" The Blue Revolution"

Aquafarming: Fish or Shrimp farming

Since the supply of wild fish is declining, and some species, such as cod, striped sea bass, salmon, haddock, and flounder, have already been over fished, aquaculture, or fish farming, seems to be the solution to the problems created by the law of supply and demand and our increasing demand for seafood. Farm-raised fish currently account for about 15% of the market. There are 93 species of fin fish, seven species of shrimp, and six species of crawfish, along with numerous species of clams, oysters and shellfish that are currently being farm raised worldwide. In the next twenty years, aquaculture will surpass capture fisheries in supplying seafood to the world.

Aquacultural output, growing at 11 percent a year over the past decade, is the fastest growing sector of the world food economy. Aquaculture is the farming of aquatic organisms, including finfish, shellfish (mollusks and crustaceans), and aquatic plants. Fish farming is the principal form of aquaculture. It involves raising fish commercially in tanks or enclosures, usually for food for human consumption. Fish species raised by fish farms include salmon, catfish, tilapia, cod, carp, trout and others. Fish farming, or “aquaculture,” has become a billion-dollar industry, and more than 30 percent of all the sea animals consumed each year are now raised on these “farms.” The United Nations’ Food and Agriculture Organization reports that the aquaculture industry is growing three times faster than land-based animal agriculture, and fish farms will surely become even more prevalent as our natural fisheries become exhausted. Over 1100 species of fishes, molluscs and crustaceans directly contribute to production of the world’s major fisheries. There are many additional species contributing to smaller-scale fisheries. In aquaculture, although the majority of production comes from a few species, there are over 300 species, which do contribute.

Aquafarms can be based on land or in the ocean. Land-based farms raise thousands of fish in ponds, pools, or concrete tanks. Ocean-based aquafarms are situated close to shorelines, and fish in these farms are packed into net or mesh cages.

Expanding at a rapid rate, fish farming now accounts for over 30 percent of all fish protein consumed annually in the world. But it is single-handedly responsible for the destruction of countless ecosystems and the fishing communities that rely upon them, in some of the most vulnerable marine environments on the planet.

Salmon farming involves the raising and feeding of vast numbers of fish in small contained net pens. A typical farm may contain up to a dozen pens with anything from ten to 15000 fish in each pen.

A typical salmon farm of 200 000 fish produces roughly the same amount of fecal matter as a town of 62 000 people.

Issues related to farming:

pH
Alkalinity
Nitrification
Dissolved Air
Algae blooms
Toxicity
Regulations
Bioaugmentation in Aquaculture

The life of a farm-raised fish begins in temperature-controlled hatching tanks. From here, small fish (called "fry") are transferred to rearing areas where they grow to maturity. The fish may be raised in highly- controlled tanks or raceways (rectangular concrete enclosures up to 20 acres in size) constructed inland, or they may be raised in artificial enclosures in coastal estuaries.

Various types of fish farming exists.

Intensive (closed-circulation) aquaculture
In this kind of systems fish production per unit of surface can be increased at will, as long as sufficient oxygen, fresh water and food are provided. Because of the requirement of sufficient fresh water, a massive water purification system must be integrated in the fish farm. A clever way to achieve this is the combination of hydroponic horticulture and water treatment

Fish food must contain a much higher level of protein (up to 60%), in order to achieve fish weight gain in small quarters. Quite a bit of the food is wasted, and also quite a bit of fish waste is deposited into the water. High BOD, as well as nutrient content due to the fish waste can be found in these types of farms.

Catfish, Clarias ssp. can breathe atmospheric air and can tolerate much higher levels of pollutants than, e.g., trout or salmon, which makes aeration and water purification less necessary and makes Clarias species especially suited for intensive fish production. In some Clarias farms about 10% of the water volume can consist of fish biomass.

Especially when fish densities are high, the risk of infections by parasites like fish lice, fungi (Saprolegnia ssp.), intestinal worms (such as nematodes or trematodes), bacteria (e.g., Yersinia ssp, Pseudomonas ssp.), and protozoa (such as Dinoflagellates) is much higher than in animal husbandry because of the ease in which pathogens can invade the fish body (e.g. by the gills). The same holds for water pollution or depletion of oxygen in the water, which can ruin a fish crop within minutes. This means, intensive aquaculture requires tight monitoring and a high level of expertise of the fish farmer.

Integrated recycling systems
One of the largest problems with freshwater aquaculture is that it can use a million gallons of water per acre (about 1 m^3 of water per m^2) each year. Extended water purification systems allow for the reuse (recycling) of local water.

The largest-scale pure fish farms use a system derived (admittedly much refined) from the New Alchemists in the 1970s. Basically, large plastic fish tanks are placed in a greenhouse. A hydroponic bed is placed near, above or between them. When tilapia are raised in the tanks, they are able to eat algae, which naturally grows in the tanks when the tanks are properly fertilized.

The tank water is slowly circulated to the hydroponic beds where the tilapia waste feeds a commercial plant crops. Carefully cultured microorganisms in the hydroponic bed convert ammonia to nitrates, and the plants are fertilized by the nitrates and phosphates. Other wastes are strained out by the hydroponic media, which doubles as an aerated pebble-bed filter.

In small systems the fish are often fed commercial fish food, and their waste products can help fertilize the fields. In larger ponds, the pond grows water plants and algae as fish food. Some of the most successful ponds grow introduced strains of plants, as well as introduced strains of fish.

Cage system

Fish cages are synthetic fiber cages kept in existing water resources to contain and protect fish until they can be harvested. A few advantages of fish farming with cages are that many types of water can be used (rivers, lakes, filled quarries, etc.), many types of fish can be raised, and fish farming can co-exist with sport fishing and other water uses. However, fish are vulnerable to disease, poaching, and low levels of dissolved oxygen. In general, pond systems are easier to manage, and simpler to start.

Control of water quality is crucial. Fertilizing, clarifying and pH control of the water can increase yields substantially, as long as eutrophication is prevented and oxygen levels stay high. Yields can be low if the fish grow ill from electrolyte stress. Many critical parameters are monitored and controlled, not only for the health of the fish, but the algae they may eat, also the bacteria that will help consume the excess organics and nutrients.

One critical parameter is pH. Not only for the health of the fish, but for the bacteria that clean up the water as well as nitrifiers that remove excess nutrients.

pH is important in aquaculture as a measure of the acidity of the water or soil. Fish can not survive in waters below pH 4 and above pH 11 for long periods. The optimum pH for fish is between 6.5 and 9. Fish will grow poorly and reproduction will be affected at consistently higher or lower pH levels (Table 6).

Table 6: The effects of pH on warm-water pond fish

pH	Effect on fish
4	Acid death point
4 to 5	No reproduction
4 to 6.5	Slow growth
6.5 to 9	Desirable ranges for fish reproduction
9 to 10	Slow growth
≥ 11	Alkaline death point

Source: Swingle 1969

Alkalinity

Alkalinity is the most important thing when trying to establish nitrification in aquaculture. Nitrifiers use the alkalinity as a food source, and the excess ammonia as an energy source. 7.14 parts of alkalinity are required for every part of excess ammonia in the water that is to be removed. Oxygen is a critical component in the nitrification equation. Higher levels of oxygen are required for nitrification than for carbon removal. As ammonia is removed it is transformed. 4.5 parts of O_2 are needed for every part of NH3 to be degraded.

Nitrification-

Ammonia can be toxic to fish. Toxic concentrations of NH_3-N for short-term exposure vary between 0.6 and 2 mg/litre for many pond fish, and some effects can be seen at 0.1 to 0.3 mg/litre (Boyd 1979). Normally warm-water fish are more tolerant to ammonia than cold-water fish. To be safe, ammonia concentrations below 0.05 mg/litre as NH_3-N and 1.0 mg/litre as TAN are recommended for long-term exposure. Nitrification is the process of bacteria converting the ammonia to a less toxic compound. Ammonia is converted to nitrates by bacteria. The safe values of NO_3-N for many fish and invertebrates lie between 1000 to 3000 mg/litre (Colt and Tchobanoplous 1976).

The Nitrification Process

First Conversion (Ammonium to Nitrite)

Nitrosomonas bacteria oxidize ammonium to nitrite via hydroxylamine.

$2NH_4^+ + O_2 \rightarrow 2NH_2OH + 2H^+$

$NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 2H^+ + H_2O$

Second Conversion (Nitrite to Nitrate)
Nitrobacter bacteria convert nitrite to nitrate.

$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$

Nitrification also occurs 3-4 times slower than carbonaceous oxidation. Upsets to a plant can take nitrifiers weeks to recover for nitrification as opposed to days or hours for carbon bacteria. For each 1-gram of NH3-N oxidized to NO3, 0.15 grams of new bacteria cells are formed. Sludge generation from nitrifiers is minimal.

We have an entire training for nitrification if you need help. Also nitrification is very mathematical. See nitrification math. Nitrifiers can be added to supplement a system and speed up ammonia removal. MicroSolv 600l is the product we would use to supplement a system if needed. See troubleshooting sheets on nitrification, dosing wizard and product spec sheets.

Dissolved Oxygen

Dissolved oxygen is not only critical for the fish, but again, it can impact the biomass in the surrounding water also. Here are the fish limits for DO:

Swingle (1969) developed a dissolved oxygen (DO) scale for warm-water fish:
· DO: < 0.3 mg/litre : Fish die after short-term exposure
· DO: 0.3 mg to 1 mg/litre : Lethal for long- term exposure
· DO: 1mg to 5 mg/litre: Fish survive, but growth is slow for long-term exposure.
· DO ³ 5mg/litre : minimum for warm water fish (fast growth)

Fish do not grow well when the DO concentration is below 25% of saturation for long periods (Romaire 1985). Fish perform better when DO concentrations are near saturation. Some authors recommend that the DO concentration in aquaculture systems be kept at about 90% of saturation, as a minimum at all times, for optimum performance.

Nitrifiers require large amounts of oxygen, 4.5 parts of O2 are needed for every part of NH3 to be degraded. Facultative bacteria require oxygen and grow significantly faster than in an anoxic or anaerobic condition, with few byproducts that can impact the health of the fish.

Algae:

Phytoplankton is often used as a food source in some fish farms. Phytoplankton is mostly autotrophic microscopic algae, which inhabit the illuminated surface waters of the sea, estuaries, lakes, and ponds.

Phytoplankton can include diatoms, green algae, dinoflagellates, Euglenophyceae and saltwater Coccolithophorids
A main point of concern is the risk of algae blooms. When temperatures, nutrient supply and available sunlight are optimal for algal growth, algae multiply their biomass at an exponential rate, eventually leading to an exhaustion of available nutrients and a subsequent die-off. The decaying algal biomass will deplete the oxygen in the pond water and pollute it with organic and inorganic solvents (such as ammonium ions), which can (and frequently do) lead to massive loss of fish.

Toxicity

Heavy metals in the water could harm fish growth and cause “body-curved disease” of fry. Water pollution (eutrophication) in case of excessive fertilization can deplete oxygen levels and kill the fish. Too many nutrients also can add high levels of ammonia, which are toxic to the fish. Different species of fish have different susceptibilities to carbon dioxide toxicity. In some species, excess carbon dioxide hinders the ability of the blood to hold oxygen. Produced during respiration and consumed during photosynthesis, carbon dioxide levels fluctuate throughout the day opposite to dissolved oxygen levels. High carbon dioxide levels lower the pH, which in turn affects the ratio of un-ionized to ionized ammonia.

Chloride levels can affect fish health in two ways: as the major constituent of salinity or as a treatment to prevent nitrite toxicity. In systems with existing or chronic high nitrite levels, chloride will often be added to prevent the fish from succumbing to nitrite toxicity.

Copper, in the form of copper sulfate, is often used in aquaculture systems as an algicide and bactericide; however high levels can be toxic to fish. High pH and alkalinity levels will complex copper, helping to reduce its toxicity.

Dissolved oxygen levels can affect fish respiration, as well as ammonia and nitrite toxicity. Salinity and temperature are both factors that affect dissolved oxygen levels.

High nitrite levels, combined with low chloride and dissolved oxygen concentrations, may result in methemoglobinemia, better known as brown blood disease. The greatest concern with pH is how it affects the toxicity of many other substances, including nitrite and ammonia.

Phosphates enter the water supply from many sources, including agricultural runoff and sewage. Although phosphorus is an essential nutrient for bone formation and is a primary ingredient in fertilizers, excessive levels can promote an overabundance of algae.

In an established system, the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to fish.

Regulations: On June 30 2004, The EPA establishing effluent limitations guidelines (ELGs) for concentrated aquatic animal production (CAAP), or aquaculture, facilities. The regulation will apply to CAAP facilities that generate wastewater from their operations and discharge that wastewater directly into waters of the United States. The CAAP ELGs will help reduce discharges of conventional pollutants, primarily total suspended solids. The regulation will also help reduce non-conventional pollutants such as nutrients. To a lesser extent, the regulation will reduce the discharge of drugs that are used to manage fish health and chemicals, such as those used to clean fish tanks and nets. Facilities covered-The final rule applies to existing and new CAAP facilities with the following characteristics:

Use flow-through, recirculating, or net pen systems
Directly discharge wastewater
Produce at least 100,000 pounds of fish a year.

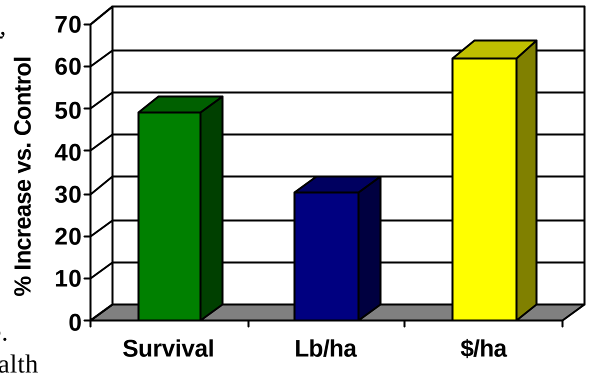
Bioaugmentation in Aquaculture

Bioaugentation is becoming more and more popular as the health of the fish, as well as growth and productivity becomes big business in Aquaculture.

Bioaugmentation is using a feed additive and water treatment product specifically formulated to promote the production of healthy shrimp and fish.

Bioaugmentation can Reduces Odor, Increases Settleability, is safe to the Environment, Restores Water Quality, Environmental Friendly, Contains No Chemicals, Removes Available Nutrients from Water, Leaves Little Nutrients or BOD for Algae to Grow, Allows for better production of Fish/shrimp species, and Reduces BOD and TSS thus allowing for EPA or regulatory permit levels to be met when discharge permits are applicable.

Microclear 108 is a high potency, bacteria-laden, powdered formulation for use in controlling algae and BOD through the competition of available nutrients in the water. This product is designed as a feed additive and water treatment product formulated to promote the production of healthy shrimp and fish. **Microclear 108** contains a specially formulated, proprietary blend of microorganisms and surface tension suppressants/penetrants. Because of the diversity of the microorganisms enzyme systems, this product is excellent for *increasing water clarity through controlling algae population, lowering BOD and TSS levels.* MicroClear 108 reduces harmful ammonia levels that can be toxic. The safe naturally occurring bacteria and enzyme systems are present in high numbers to handle difficult algae, BOD and odor related problems.



Case history at a Prawn farm

Obviously there are numerous things to look at in Aquaculture. Water quality can significantly impact the productivity and health of the fish species.

More information on these topics can be found on our website or by requesting information.

WWW.EnvironmentalLeverage.com