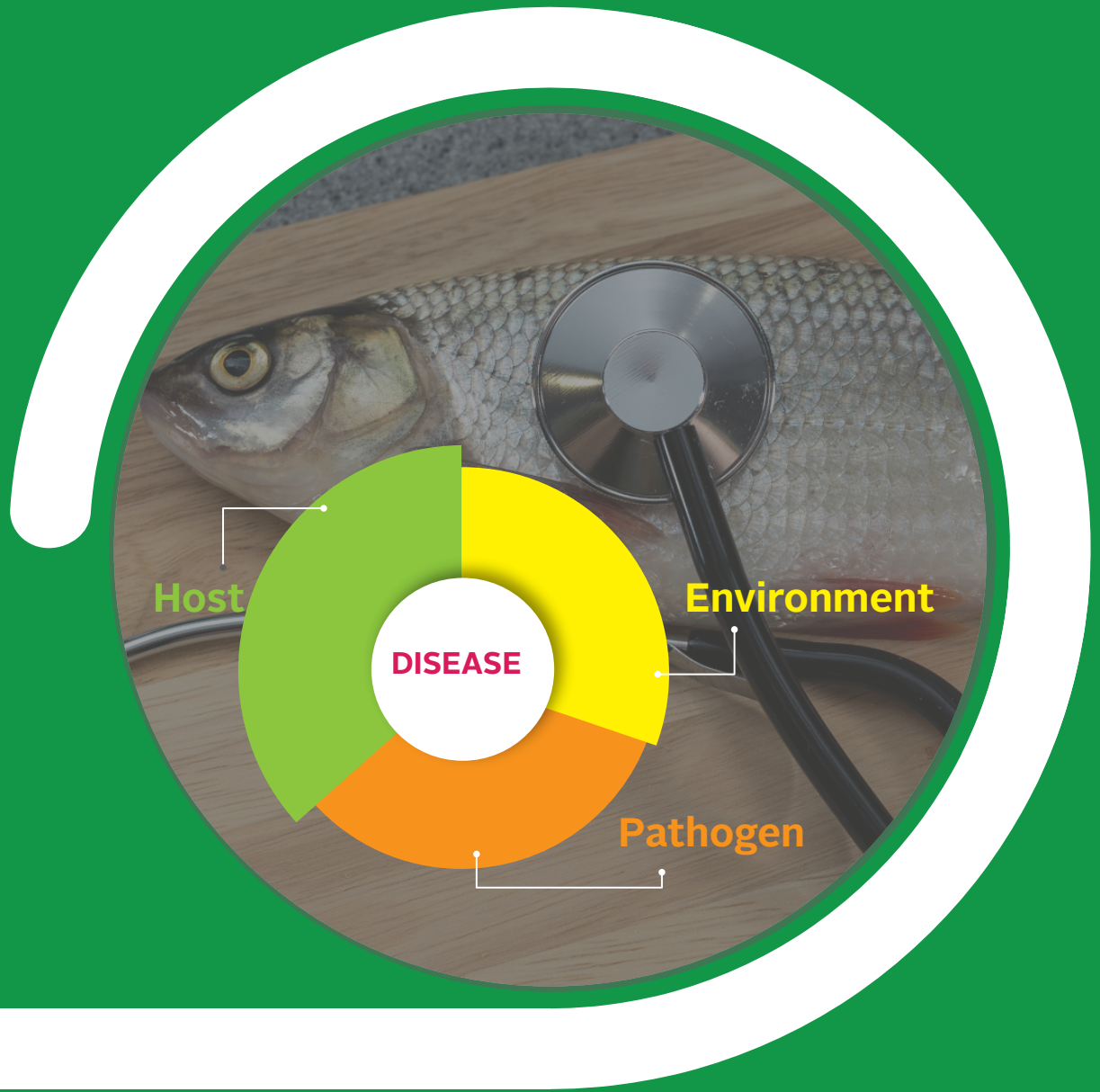




VALIDATING AND PROMOTING IMPROVED FISH STRAINS AND HEALTH MANAGEMENT PRACTICES FOR CLIMATE SMART AQUACULTURE



A Training Manual on Fish Health Management Practices/Systems and Biosecurity Measures in Aquaculture

ELICK OTACHI, GEOFFREY ONG'ONDO, DOMITILA KYULE, KEVIN OBIERO, ERICK OGELLO, JONATHAN MUNGUTI

March 2022

Photo credits:

Cover page: ©2022 a schematic pathway for disease infection

Recommended citation:

Otachi E, Ong'ondo G, Kyule D, Obiero K, Ogello E, Munguti J (2022). A Training Manual on Fish Health Management Practices/Systems and Biosecurity Measures in Aquaculture. Kenya Climate Smart Agriculture Productivity Project (CSAPP),24pp

Contents

ACKNOWLEDGMENTS	v
1.0 INTRODUCTION	1
1.1 Obtaining healthy animals (eggs, fry, juveniles, broodstock) from a reputable supplier is critical	6
1.2 Strains of some aquacultured species are known to be more resistant to specific diseases	7
1.3 Good husbandry is also important to biosecurity	7
1.4 Good preventive medical practices	7
2.0 Pathogen Management	9
2.1 Not all pathogens (disease-causing organisms such as viruses, bacteria, fungi and parasites) are of equal concern	9
2.2 Regulatory significance	10
2.3 Reservoirs	10
2.4 Diagnostics	11
2.5 Disease control	11
2.6 Sanitation and Disinfection	12
3.0 People Management	15

ACKNOWLEDGMENTS

We wish to thank the Kenya Climate Smart Agriculture Productivity Project (KCSAP) through Kenya Agriculture and Livestock Research Organization (KALRO) for providing funding for this study.

1.0 INTRODUCTION

Fisheries and aquaculture play a great role in food security and livelihood and are a source of income and social development in Kenya. Sustainability of this sector will depend on proper management and understanding of fish biology and its habitat. As the sector expands, challenges on fish health and disease management will set in leading to economic losses. Huge loss of production in aquaculture is occurring because of many reasons. Among these causes, a disease is the most serious constraint that causes damage to the livelihood of farmers, loss of job, reduced incomes, and food insecurity. Studies have shown that almost fifty percent of production loss is because of diseases which are more severe in developing countries (Assefa and Abunna 2018). Mitigation against such losses is therefore for the success of the investment. This entails prevention rather than cure.

Capacity building to farmers through practical training on disease prevention is a key intervention in the fish health management in aquaculture. This project focused on training farmers on fish health management practices and biosecurity measures in Busia, Kakamega and Siaya counties. This is expected to spur aquaculture growth in the focal counties for food and nutritional security.

Project background

The proposed adaptive research is designed in collaboration with beneficiaries, research partners and multiple stakeholders to validate climate smart TIMPs that optimize individual and joint contributions of aquaculture to achieve KCSAP's triple wins of increasing productivity and incomes, adapting and building resilience to climate change and reducing greenhouse gas emissions. In so doing, it addresses critical gaps that need to be addressed to build evidence on the most promising pathways to impact. Our focus is on enabling small holder farmers to progressively enhance production efficiency and sustainability through the use of domesticated, selectively bred and high-health fish in a gender-inclusive manner. The project's beneficiaries will include the small holder fish farmers (both male and female) (Groups or individuals) and hatcheries (both government and private-owned).

The project attempts to achieve this through:

- I. Validating and promoting certified and improved Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) seed and broodstocks, with hatcheries and farmers.
- II. Validating and promoting certified and improved African catfish (*Clarias gariepinus*) seed and broodstocks, with hatcheries and farmers.
- III. Validating and promoting best management practices, water quality monitoring, prophylactic and therapeutic treatment, probiotics, biosecurity measures for improved fish health.
- IV. Adapting and delivering at scale innovative farmers' advisory services on seed availability and fish disease status.

Objectives

The objective of the training manual is to disseminate information which will help the fish farmers achieve best fish health management practices and biosecurity measures to minimize diseases hence achieve higher productivities in their farms

WHAT FARMERS NEED TO KNOW

Do fish get sick?

The answer to this question is yes. There are so many diseases and parasites that infect and infest fish. Just like any other animal, fish also do have their enemies (Pathogens). The following figures illustrate some of the fish diseases:

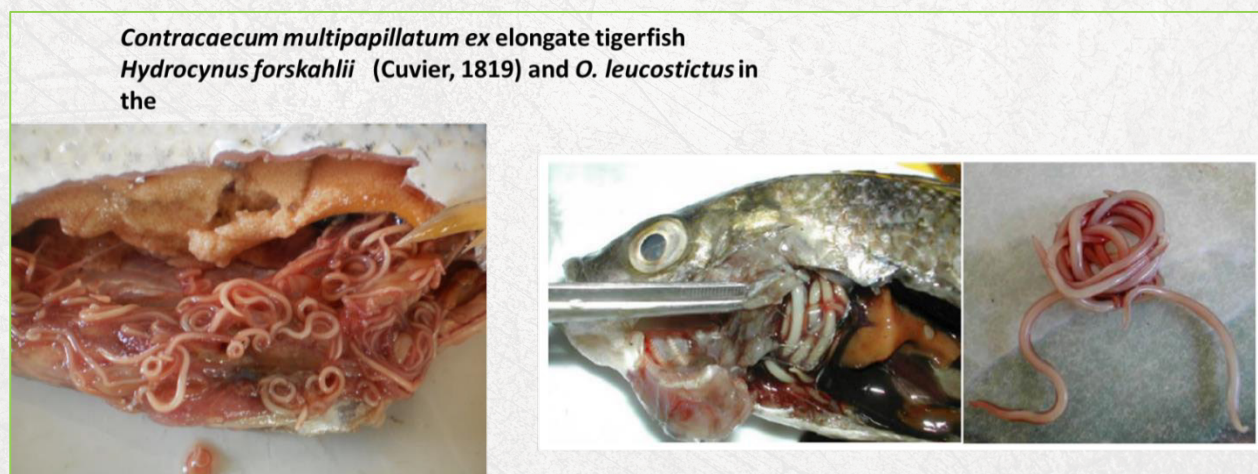


Figure 1: Heavily infested fishes with nematodes (Photo credit: Elick Otachi)

Commons signs that fish are not well

- ✓ Abnormal swimming in fish
- ✓ Lack of appetite/Decreased feeding
- ✓ Floating dead fish
- ✓ Fish gulping for air
- ✓ Not seeing fish when feeding them even at the right time
- ✓ Change of skin color especially darkening of fish
- ✓ Enlarged/popping eyes/Cloudy
- ✓ Fish not growing/stunted fish
- ✓ Open sores, lesions, loss of scales, bloated belly
- ✓ Pale, eroded, swollen, bloody or brownish gills
- ✓ Abnormally folded or eroded fins
- ✓ Presence of disease organisms on skin, gills, fins
- ✓ Roughing against hard surfaces
- ✓ Crowding/gathering at the inlet

Fish Health Management Systems/Biosecurity in aquaculture

This consists of practices that minimize the risk of introducing an infectious disease and spreading it to the animals at a facility and the risk that diseased animals or infectious agents will leave a facility and spread to other sites and to other susceptible species. These practices also reduce stress to the animals, thus making them less susceptible to disease.

Infectious agents/pathogens can cause disease and eventual mortality of fish resulting into huge losses.

A fish disease results from stressed or vulnerable fish

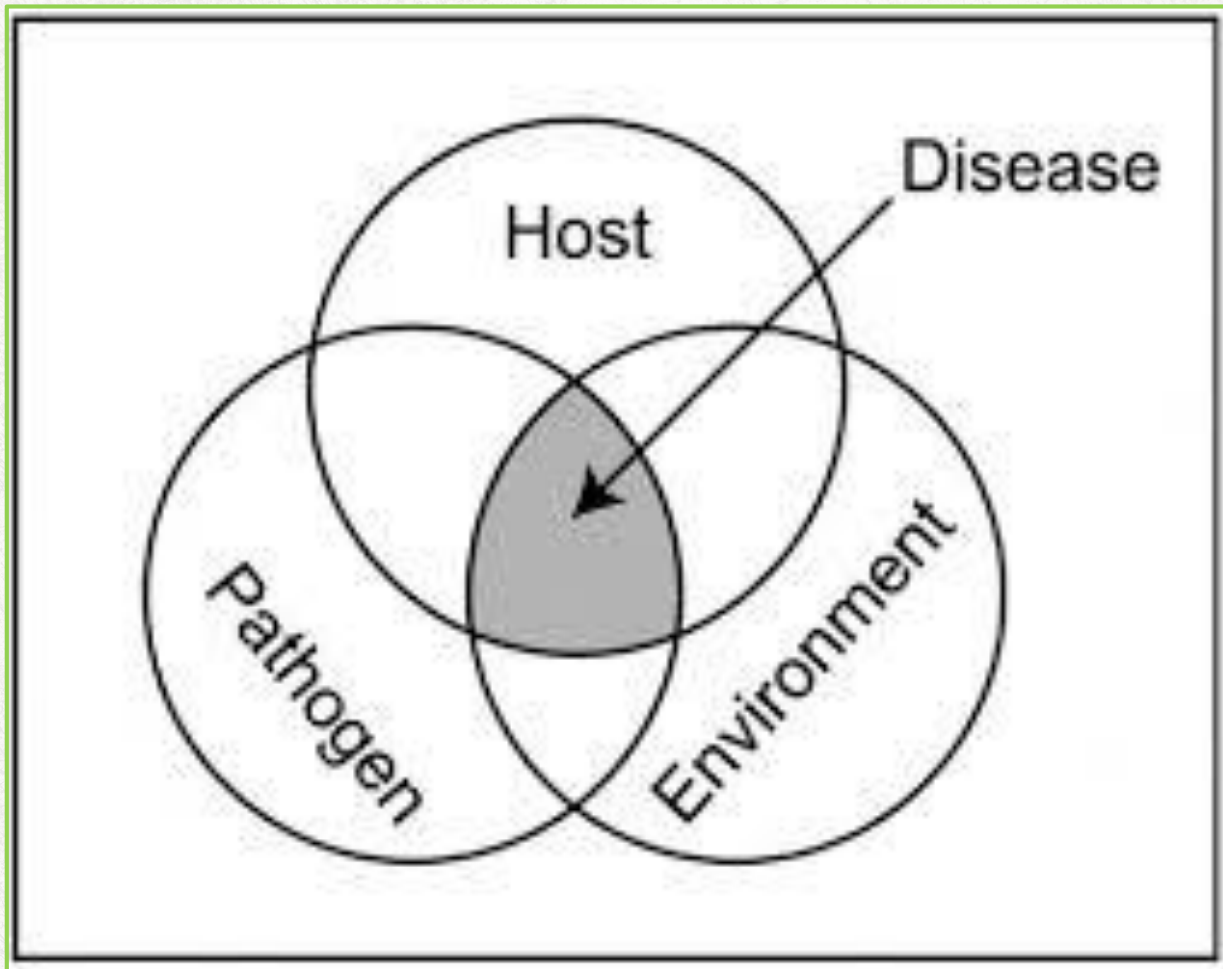


Figure 2: Showing the Fish Disease Theory adopted from Snieszko (1974)

Fish health management systems also aim at reducing stress in fish. Stress in fish results from many possible causes such as poor water quality, poor handling, inadequate feeding, overstocking hence overcrowding etc.

Examining specific points in production when pathogens (disease-causing parasites, bacteria, viruses and fungi) may be introduced or disease may develop will help producers develop precautionary measures. Good biosecurity minimizes the fishes' exposure and susceptibility to pathogens, reduces economic losses from mortalities, and helps prevent mandatory depopulation.

This manual provides an overview of major concepts in biosecurity for aquaculture. Although it concentrates primarily on finfish, the principles described also hold for other species groups.

Major Goals of Biosecurity

Major biosecurity goals are:

1. *Animal management* — obtaining healthy stocks and optimizing their health and immunity through good husbandry
2. *Pathogen management* — preventing, reducing or eliminating pathogens
3. *People management* — educating and managing staff and visitors

The ease with which a specific pathogen can enter a facility, spread from one system to another, and cause disease depends on:

- ✓ the species, immune status, condition, life stage, and strain susceptibility of the cultured fish;
- ✓ major environmental factors such as water quality, water chemistry, and husbandry practices;
- ✓ characteristics of the pathogen, such as biology and life cycle, potential reservoirs (carriers, other animals), survival on inanimate objects (equipment), options for legal treatment(s), regulatory status (exotic vs. endemic disease, reportability, and federal, state and local laws); and
- ✓ workers' understanding of biosecurity principles and compliance with biosecurity protocols.

Animal Management

Animal (Host fish management)

1.1 OBTAINING HEALTHY ANIMALS (EGGS, FRY, JUVENILES, BROODSTOCK) FROM A REPUTABLE SUPPLIER IS CRITICAL

Work with a fish health professional to determine species-specific health parameters and diseases of concern. Before obtaining animals from an outside source, learn as much as you can about their health, including where they came from, whether they have had any disease issues, and whether they have had any health examinations, disease testing, or treatments.

fish should be tested shortly after they are received.



Figure 3: Showing an accredited seed source, Wakhungu Hatchery, Busia County (Photo credit: Kevin Adwera)

1.2 STRAINS OF SOME AQUACULTURED SPECIES ARE KNOWN TO BE MORE RESISTANT TO SPECIFIC DISEASES

Tracking the lineage/ genetics of your broodstock helps avoid inbreeding and ensure the production of healthy gametes and fry.

1.3 GOOD HUSBANDRY IS ALSO IMPORTANT TO BIOSECURITY

Any environmental conditions or procedures that stress the fish or that may damage the skin, fins, gills or intestine will weaken their immune systems and make them much more susceptible to disease.

Good water quality/chemistry, nutrition, and handling methods will go far toward preventing disease.

1.4 GOOD PREVENTIVE MEDICAL PRACTICES

include quarantine, routine observation, vaccination, and the use of immunostimulants, probiotics, and diagnostics for disease management.

1.1.1 1.4.1 Quarantine

- ✓ is one of the most important animal management and biosecurity measures.
- ✓ Quarantine is the procedure by which an individual or population is isolated, acclimated, observed and, if necessary, treated for specific diseases before its release onto the farm or for live market sale (e.g., for growout or for aquarium fish stores).
- ✓ The principles of quarantine apply for new fish coming into a facility, fish moving from one area or system to another within the facility, and resident fish that become diseased.
- ✓ Well-designed quarantine systems physically separate incoming fish from the rest of the farm.
- ✓ Water in quarantine systems also should be separate from that on the main farm, and discharges should be handled appropriately.
- ✓ Proper quarantine not only protects established populations from potential exposure to pathogens but also gives the new animals time to acclimate to water, feeds and management and to recover from handling and transport.
- ✓ Handling and transport have been shown to reduce disease resistance and recovery may take weeks.

Fish in the general population that become sick may have to be isolated in tanks in the same system or room as their healthy counterparts; signs or other methods should be used to alert employees that the population is diseased.

Major components of quarantine

Includes all-in-all-out stocking, isolation or separation, observation and diet adjustment, and sampling and treatment.

All-in-all-out stocking

This involves bringing animals in as a group from only one original source population and maintaining them as a group throughout the quarantine period. It prevents exposure to other pathogens not currently in that population. Ideally, no new animals should be added to a group currently in quarantine. All-in-all-out quarantine may involve an entire facility, room or system.

Isolation or separation

A group of animals in quarantine should be physically isolated from other quarantined populations and from the resident populations. Methods of isolation should be built into the facility and system design. If logistics prevent complete isolation, populations should at least be separated by tank or vat. Regardless of the level of isolation, appropriate sanitation and disinfection measures must be used to reduce cross-contamination between quarantined and established populations and between separate populations in quarantine.

Observation and diet adjustment

Animals should be observed for normal and abnormal appearance and behaviors throughout the quarantine period so disease problems can be detected early. Loss of appetite, for example, is a very common, early sign of disease. Good nutrition will increase disease resistance and careful adjustment from the diet of origin to the on-farm diet will reduce problems from sudden changes.

Sampling and treatment

Fish in quarantine should be sampled for specific diseases of concern at the beginning and end of the quarantine period and at any time that disease signs develop. Although complete necropsy evaluation of a number of specimens is best, limited sampling of more valuable specimens can be done without sacrificing the animals by examining small sections of skin, fin and gills for parasites and doing a blood culture for systemic bacterial infections. The results can then be used to improve quarantine methods and the use of drugs. Consult with a fish health professional to assist with this. Legal issues associated with drug usage should be considered before treatment.

2.0 PATHOGEN MANAGEMENT

2.1 Not all pathogens (disease-causing organisms such as viruses, bacteria, fungi and parasites) are of equal concern

Pathogens vary in their regulatory significance, survivability in reservoirs, pathogenicity (how easily they can infect and cause disease), diagnostics, and control.

Pathogens differ in their ability to infect and cause disease. Some, like many *Aeromonas* and *Vibrio* bacteria common in aquaculture, are more opportunistic and cause disease only when environmental conditions are poor or when fish are stressed. Other pathogens, such as *Edwardsiella ictaluri* of catfish and koi herpesvirus, can cause disease quite readily in susceptible fish species. Most pathogens fall somewhere between these two extremes.

Although some pathogens cause disease more readily than others, environmental and host factors—especially the species and its immune status—will ultimately determine whether fish become sick.

2.2 Regulatory significance

Some diseases and pathogens are considered important internationally and listed by the OIE (World Organization for Animal Health) because of their economic or environmental importance. For example, the Tilapia Lake Virus (TiLV) is categorized as a serious threat to aquaculture because it can cause up to 80-90% losses in farms.

Epizootic/Outbreaks of some of these diseases require depopulation, which will greatly affect the operation.

The proper authorities (local, state and federal) must be notified if a reportable disease is suspected or diagnosed on your facility. Work with a fish health professional to determine if your species is susceptible to any regulated diseases, and get professional assistance with disease diagnostics and management.

2.3 Reservoirs

Pathogens can survive and thrive in “reservoirs” within a facility. Reservoirs (STORES) can be divided into two: The non-living and the living reservoirs

2.3.1 Non-living reservoirs

Includes water, system components, equipment, floors and walls, and feed.

2.3.2 Living reservoirs

Includes the aquacultured animals themselves, other animals (such as snails, frogs and birds), plants, and live (or frozen) food. Understanding the biology of pathogens is important, including the factors that permit them to survive in reservoirs and how easily they can be killed by common disinfectants.



Figure 4: Showing snail intermediate hosts (reservoirs) (Photo credit: Renis Auma Ojwala)

Pathogens can enter facilities in aerosol (fine water droplets), on equipment and vehicles, and on people's hands, arms and feet. Once inside, they may survive in pockets of moisture on the ground, walls or ceiling.

2.4 Diagnostics

Many pathogens can be diagnosed using routine tests. However, some are more difficult to identify in either disease cases or healthy-looking fish that are carriers because the pathogens are either "hidden" or are present in very small numbers. For example, small numbers of herpesviruses may survive in healthy-looking carriers and these fish may test negative. Most viruses have a specific temperature range at which they thrive; testing infected fish that are in water outside that temperature range may also cause negative results.

2.5 Disease control

Some infectious diseases are easily controlled by good sanitation and disinfection or with drugs. Other pathogens, including mycobacteria, some parasites, and many viruses, cannot be treated effectively or easily. In those situations, good preventive practices and the proper use of vaccines may be the best option for control. Remember that the improper and frequent use of drugs can lead to resistance, especially in many bacterial species.

2.6 Sanitation and Disinfection

Sanitation (good hygiene) through cleaning is the first step; it involves removing all foreign material (soil, organic material, biofilm) from objects by scrubbing them thoroughly

Disinfection is the second step; it eliminates many or all pathogenic microorganisms. Disinfection is effective only if organisms on all surfaces are exposed to an appropriate disinfectant at the recommended concentration for the recommended length of time.

Liming

Apply lime to the pond bottom and dyke slopes.

- Agricultural limestone (CaCO_3) should be selected for application in the fishpond. If agricultural limestone is not available in the farming area one can use other liming materials, e.g., quick lime or slaked lime.
- The lime should be applied dependent on the soil pH or on the total alkalinity of the pond water as shown below:

Total alkalinity Soil pH Apply this amount of limestone

T.alk	Soil pH	Apply this amount of limestone	
<5	<5	3000Kg/ha	300g/m ³
5-10	5.0-5.4	2500 Kg/ha	250 g/m ³
10-20	5.5-5.9	2000 Kg/ha	200 g/m ³
20-30	6.0-6.4	1500 Kg/ha	150 g/m ³
30-50	6.5-7.0	1000 Kg/ha	100 g/m ³

The lower the Total alkalinity the more the amount of limestone

1.1.2 2.6.1 Cleaning and Disinfection Protocol

The following steps are recommended in this order to routinely clean and disinfect equipment.

- ✓ Manually remove dirt and organic matter.
- ✓ Clean vigorously with a detergent or soap and water.
- ✓ Rinse.

- ✓ Apply a disinfectant with appropriate contact time.
- ✓ Rinse again or neutralize.
- ✓ Dry completely (preferably in the sun).

Good sanitation (cleanliness) practices remove the organic debris that harbors many pathogens. Removing dirt and organics also improves the effectiveness of disinfectants. Manual cleaning alone greatly reduces the numbers of contaminating organisms. An important sanitation practice is making sure filtration and aeration systems are well maintained and that excess suspended particulates, uneaten food, dead or dying fish (a major pathogen reservoir), detritus, and other organics are removed and disposed of appropriately according to all relevant regulations.

All equipment, all surfaces within the facility, and all vehicles/tires must be cleaned and then disinfected. It may be advisable to limit vehicle access to specific areas, especially if vehicles have been driven to other aquaculture facilities.

Once objects have been cleaned they can be disinfected. It is important to understand that in some situations complete disinfection may be impossible; however, using disinfectants will greatly reduce pathogen numbers.

There are a number of disinfection methods that can be used in aquaculture. Logistics, residue toxicity, and cost will determine which methods will work best for a given situation. Most common disinfection methods are either physical or chemical.

Physical methods

Include heat, sunlight and drying (desiccation). Exposure to temperatures of 80 to 100 °C for 10 minutes kills all active microorganisms, but some life stages such as spores may require much longer time periods. Sunlight can be effective, but exposure time will vary depending upon intensity, temperature and other factors, and little research has been done on effective exposure times. Drying equipment can also help reduce pathogen numbers, although spores, cysts or eggs may survive treatment. In areas with high humidity (such as closed aquaculture buildings or outdoors during rainy or wet seasons), complete drying may not be possible.

Chemical Disinfectants

Chemical disinfectants are very useful, but vary in their effectiveness against specific disease organisms. Standard doses will kill many pathogens, but some may require more specific doses or contact times. The commonly used chemical disinfectants are inorganic chlorine products (bleach, as sodium hypochlorite or calcium hypochlorite), alcohols (such as isopropyl alcohol), iodophors, hydrogen peroxide, and phenol derivatives

Chlorine disinfectants are effective against many common bacteria, viruses, parasites and fungi. Inorganic chlorine compounds include sodium hypochlorite and calcium hypochlorite. Sodium hypochlorite is available as a liquid, and calcium hypochlorite is available as HTH powder. HTH chlorine can form precipitates in the presence of some organics. Chlorine compounds are very corrosive to metal and harsh to human skin and mucous membranes. Their effectiveness depends on pH (optimal ~6 to 8) since much of the activity is attributed to the hypochlorous acid (HOCl) product. Very low concentrations can kill aquatic organisms, so the accidental exposure of nearby tanks is always a potential problem. Chlorine can be inactivated with sodium thiosulfate. One suggested ratio for inactivation is 7 mg of sodium thiosulfate to 1 mg of chlorine. Chlorine test kits should be used to make sure there are no residues left.

Alcohols (isopropyl alcohol or ethanol at concentrations of 60 to 90%) kill many common pathogens of fish (bacteria, fungi, parasites, viruses) and are one of the few readily available disinfectants that are effective against mycobacteria. Alcohols are highly effective once surfaces have been cleaned of organic matter and soil. However, some life stages such as spores are more resistant. Isopropyl alcohol is less flammable than ethanol and is a safer option.

Iodophors (iodine stabilized within a solubilizing carrier complex, such as povidone-iodine products) can be effective disinfectants and antiseptics, but each product must be used according to manufacturer's recommendations. Iodophors are effective for pathogen-specific egg disinfection (see the section on critical control points) and for disinfecting surfaces.

Hydrogen peroxide is a strong oxidizing agent that can be effective as a surface disinfectant at 3% concentration. It kills bacteria and some other pathogens. Because hydrogen peroxide breaks down into oxygen and water, it is considered environmentally safe. 35% PEROX-AID® (a 35% hydrogen peroxide product) is FDA approved to kill specific pathogens in fish and fish eggs.

Another practical method used for disinfection is pH adjustment. Depending upon the pathogen, either decreasing pH to acidic levels (using acids such as hydrochloric acid or sulfuric acid) or increasing pH to extremely basic levels (using quick lime), and maintaining this pH for a specified time period, may be enough to kill all life stages of a pathogen.

3.0 People Management

Biosecurity will be successful only if fish farm owners/managers, other staff/family members and visitors understand and follow the necessary practices. All people who do not follow established protocols will increase the risk of disease. Access to sensitive areas should be restricted to authorized personnel.

Visitors who come to your facility immediately after visiting another aquaculture facility should be considered a serious risk.

In the farm personnel should be assigned specific work areas based on the age of fish, the species, and the disease status.

If there aren't enough personnel to do that, clean, healthy fish should be handled first, then diseased or possibly diseased fish, and finally, fish in quarantine.

Age also plays a factor. Younger fish are considered the most susceptible, and so the order of handling should go from youngest to oldest fish.

Biosecurity Critical Control Points: Where Can Things go Wrong?

Critical control points are the physical locations or production steps at which the fish may be exposed to disease pathogens. Pathogens can enter aquaculture systems:

- ✓ on the fish

- ✓ in water
- ✓ from the environment
- ✓ on other organisms
- ✓ in commercial feeds or live or frozen foods

Each of these represents a critical control point.

Predator control and integrated pest management are critical to biosecurity.

Water

Good water quality is critical to the health of the fish and to the control of pathogens. System water quality and water chemistry parameters should be compatible with the species in culture and should be monitored closely for any deviations from the ideal.

Water sources have different degrees of risk. Deep wells and municipal water sources are much less likely to harbor significant levels of disease organisms than surface water and shallow wells. Water used in an aquaculture facility should be tested to make sure it is safe. If even a small amount of unsafe water is used (e.g., surface water used to prime a well pump), the entire water supply should be considered unsafe. Similarly, water used to ship fish should not be poured into the system.

Water quality & pond management

Pond management involves manipulation of many environmental factors. Pond management starts with site selection, design and construction considerations. Pond aquaculture may have major problems if the following are *not taken into consideration right from the beginning*:

- Suitable site selection,
- correct design and
- construction

For example, at the grow-out phase, the pond manager must be concerned with factors such as, temperature, rainfall, solar radiation and wind and there is no control

over these factors outside planning. However, many other factors can be controlled to a certain extent.

i. Water quality

Water quality in aquaculture encompasses all *physical chemical* and *biological* variables that affect aquacultural production. These variables affect the survival, reproduction, growth and management of fish and other creatures. There are many water quality variables but only a few play important roles in determining the success of fish in culture ponds.

Physical factors

Most of the water quality variables are uncontrollable or can only be controlled through:

- wise site selection,
- good pond design and construction practices as
- well as management of ponds in harmony with the existing climatic and geological regimes.

Temperature and light are important physical water quality variables, but these two variables are also known to affect other water quality variables.

Weather and climate

An aquaculturist should have a good understanding of local weather and climate and also know how the weather conditions change with season and reasonable prediction of the expected variation from year to year. The aquaculturist should also be aware of the normal and extreme values for all-important meteorological variables. The most important of these variables are air temperature, solar radiation, cloud cover, wind velocity, precipitation, evaporation and atmospheric pressure. All these variables will determine the extent of primary production in culture ponds.

Solar radiation: This is an important variable to an aquaculturist because it provides energy which drives the natural production in semi-intensive production systems. Solar

energy also controls the water temperature, which is one of the factors governing fish growth, and indirectly affects fish yields through stratification.

Air temperatures

Temperature is closely related to solar radiation and places with higher solar radiation are warmer than places with less solar radiation.

Water temperature

Because of the relationship between air and water temperatures, it is possible to predict water temperature by season and location. Temperature has a pronounced effect on the chemical and biological processes in culture systems. The rates of chemical and biological reactions double for every 10oC increase in temperature. This means that chemical reactions in aquatic organisms will proceed twice as fast at 35oC as at 25oC. This also implies that dissolved oxygen requirements of aquatic organisms are more critical in warm water than in cold water. Also chemical processes in ponds are affected by temperature. For example, in warm water, fertilizers dissolve faster, organic matter degrades faster and oxygen utilization by bacteria decaying organic matter is higher in warm than cold water. Drastic change of water temperatures is harmful to most aquatic organisms. However, rapid changes in large volumes of water temperature are muted because water has a large heat capacity, 10C is required to raise the temperature of 1g of water through 1o C. This is a substantial amount of heat. 30

Stratification

Stratification can be defined as separation of a water mass into layers as a result of differences in water densities. These layers are resistant to mixing. However, due to wind influence, surface temperatures are uniform up to the point of mixing depending on the strength of the wind. The result is a water body that is split in two layers with different water densities. In effect three distinct layers are created. These are the upper warmer, well mixed lighter layer (low water density), the epilimnion, the middle layer with the greatest change in water temperature with depth, the metalimnion and lower, cold heavier water (higher density) the hypolimnion. It requires a lot of energy to mix these two layers and only strong wind is able to destroy this stratification.

Implications of thermal stratification for aquaculture: Stratification cuts off communication between the different layers of a water body. Although, the top layer may be rich in oxygen, the strata below may be devoid of oxygen. This reduced environment can generate a host of compounds that are toxic to most aquatic organisms including fish. Following oxygen reduction in the lower layers, organisms may take refuge at the upper well aerated layers but if the temperatures are high, these organisms have nowhere to take refuge. As a result, they may be eliminated from the system.

Effect of temperature on photosynthesis.

Light

Fate of light in water

Fate of light in water

- light is diminished with depth
- split into its spectral components (spectral quality)

Turbidity refers to the decreased ability of water to transmit light, and is affected by:

- Suspended particulate matter
- Colloids
- Plankton
- Humic substances from decay of vegetative material

Ponds have low euphotic zones because of phytoplankton turbidity. Self-shading, which is estimated by use of a Secchi disc (SD) is a common phenomenon. Turbidity leads to greater water temperature and lower dissolved gases.

pH

In aquaculture ponds, lower pH results from weak acids such as carbonic acid, tannic acid as well as salts like ferrous and aluminum sulfate. Fish are able to live in waters within a pH range of about 3.5 - 10 but the most desirable range for most fish is generally considered to be 6.5 - 9.0. Fish have less tolerance of pH at high temperatures. Ammonia toxicity becomes important at high pH while hydrogen sulfate is more toxic at low pH. In most culture ponds the pH of the water is highest in the late afternoon and lowest just before sunrise. The range of daily pH fluctuation is dependent upon the buffering capacity of the water. There is generally an increase in pH in the afternoon and lowering of pH in the morning. The carbonic acid-carbonate buffer will lower the daily range in pH and the buffering capacity can be increased by liming of ponds.

Liming materials

- Limestone (CaCO_3)
- Dolomite $\text{CaMg}(\text{CaO}_3)_2$
- Calcium hydroxide (CaO) - quicklime.
- Calcium hydroxide is referred to as slaked lime or builder's lime.

Effects pH on fish:

- Low pH causes increased mucus secretion in fish gills. This reduces the efficiency of oxygen diffusion across the gills.
- High pH causes elevated levels of un-ionised ammonia. This component of total ammonia is toxic to fish.
- High pH also leads to loss of phosphorus to the sediments thus making it unavailable for phytoplankton for primary production.

Carbon dioxide

Carbon dioxide not only acts as a source of carbon for primary production but also affect fish in various ways; 33

- reduces the capacity of blood to carry oxygen.
- reduces the release of carbon dioxide in the bloodstream.

The type and amount of species of carbonate present in solution is mainly determined by the level of pH

Fig showing the relationship between the carbonate species and pH

Conclusion from the above figure show that:

- Above pH 8.3, carbon dioxide is absent.
- Below pH 8.3 no carbonate occurs.

Photosynthesis and pH

pH will increase during photosynthesis in poorly buffered waters.

- Total alkalinity

Alkalinity refers to the total amount of titrable bases in water and provides a buffering action. Total hardness - have an association with alkalinity.

Nitrogen

Nitrogen is important in aquaculture as a nutrient and is also toxic in some forms. Nitrogen gas is not important as long as it remains below 100%, saturation. However, at saturations above 100%, it can cause gas bubble disease. Any gas can cause this disease but in practice the problem is always because of excess nitrogen. Such cases may be caused by reduction in pressure or increase in temperature. The bubbles lodge in blood vessels of fish and restrict blood circulation resulting in death by asphyxiation

Dissolved oxygen

This is the most critical water quality variable in aquaculture. The oxygen concentration in water is inversely related to temperature. Salinity also affects the levels of dissolved oxygen inversely. Another factor that controls the levels of dissolved O₂ is atmospheric pressure. DO concentration can be predicted if the barometric pressure is known. 35

Effect of oxygen on culture species: When O₂ concentration falls, the organisms may die. However reduction affects fish growth and may lead to fish having greater susceptibility to diseases. In ponds with low dissolved oxygen concentration, fish will eat less and will have lower food conversion ratio. Gas supersaturation can also be

harmful to fish but this is rare with oxygen. Gas bubble trauma results from bubbles of gases forming in the blood. This happens when an organism that moves from gas supersaturated water is exposed to water of much lower gas concentration.

Death of phytoplankton

Mainly blue-green algae

- Reason - forms scum and when acted upon by intense heat, they are injured and death follows. The dead phytoplankton consumes the available oxygen.
- Feeding is also affected by the levels of O₂ and fish should not be fed when oxygen levels are low.

Hydrogen Sulfate (H₂S)

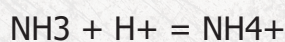
This gas is a serious problem in fish farming. It is colourless and smells like rotten eggs. The gas kills fish by interfering with respiration. It results in ponds from bacterial decomposition of organic matter. H₂S is more toxic to fish at low pH because a greater percentage of H₂S is un-ionised. Liming of ponds will raise pH and increase fish survival. High temperatures can greatly increase the toxicity of H₂S to fish.

The gas can be managed through aeration of ponds.

Ammonia

Combination of high total ammonia nitrogen and high pH can result in toxicity to fish.

Ammonia occurs in the following equilibrium;



Major sources of ammonia are:

- Excretion by fish through the gills decomposition of organic matter (mainly from feed and dead phytoplankton).
- There are two forms of ammonia :Ammonium NH₄⁺ and NH₃ and it is latter that is toxic to fish

Effects of ammonia to fish;

- Affects the function of enzymes.

- Affects the permeability of water - reducing the internal concentration in the blood and other tissues
- Ammonia also increases oxygen consumption by fish
- Damages gills leading to respiratory problems
- Reduces the ability of the blood to transport O₂
- Leads to histological changes in the kidney, spleen, thyroid and blood

Chronic exposure leads to reduced growth and susceptibility to diseases. Toxic levels for short term exposure for freshwater fish

0.7 - 2.4 mg/L as NH₃.

Ammonia is more toxic when the dissolved oxygen concentration is low. However, this is counteracted by high levels of CO₂. CO₂ will also lower the pH and therefore the concentration of NH₃. Although total ammonia concentration may remain constant in water, the pH changes with the process of photosynthesis, and NH₃ may increase to levels that affect fish growth. This invalidates the application of results obtained from aquaria experiments.

Management of ammonia:

- pH reduction to reduce the un-ionized component
- Water exchange
- Maintenance of healthy phytoplankton.
- High quality feeds which contains no more protein than necessary.
- Treatment with calcium oxide.
- Periodic removal of hypolimnetic waters.

Nitrite

Nitrite is toxic to fish. It combines with the haemoglobin of the blood to form a more stable compound than oxyhaemoglobin

$\text{Hb} + \text{NO}_2 = \text{Methemoglobin} - \text{Hb}$

This results in oxidation of ferrous to ferric state, therefore the resulting compound is not capable of complying with O_2 .

Blood with methemoglobin is brown and is referred to as brown blood disease. Nitrite toxicity is reduced by addition of Sodium Chloride.

Factors affecting NO_2 toxicity

- Chloride ion concentration
- Nutritional status
- pH
- Size of fish and dissolved O_2 concentration
- Presence of ammonia

Algal toxins

Algae may affect fish production in the following ways:

- Oxygen depletion - resulting from algal crashes
- Release toxins - peptides - microcystis aeruginosa that have neurotoxic or hepatotoxic activities
- Marine dinoflagellates injure the gills of fish

Developing a Written Biosecurity Program

The most effective way to ensure biosecurity at an aquaculture facility is to develop a written biosecurity program based on risk analysis. This includes a thorough risk assessment to determine which areas or factors may cause the spread of pathogens; risk management, whereby a prevention plan is developed and carried out; and risk communication to make sure all employees, suppliers, visitors, and others who may enter the facility are educated about the plan and cooperate with it.

ON SUSPICION OF OUTBREAK OF DISEASE IN A FARM USE THE FOLLOWING FORM

Details	Date	Numbers	Observations/signs
Date stocked			
Species of fish			
Date mortality began			
Day 2 of mortality			
Day 3 of mortality			

Bibliography

Barnie (2013) Southern Regional Aquaculture Center (SRAC). Factsheet

Bhujel R.C. (2014). *Fish health management and biosecurity*. In Bhujel R.C. (Ed.) A manual for Tilapia business management. DOI [10.1079/9781780641362.0136](https://doi.org/10.1079/9781780641362.0136)

Delabbio, J., Johnson, G., Murphy, B., Hallerman, E., Woart, A. and McMullin, S. (2005). Fish Disease and Biosecurity: Attitudes, Beliefs, and Perceptions of Managers and Owners of Commercial Finfish Recirculating Facilities in the United States and Canada. *Journal of Aquatic Animal Health - J AQUAT ANIM HEALTH*. 17. 153-159. 10.1577/H04-005.1.

Delabbio, J., B. Murphy, G. R. Johnson and McMullin S. L. (2004). An assessment of biosecurity utilization in the recirculation sector of finfish aqua-culture in the United States and Canada. *Aquaculture* 242:165–179

FAO. (2018). Development of a Regional Aquatic Biosecurity Strategy for the Southern African Development Community (SADC) FAO Fisheries and Aquaculture Circular No. C1149. Rome. 344 pp.

Lee, C. S. and O'Bryen, J. P. (2003). Biosecurity in aqua-culture production systems: exclusion of pathogens and other desirables. World Aquaculture Society, Baton Rouge, Louisiana.

Mohamed, D.M.S and Subasinghe, R. (2017). Basic biosecurity manual for tilapia hatchery technicians in Bangladesh. Penang, Malaysia: WorldFish, the CGIAR Research Program on Fish Agri-Food Systems. Manual: FISH-2017-10, licenced under CC BY-NC-ND 4.0.

Ngugi CC, Bowman JR and Omolo BO. A new guide to fish farming in Kenya.2007; 100pp. ISBN 978-0-9798658-0-0