a point of diminishing marginal returns. Feed conversion ratios begin to increase (it takes more feed to produce each pound of fish). If the fish are large enough, they should be harvested. If they have not reached a harvestable size, then their density needs to be reduced. The tank's growth has slowed because of some limiting environmental factor (usually water quality limitations and/or because the tank has reached it's maximum feeding rate). If a group of fish are not harvested at this point, they will continue to gain weight slowly until growth completely stops. The point at which growth stops is called the carrying capacity.

Monitoring growth rates carefully will allow you to eliminate periods of slow growth. The following is a list of some of the factors that influence growth and how they can be used to enhance growth rates.

Temperature

Fish will grow faster in warmer water. If possible, try to maintain water temperatures in the upper range of the fish's tolerance. The growth of small fish will especially benefit from warmer water temperatures.

Water Quality

Prolonged exposure to poor water quality stresses fish. They may not die from sub-optimum water quality variables, but they also will not grow at maximum rates. You should work on providing the fish with as good a water quality as possible at all times. Good water quality results from a good feed management program, a healthy biofilter, careful water quality monitoring and good recordkeeping.

Density

Fish growth is density-dependent. Fish density can be measured two ways: the number of fish per volume of water (# fish/m^3) or; more importantly, the weight of fish per volume of water (kg fish/m^3) which is called the standing crop of fish. Whether or not your tank is "loaded" (pushing the upper limits of the system) depends on the standing crop, not just the numbers of fish. A graph of fish standing crop (kg/m^3) versus time for a tank of fish should look similar to a growth curve. Fish will grow at maximum rates until some density dependant factor begins to limit growth (in closed recirculating systems, maximum feeding rates are often the most important factor limiting additional growth). It is at this point fish density (standing crop) must be reduced because the tank has reached critical standing crop and is nearing carrying capacity. You should monitor standing crops of fish so you know which tanks of fish are heavily "loaded" (these tanks will require close monitoring) and when you should reduce fish density. Monitoring standing crops will also allow you to establish the carrying capacity for each system (the maximum kg/m^3 for all the tanks in a system).

Handling Fish

Proper care when handling fish will result in lower mortality rates, a lower incidence of disease, and better growth for the fish. Careful planning of when to handle fish and what equipment is necessary to accomplish the task is important. The entire process needs to be well thought out in order to minimize the number of times each fish must be handled, and the amount of time that the fish must be out of their normal environment. The objective is to reduce the stress put on the fish during the handling process.

Fish should never be handled just after feeding. Fish begin to divert bloodflow to their organs after feeding. As they begin to digest the feed, their oxygen demand increases. Handling fish within 5-6 hours of feeding can increase mortalities.

Fish tend to handle better at lower water temperatures. Not only is there more oxygen in colder water, their metabolisms are slowed by the colder water. Tilapia don't handle well (have a higher incidence of mortality) at the upper (>90°F) and lower end (<60°F) of their temperature tolerances.

Pure salt can be used in handling and transport containers to reduce stress (0.1 to 0.3% solution).

Fish cannot be held in small containers indefinitely without water exchange or filtration (ammonia will build to toxic levels).

Acclimating Fish

Any time fish are moved, they may have to be acclimated to their new environment. Differences in temperature, pH or other water quality variables can cause fish to suffer undue stress adapting to their new environment resulting in lost growth and/or higher mortalities. Try to gradually change the water the fish are in until it matches the water of their new environment. Measure water quality variables to determine any differences. Fish adapt more easily to decreases in temperature than to increases. Allow 3-5 minutes of acclimation for every 2°F down in temperature, but 5-10 minutes for every 2°F up. Allow 2-3 minutes for each 0.1 change on the pH scale.

Stocking Fish

Be sure to acclimate fish before stocking. It is also important that the biofilter is able to cope with the sudden increase in biological activity (see acclimating the biofilter). Carefully watch water quality and check for mortalities for a few days after stocking. Make accurate counts of fish and determine the total weight of fish stocked.

Harvesting Fish

Any time a tank is completely emptied, or harvestable size fish are removed, it is said to have been "harvested". Fish should not be fed within 12 hrs of harvesting. This allows them to empty their digestive system. The water flow to the tank can be discontinued and water should be pumped out as needed to have suitable access to the fish. Air stones can be in the way and damaged during vigorous netting. You may move some of the air stones out of the way but continued aeration is necessary. All fish should be counted, weighed (sample weights will suffice if time is short) and graded. If the fish are on their way to another tank, be sure and acclimate them (if possible) and begin feeding the next day. If it is a final harvest you may want to "purge" the fish before cleaning. The meat tastes better if the fish are allowed to sit unfed in clean water for a few days. Tanks should be cleaned and prepared for the next batch of fish.

Shipping Fish

Small fish can be shipped live in boxes for over-night delivery to just about anywhere. Boxes should be very sturdy and insulated. Fish should be transported in about 1-1 ½ inches of water (0.3% salt) in a thick plastic bag using pure oxygen to fill the rest of the bag in the box. The bag can be tied off with rubber bands and should be double bagged for safety. The fish should be packaged just prior to pickup time. Live fish are preferable for diagnostic services.

Transporting Fish

The objectives of transport are to maximize the weight of fish transported in the least amount of water with minimal mortalities and cost. Historically, there are references of fish transport in Chinese and Roman literature that confirm that man has been moving live fish for centuries. More recent examples include: in the early 1800's trout eggs were taken to Africa and Australia. Common Carp were introduced to the United States in 1877. The American Shad was introduced to California in 1874 using ice, water exchanges and hand aeration.

A transport container (hauler) should be durable and made from a material that is non toxic to fish. Milk cans and 55 gallon drums can be adapted for hauling fish. The hauler must allow for easy loading and unloading. It needs to be well secured in the vehicle.

The factors that influence the weight of fish that can be transported are:

<u>species</u> - Trout require higher dissolved oxygen levels and are less tolerant of warm water temperatures than tilapia. Each species of fish have their own environmental tolerances.

<u>fish size</u> - Larger fish are more tolerant of transport than an equal weight of small fish. Small fish have a much higher metabolic rate and therefore consume more oxygen per pound and excrete more ammonia per pound. The loading rate generally decreases by as much as 50% for a 50% decrease in fish length.

<u>water temperature</u> - Cool water not only slows down a fish's metabolic rate, but it is able to hold more oxygen. Each one degree F increase or decrease in water temperature results in

approximately a 3-5% increase or decrease, respectively, in the loading rate (lbs/gal). Ice can be used to decrease the water temperature.

fish health - Fish that are already in poor shape are not going to handle transport well. The increased stress associated with transport (handling, crowding) require that the fish are in good shape when they start their journey. Postpone transport if the fish have already been unduly stressed. Do not feed fish within 24 hrs of transport.

length of trip - The longer the trip, the less pounds per gallon you should load. Water exchanges can allow you to carry more fish on a long trip.

time of day - Loading fish in mid day during the summer when ambient temperatures are above the fish=s environmental tolerances will certainly increase mortality. When it is hot out, load early in the morning. When it is cold, load during mid day. Consider postponing transport until environmental temperatures are better.

equipment used - Insulated hauling tanks have higher loading rates because they can maintain cool water temperatures during summer. Hauling tanks that utilize pure oxygen instead of agitators can increase loading rates up to 25%.

water quality -

- *dissolved oxygen* - This is the most important factor. It should be maintained near saturation. Handling stress at loading requires increased oxygen levels for the fish (twice the normal demand). Avoid supersaturation. It not only wastes oxygen, but it can make the fish behave sluggishly as if they are anesthetized.
- *carbon dioxide* - 5-10mg/l CO_2 can interfere with a fish=s ability to utilize oxygen. Reduce the CO_2 concentration with aeration. Avoid tight covers on live haulers.
- *hardness and alkalinity* - 50 mg/l+ hardness and alkalinity not only helps buffer the water pH (it will want to decline as fish respiration produces CO_2), it will help the fishes= osmotic regulation and reduce stress. Calcium chloride can be used to increase hardness. Sodium bicarbonate (baking soda) can be used to increase alkalinity.
- *ammonia* - ammonia levels begin to climb as soon as the fish are put in the hauler. Exchanging some of the hauler water en route will dilute the ammonia present. Be careful not to stress the fish by dramatically changing the water temperature, pH etc. when exchanging water. Zeolite and other substances can be used to remove/neutralize ammonia.
- *salinity* - using 0.5 - 1% salt (uniodized) solution will greatly reduce stress resulting from osmotic imbalance.
- *antifoaming compounds*- foam will buildup in the hauler resulting in poor exchanges of oxygen and/or carbon dioxide unless treated.

How the Biofilter Works

The biofilter (gravel beds) prevents the buildup of toxic ammonia (NH_3) and nitrites (NO_2^-) in the water. Ammonia and nitrites build up because of the transformations of nitrogen within the nitrogen cycle. The principle source of nitrogen is the protein contained in feeds. The more feed the fish eat, the more ammonia they will excrete. Ammonia is also released during the decay of organic materials such as uneaten feed and feces (proteins are deaminated through microbial activity). This is an acid-producing reaction called mineralization or ammonification. Therefore, the amount of feed you put into your tanks determines how much ammonia your system will be producing. Ammonia (total ammonia) exists in two forms: toxic ammonia (NH_3) and ammonium (NH_4^+). The ammonia equilibrium is:

$$NH_3 + H_2O <=> NH_4^+ + OH^-$$

Under most conditions, the NH_4^+ is the predominant species. The ratio of NH_3: NH_4^+ will increase as pH and/or temperature increases.

Ammonia would reach toxic levels quickly if it weren't for the nitrifying bacteria that colonize the RBC. *Nitrosomonas* and *nitrobacter* are responsible for the process of nitrification (converting ammonia to nitrate).

Nitrosomonas will convert ammonium (NH_4^+) to nitrite (NO_2^-) as follows:

$$NH_4^+ + 1\ ½\ O_2 \text{ -> } NO_2^- + 2H^+ + H_2O$$

Nitrobacter will convert nitrite (NO_2^-) to nitrate (NO_3^-) as follows:

$$NO_2^- + ½\ O_2 \text{ -> } NO_3^-$$

Note that both of these reactions require the presence of free oxygen. The dissolved oxygen levels in the RBC should remain above 3 mg/l at all times. Nitrification is an acid-producing reaction causing the pH of your system to decline. Nitrification is most rapid at pH 7-8 and 25-35°C.

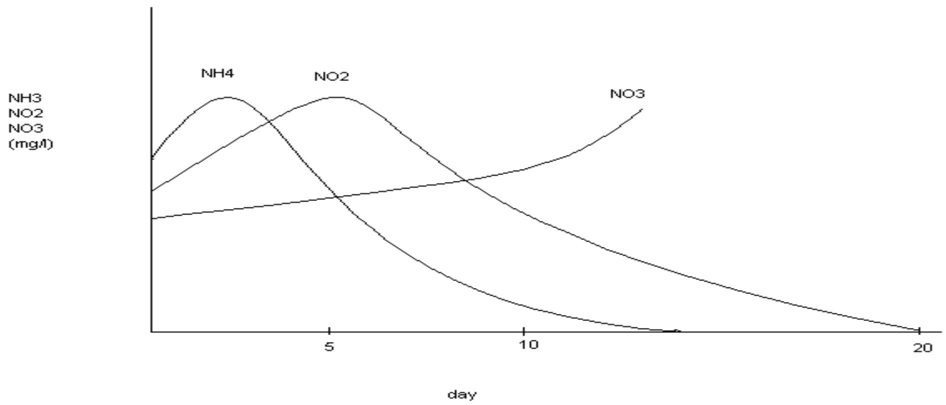

Figure 5 - Nitrification lag times.

Figure 5 shows the concentrations of ammonia (NH_3), nitrites (NO_2^-) and nitrates (NO_3^-) as a biofilter develops healthy nitrifying bacteria populations. Within a week of adding fish, the growing *Nitrosomonas* bacteria populations begin to reduce the amount of ammonia (NH_3) by converting it to nitrites (NO_2^-). *Nitrobacter* bacteria populations respond to the increasing nitrites (NO_2^-) by multiplying rapidly. They will convert the harmful nitrites (NO_2^-) into harmless nitrates (NO_3^-). The actual duration of this process can depend on several factors (water temperature, pH, and DO). Sudden changes in ammonia production drastically alters the balance of these two bacteria populations. Drastic changes in any water quality variables (especially temperature and pH) can cause a population to "crash". If a large weight of fish is added to or removed from a system, the effects could be detrimental to the biofilter when the feeding and ammonia loading rates change. It can take as long as 3-4 weeks for a biofilter to become "conditioned" and stabilize the water quality in your system. Large water changes reduce the amount of food available to the bacteria on your biofilter.

Acclimating the Biofilter

Before you add fish to a new system, you must build up a healthy bacteria population to process their wastes. Inoculating the water in your system with the appropriate bacteria can decrease the acclimation period. There are several different products available from a variety of fish supply catalogs. You can add pure ammonia (about one capful per tank per day) to the system until ammonia (NH_3) levels reach 1.0 mg/l. Maintain 1.0 mg/l ammonia levels for at least 2 weeks before adding fish. After one week, begin monitoring the nitrite (NO_2^-) levels. Stabile ammonia and nitrite levels indicate that the biofilter is ready for fish.

Fish Health Management

Maintaining healthy fish will increase survival rates, result in better growth and improve yields. The manager should understand the factors that cause disease and know how to recognize sick fish. The key to a good fish health management program is the prevention of disease. This is done by constantly minimizing stress on the fish and taking precautions to make sure sick fish or diseases are not inadvertently introduced to healthy fish.

Disease is defined as a departure from health. Fortunately Tilapia are extremely resistant to disease. Diseases may be infectious (parasites, bacteria, viruses and fungi) or non-infectious (nutritional, environmental, genetic, or traumatic). The following are some of the factors of disease.

Stress

Stress is defined as any factor that produces bodily or mental tension. Any factor that makes the fish unduly “uncomfortable” or “out of ease” can result in disease. Stressful episodes may weaken a fish’s immune system and leave them prone to disease. If a group of fish endure a stressful episode (such as low dissolved oxygen levels), then it is usually a matter of a few days to a week before all of the mortalities from this episode will show up (often there is a lag time between the stressful episode and eventual mortalities).

Temperature

Sudden changes in temperature (poor acclimation) or exposing fish to temperatures near the upper or lower end of their tolerances will stress them.

Water Quality

Maintain the best water quality variables possible. Chronic water quality problems may not cause immediate mortalities but may result in greater susceptibility to disease. Don’t unnecessarily handle or move fish that are experiencing poor water quality.

Spawning Activities

Males often damage themselves and females during spawning activities. The females don’t eat while incubating eggs. This means that spawning activities may leave fish prone to disease.

Handling

Anytime the fish are handled they are stressed. Make sure you do all that is possible to minimize the stresses associated with handling.

Nutrition

Fish that are not receiving enough feed or are receiving old feed may be more prone to disease (see Vitamin Deficiencies and Their Symptoms).

Genetics

Chromosomal defects or a predisposition to disease may be caused by genetic traits.

Recognizing Sick Fish

One of the key signs of stressed or sick fish is that they will not feed very well. Prolonged periods of fish being "off feed" during acceptable water quality parameters may warrant a closer inspection of the fish to determine the problem. Other signs of sick fish are: erratic or lethargic swimming, excess mucous, ascites (an abnormally swollen belly), exopthalmia (bugged-out eyes), degeneration of internal organs (internal organs are pale or mottled), pale or swollen gills, eroded fins, depigmentation, or necrosis (the presence of dead tissue). You should try to capture fish that exhibit signs of disease and inspect them more closely (see necropsy procedure). Sending a sample off to a qualified diagnostician may be prudent (state labs often provide these services for free). Early diagnosis of disease is crucial to successful treatment.

Severity of Infections

Infections are classified as either acute, sub-acute, chronic or latent. In acute infections, the disease will occur quickly. There will be no sign of disease and then sudden, high mortalities will occur over 1 or 2 days. There is little time for identification or treatment of these highly virulent pathogens. Mortalities from sub-acute infections will occur over about a week and will be more moderate. Chronic infections are slow to develop, typically have low mortalities, and will occur over a long period of time. In latent infections, the fish may show no clinical signs of disease. They will simply be carriers, and may infect other fish.

Prevention of Disease

There are several things a manager can do to lessen the incidence of disease besides minimizing the amount of stress on the fish. New fish (fish shipped in) may be examined before stocking or even held in quarantine for observation before adding to the general population. There should be separate nets and buckets for each system. This will prevent the spread of disease from one system into another. Nets should be hung to dry when not in use. All equipment should be kept clean and may be sterilized with a weak bleach solution occasionally (rinse well with fresh water before use). Feed should be fresh and stored in a cool dry place. Any dead or dying fish should be promptly removed and disposed of properly.

Treating Diseases

There are only a few materials available to treat the diseases of fish (many treatments are not FDA approved for use with foodfish). The fish can be treated for external parasites/bacterial infections with dips or baths. Antibiotics are used to treat internal bacterial infections. It is essential that you have an accurate diagnosis before treating any disease. Treatments may cause high mortalities unless done correctly.

Troubleshooting

Being able to identify and correct a potential problem before it affects the growth and well-being of the cultured fish will not only avert disasters, but will also determine the ultimate production capacity of the system. Such problems can be considered acute or chronic. An acute problem, such as loss of aeration, can result in the loss of an entire stock of fish. Chronic problems, such as high levels of ammonia and low pH, can produce stress on the fish, reducing growth rates and predisposing the fish to a disease problem. A certain amount of ingenuity is required to solve unusual problems with limited materials and immediate needs. Here are some solutions to problems you may encounter:

Low DO Levels

If aeration is interrupted at any time, the dissolved oxygen levels will begin to drop rapidly. The rate of this drop will be directly proportional to the standing crop of fish in each tank. You have probably experienced either a power outage or a blower failure. If the power is out, you should crank up the emergency generator to power the blowers. If the blower is out, you should plug in the backup blower.

If the DO has been gradually decreasing over time, you should check the airstones for clogging (see maintenance) or move airstones shallower. If it appears that the airstones are working fine but you still have low DO, reduce feeding rate while you check to make sure your feed amounts are correct and all of the feed is being utilized by the fish (uneaten feed increases oxygen demand too). You may have to add more airstones. You may have to backwash more frequently.

Lowering the water temperature or doing 10% water changes will provide some temporary relief.

High NH_3 Levels

Levels of toxic, un-ionized ammonia (NH_3) should be kept below 0.1 mg/l. It is possible that your biofilter is having a problem (see How the Biofilter Works). You could have a filtration or circulation problem. An immediate solution to life-threatening ammonia levels is to exchange 10% of the water in the system and measure ammonia again. Repeat until ammonia levels are acceptable. You may have to reduce feeding levels to let the biofilter catch up with the ammonia production. Do not add baking soda to increase alkalinity of water that already has dangerously high ammonia levels without doing water exchanges to lower the ammonia levels first. Backwash more frequently.

High NO_2^- Levels

Nitrites (NO_2^-) are an intermediate product of the nitrification process. A buildup of nitrites indicates a problem with the biofilter. An immediate solution to high nitrites is to add pure salt. Add salt until chloride concentrations are about 8 times the nitrite levels. For example, a nitrite level of 10 mg/l should be treated by increasing the salt concentration of the water to 80 mg/l.

Usually nitrite levels will decrease in a few days.

Reduced Flow

The gravel beds will need more frequent checking as feeding rates increase. Check the pipes for blockage (fish may be lodged in a pipe) or buildup (the pipes may need cleaning). Check for pump failure. Without proper circulation your water quality will continue to deteriorate.

Low pH

Before increasing pH, calculate the amount of toxic ammonia at the anticipated pH value to make sure you don't stress the fish. Adding baking soda ($NaHCO_3$) will increase the pH of the water in your system and act as a buffer. Gradually increase the pH.

High pH

There are very few instances that will require you to lower the pH of the water (measure it twice). Household vinegar can be added to decrease the pH of the water in your system.

Power Outage

If the power to your system is lost, you should be notified by the automatic telephoning alarm. You will have only a short period of time to restore aeration before fish losses are substantial. The emergency generator should be started and the blower should resume aeration. If the duration of the power outage is short, this will be all you need to do until the power returns. If the power outage is prolonged, you will have to check water quality (ammonia, pH and temperature) periodically and perform water changes as necessary to keep the fish alive.

Equipment Maintenance

All equipment must be kept in good working condition. Preventive maintenance not only extends the useful life of the equipment but decreases the likelihood of surprising failures.

- Air blowers should be checked and maintained as per manufacturers instructions, with air filters cleaned or exchanged, and bearings replaced periodically.

- Air stones should be rotated and periodically cleaned with muriatic acid when the air flow rates appear to diminish.

- All tanks should be periodically cleaned (walls and floors) to prevent buildup of solids.

- All pipes should be periodically cleaned to prevent buildup on the inside surfaces, especially the drain pipes. This can be done by pulling a bristle brush or towel through the pipes with a flexible line.

- The emergency generator should be tested periodically to make sure it will start during an emergency. Follow all manufacturers suggested maintenance requirements.

- The sump screen should be checked periodically for blockage. The sump may experience a buildup of solids in the bottom that should be periodically removed.

There is a tendency for the floors, walls and all of the equipment in the aquaculture lab to become fouled with materials that are unsightly and cause bad odors. Keep the lab as clean as possible.

Definitions

Absolute growth - this is growth measured in grams/day.

Acclimation - The process of metabolic compensation in response to change in an environmental factor.

Aerobic - this refers to chemical or biological processes which take place in the presence of oxygen.

Allele - one of two or more forms of a given gene.

Ammonia - NH_3. sometimes this term is loosely used to refer to both forms of total ammonia present in the water (NH_3 and NH_4^+).

Ammonia volatization - this is the loss of ammonia (NH_3) directly into the atmosphere resulting from aeration (called Astripping@). Ammonia is volatilized more readily at high pH values.

Ammonia-nitrogen - this is the amount of ammonia expressed in terms of nitrogen concentration. The molecular weight of ammonia (NH_3) is 17 and the molecular weight of nitrogen is 14. Therefore, 1 mg/l of ammonia-nitrogen = 1 x 17/14 or 1.2 mg/l of ammonia.

Ammonification - This is an aerobic or anaerobic heterotrophic process that deaminates proteins and produces ammonia-nitrogen.

Ammonium - NH_4. This is the predominant form of the ammonia equilibrium.

Anaerobic - A chemical or biological process that takes place in the absence of oxygen.

Aquaculture - The controlled production of a crop in water.

Autosome - a chromosome other than the sex chromosome.

Backcross - crossing an F_1 hybrid heterozygote back to one of the parental types.

Broodfish - fish used to produce fish that will be cultured.

Carrying capacity - biomass in a given area where growth stops (lbs/ft^3, kg/m^3).

clarification - The process of removing suspended solids from water.

Cohort – A group of fish of the same age or size stocked in the system at the same time.
Critical standing crop - the inflection point on a growth curve indicating the presence of a

growth limiting factor.

Denitrification - this is the anaerobic process by which chemotropic bacteria convert nitrates ($NO_3^{=}$) to nitrogen gas (N_2), N_2O or ammonia (NH_3).

Feed conversion ratio - This is the ratio of the amount of feed fed to the amount of weight gained fro a group of fish.

Genotype - genetic determination of sex.

Grading - the process of sorting fish by size.

Gross yield - total weight of fish harvested for a volume of water.

Gynogenesis - producing all female fish.

Hapa - a net enclosure used to hold fish that allows water circulation. It is usually suspended in a tank or pond.

Harvest - the removal of harvestable sized fish or the removal of fish from any stage of the production cycle.

Haploid - half the normal number of chromosomes.

Heterogametic - fish whose sex determining alleles are different (IE. XY or WY).

Homogametic - fish whose sex determining alleles are the same (IE, XX or WW).

Hybrid vigor - exceptional growth ability of the first generation (F1) resulting from a cross of two different species.

Meiosis - the process by which chromosomes replicate, form homologous pairs, and then segregate into different nuclei to produce haploid cells.

Mortality rate - this is the calculation of the number of fish that die versus the number of fish stocked for any part (or all) of the production cycle.

Mitosis - a process of cell division in which the chromosomes replicate and divide equally so that identical daughter cells are produced.

Net yield - total weight harvested minus total weight stocked for a volume of water (lbs/ft^3, kg/m^3).

Necropsy - A postmortem internal and external examination of fish.

Nitrate-nitrogen - this is the nitrite concentration expressed in terms of its equivalent nitrogen concentration. The molecular weight of nitrite is 62 and the molecular weight of nitrogen is 14. Therefore, 1 mg/l of nitrite-nitrogen = 1 x (62/14) or 4.4 mg/l of nitrate.

Nitrification - the aerobic process by which bacteria convert ammonium (NH_4^+) to nitrates ($NO_3^=$). Nitrification is most rapid at pH of 7-8 and at temperatures of 25-30°C. Nitrification causes waters to decrease in pH.

Nitrobacter - the nitrifying bacteria responsible for converting nitrites (NO_2^-) to nitrates ($NO_3^=$).

Nitrosomonas - the nitrifying bacteria responsible for converting ammonium (NH_4^+) to nitrites (NO_2^-).

Osmotic regulation - This is a process by which freshwater fish are able to excrete excess water yet retain ions and substances vital to normal function. There is a constant flow of water into their bodies caused by the difference in ion concentrations between the inside and outside of their body. Saltwater fish have the opposite problem. They are continually losing water from their bodies and must work to retain water needed for normal function.

Phenotype - secondary characteristics (not genetic makeup) that indicate sex (IE. Genitals, size, color).

Polishing filter - These are secondary filters that remove fine solid materials from water that has already passed through a primary filter (ozone, ultraviolet filters, cartridge filter, drum filter, foam fractionator).

Polyploidy - other than the normal number of chromosomes (ie. triploids, tetraploids).

Purging - a process that removes any Aoff flavor@ in harvestable sized fish by holding fish unfed in clean water for a few days.

Relative fecundity - This is a measure of egg production from broodfish. It is the number of eggs received per spawn for each kilogram of broodfish weight.

Relative growth - growth measured as a percent of the fish=s body weight.

Settleable solids - This is the volume or weight of solid material that will settle in one hour from one liter of water confined in a cone shaped cylinder called an Imhoff cone.

Sex chromosome - a chromosome, usually X or Y that plays a major role in the determination of sex.
Species - a population or populations of individuals that share a common gene pool, are phenotypically similar, and are reproductively isolated from other species.

Standing crop - biomass in a given volume of water at a particular point in time (lbs/ft^3, kg/m^3).

Stress - A physiological response caused by an external stimulus (stressor) that results in an energetic cost to the organism.

Supermale - a male carrying only male determining genetic information (YY).

Survival rate - the calculation of the number of fish that remains the number of fish stocked for any part or all of the production cycle.

System - a system refers to a complete aquaculture production unit that includes: production tanks, filtration and circulation.

Tetraploids - double the normal chromosome number.

Total dissolved solids - This is the total residue (mg/l) left after evaporation of a filtered water sample.

Toxic ammonia - this refers to ammonia (NH_3) which is lethal to fish at fairly low concentrations.

Triploid - 1.5 the normal number of chromosomes.