

CHAPTER II

THEORETICAL BASIS

A. Literature review

1. Nile tilapia

The common name of the host fish understudy is Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) (Biu *et al.*, 2014). Synonyms and other Names: Nile mouthbrooder. This species closely resembles *Oreochromis aureus*. (Trewavas, 1983) provided the distinguishing characteristics, synonyms, illustration, keys, and a discussion of hybrids of the Nile tilapia. Its maximum size is 63cm and its native ranges are tropical and subtropical Africa and the Middle East.

Tilapia distributed widely in the Nile river basin and Niger river basin and lakes Tanganyika, Albert, Edward, and George, as well as in many smaller drainages and lakes in western and eastern Africa; also, in the Middle East in Yarkon River, Israel; In aquaculture, the Nile Tilapia is ranked first among the species of choice (Fao, 2008). These include the fact that this fish is a fast grower, acceptable by consumers, accepts and thrills on readily, locally available supplemental feeds, tolerant to environmental conditions, and reproduces. However, this species has a problem of over-reproduction which leads to “Runding” hence monosex culture is recommended and is vulnerable to diseases and parasites (Trewavas, 1983).



Figure 1. Nile tilapia shape

1.1. History of Domestication

Nile tilapia (*Oreochromis niloticus*) has been cultured for centuries. The drawings on an Egyptian cemetery (dated 4000 years) display fish in ornamental ponds. The culture of the tilapia genus on a global scale, especially *Oreochromis mossambicus*, started in the 1940s. However, *O. niloticus* was not exported worldwide until 1960 (Gu *et al.*, 2017). Aquaculture is a perfect protein production technique for developing countries during the 1960s and 1970s. Aid organizations promoted aquaculture as a means of improving food security with low grain to feed conversion rates, and minimal environmental impacts (Canonico *et al.*, 2005).

Initially, tilapias were allowed to breed freely. However, scientists observed that this led to the production of smaller fish over a long time. In the 1960s, attempts were made to produce male monosex populations through hybridization between different tilapia species (Trewavas, 1983). Major technological developments in the 1970s allowed for the successful production of all-male populations through the use of sex-reversing hormones which resulted in higher returns from tilapia farming. Following this, and further research into culture processes, the industry boomed (Canonico *et al.*, 2005). Today, tilapia is often cultivated in various species in the same pond, such as shrimp and other species. This improves the financial return and helps prevent the growth of harmful bacteria and works to remove excess organic matter in the water (Troell *et al.*, 2009).

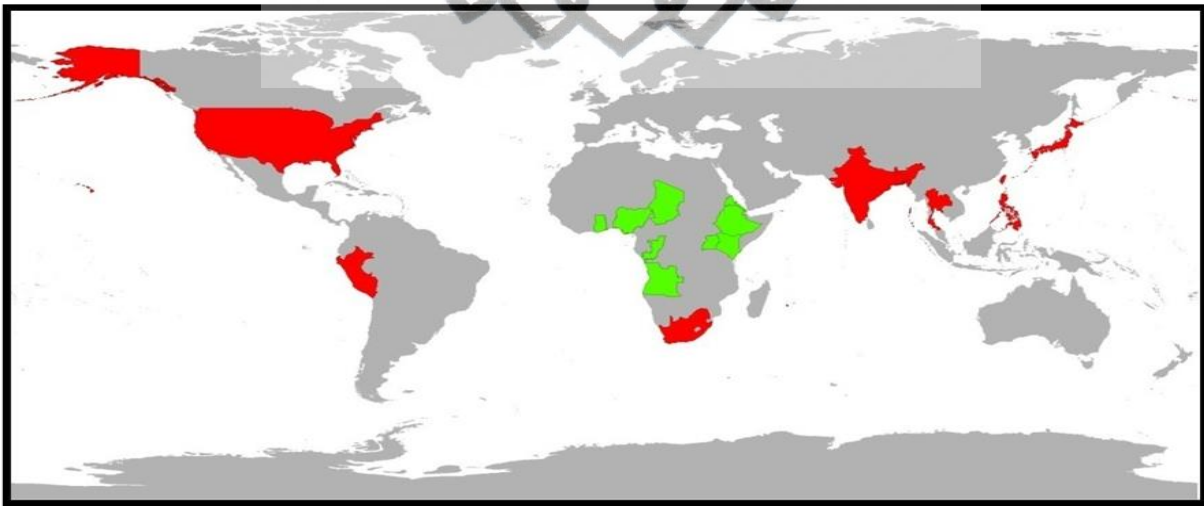


Figure 2: Native (green) and introduced (red) ranges of Nile tilapia globally Source (GISD 2012).

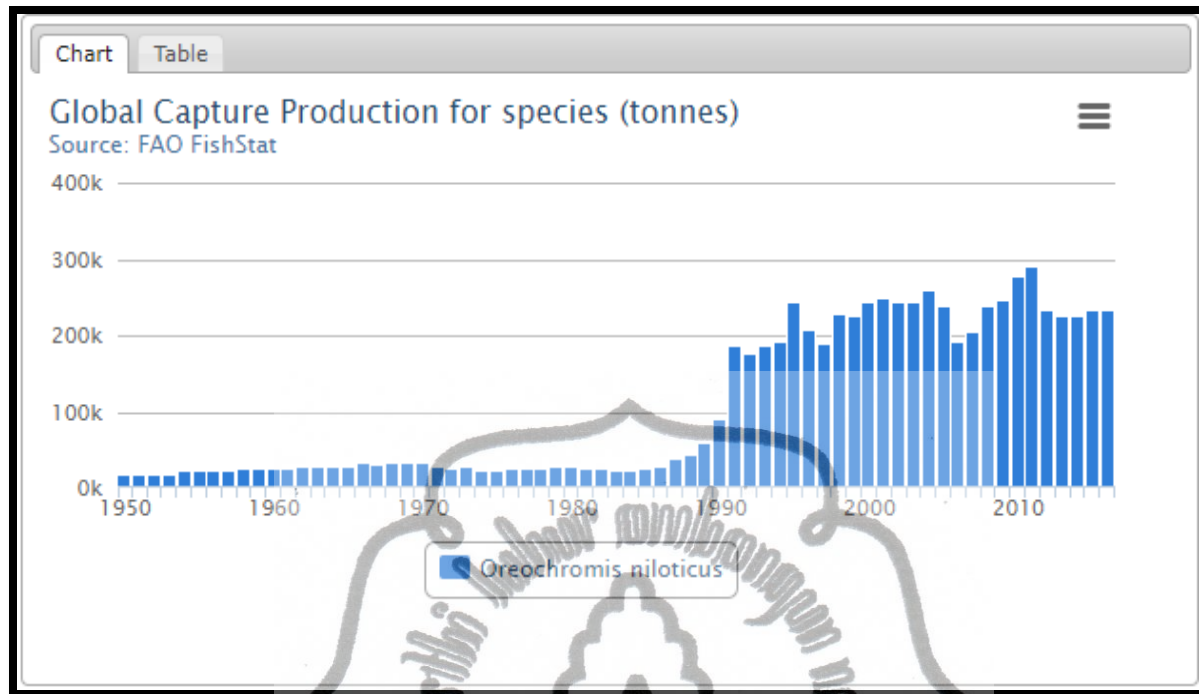


Figure 3: Global Capture Production for Nile tilapia (tones)
source (FAO Fish Stat)

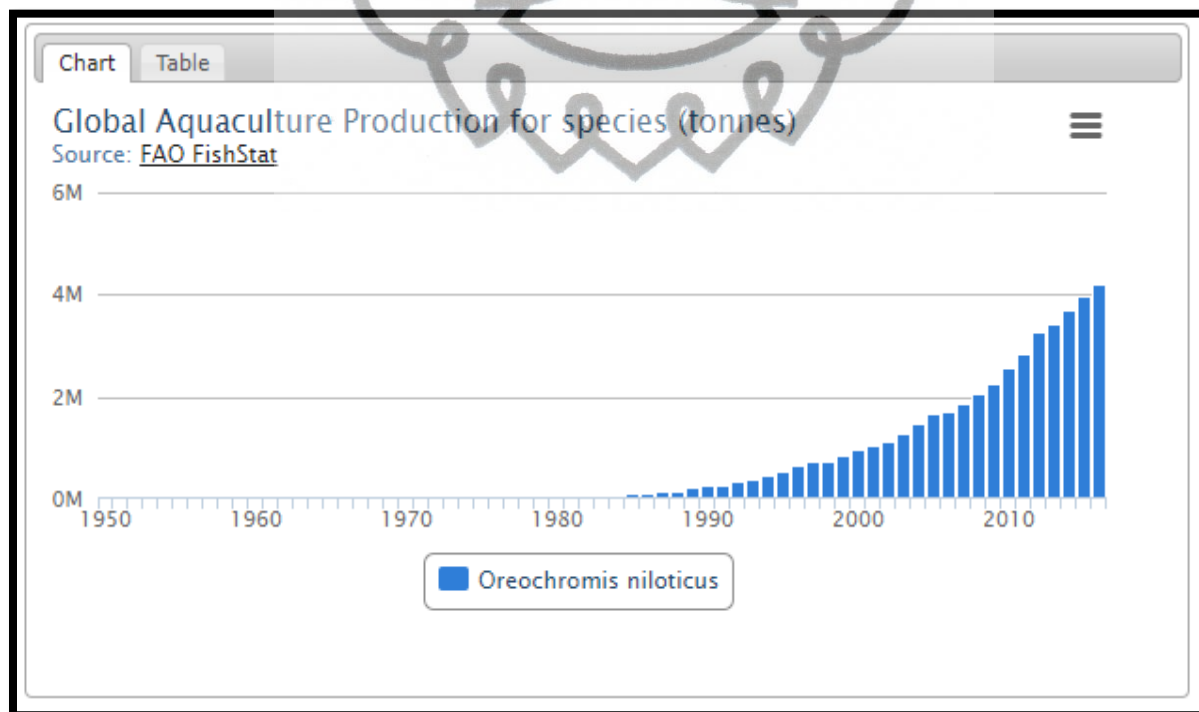


Figure 4: Global Aquaculture Production for Nile tilapia (tones)

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Source:(FAO Fish Stat)

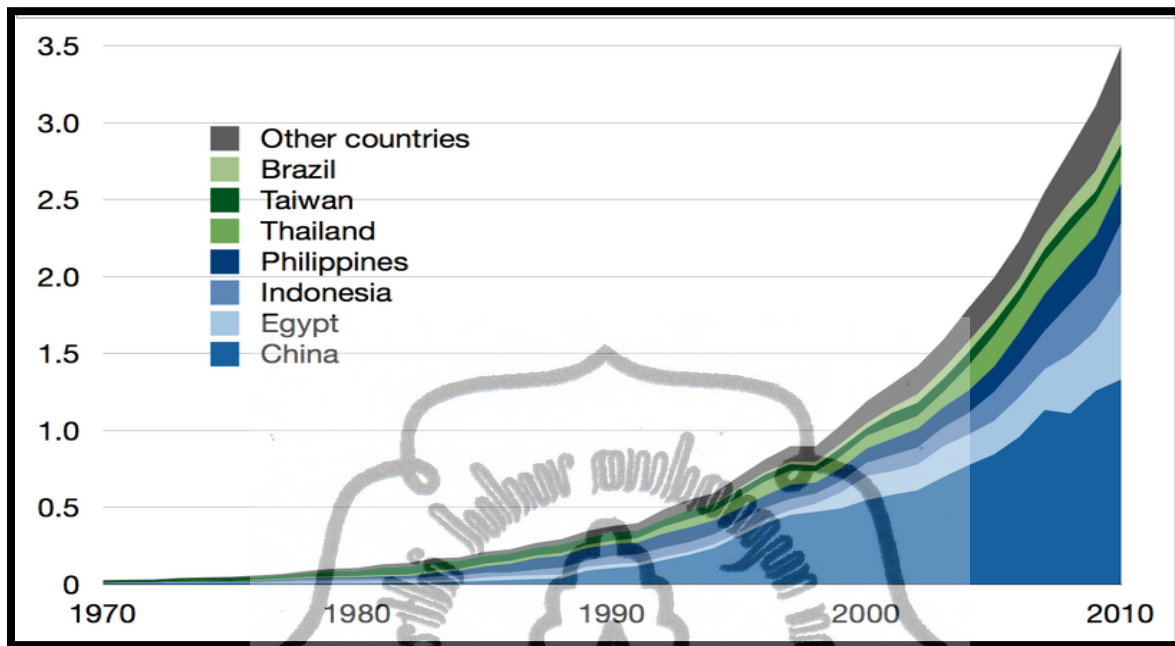


Figure 5: Top producer country of Nile tilapia

Source: commons.wikimedia.org

1.2. *Natural Distribution and Habitat*

Nile tilapia *O. niloticus* is native to central and North Africa and the Middle East. *O. niloticus* is a tropical freshwater and estuarine species. It prefers shallow, still waters on the edge of lakes and wide rivers with sufficient vegetation (Gu et al., 2017).

1.3. *Diet, Mode of Feeding, and Growth*

Nile tilapia are known to feed on phytoplankton, aquatic plants, invertebrates, benthic fauna, litter, bacterial films, and even other fish and eggs of fish (Gu et al., 2017). Depending on the food source, they're going to either feed by filtering the suspension or surface grazing. It was noted that *O. niloticus* exhibits nutritional ductility consistent with the environment and other species that coexist with it (Bwanika, et al . 2007). *Oreochromis niloticus* can live longer than 10 years, and food availability and water temperature seem to be the limiting factors for *O. niloticus* growth. The optimum growth is achieved at 28-36 ° C and reduces with a decrease in temperature. The

flexibility to vary their diet may additionally cause divergent growth (Bwanika, *et al* 2007). In aquaculture ponds, *O. niloticus* can reach sexual maturity at the age of 5-6 months (Abelti .2013).

1.4.Reproduction and Environmental Tolerance Ranges

Male fish begin to breed with the creation of an egg nest, which is highly guarded (Trewavas .1983). When the water temperature is above 24 °C, the female lays her eggs in the nest. It is then fertilized by the male before the female collects it in its mouth (known as the oral brood) (FAO, 2013). The eggs are then incubated and fried, then hatched and excreted until the entire yolk sac is absorbed after two weeks. The number of eggs the female will produce depends on the size of the body (Trewavas .1983). This can range from 100 eggs (produced by 100 grams of fish) to 1,500 eggs (produced by 1 kg of fish). Females will not spawn during the brood. Males, on the other hand, continuously fertilize multiple female eggs due to optimal environmental conditions (Trewavas .1983).

The *Oreochromis niloticus* will reportedly thrive in any aquatic habitat except for torrential river systems and the major factors limiting its distribution are salinity and temperature (FAO, 2013). The survival limits for *O. niloticus* are reported to lie between 11 and 42°C, the concentration of dissolved oxygen is not a major limiting factor for Nile tilapia, as they can tolerate levels as low as 3-4 mg/l (Indahsari, *et al* .2019).

2. Systems of Nile tilapia Culture in Indonesia

Cage culture is a major commercial effort and livelihood for those who participate in it (Indahsari, *et al* .2019). In rivers or canals that are generally found in Java, the cage is approximately 4x2 x 1 m/unit, while in Sumatra and Kalimantan, the volume is larger, at 4x2x2 m/unit. Floating net cage culture has been developed in the lakes and Tanks. Cages are placed in territorial waters using bamboo construction or iron bars, and they must form a floating cage net containing drums /containers/Styrofoam (Sari, 2010). The cage consists of a polyethylene mesh with a volume of 4 units of 7x7x2.5 m/unit, with a density ranging from 50-70 pieces/m³ and a seed size from 30-50 g/piece. After 3-4 months, production is 5-6 tons/unit/crop (FAO, 2013).

Pond culture: is traditionally done in the backyards or nearby ponds. Its area is about 1,000 square meters, fish density is 5-10 pieces/m², seed size is 8-12 cm, the cultivation period is 3 to 4 months, the pond shows a survival rate of 80%, the feed conversion ratio is 1.2 and 2 tons/crop

yield size 250-300 g/pc. Since 1960, a running water system, approved by Japan, has been developed in Indonesia. Generally, in this system, the concrete pond is square or triangular, with sizes ranging from 50-100 square meters/unit, and a density of 100 g of seeds from 5-10 pcs/m². Common carp is the main commodity, production is about 1 ton/Unit/crop, or more (FAO, 2013).

Rice field culture is: involves creating a seed nursery before it is raised in floating cages or mesh cages. The type of culture varies according to the requirements of fish farmers, i.e., common carp, wheat, and even tilapia, and the rearing period is 30 days. Rice field culture is divided into three types: "*Penyelang*" before rice cultivation, "*Tumpang Sari*" (at the same time as rice cultivation), and "*Palawija*" between two seasons of rice cultivation (FAO, 2013).

3. History of cage culture

It is a bit vague about the origins of fish cage culture. The primary cages were likely employed by fishermen as holding structures until fish may well be accumulated for the market. the primary true cages for producing fish were developed in Southeast Asia at the end of the nineteenth century. Early cages were constructed of bamboo or wood, and food scraps were used to feed the fish. the arrival of commercial materials for cage construction within the 1950's marked the start of modern cage culture (Sari, 2010). Cage research had been limited mostly because large-scale open pond culture was considered more economically viable, and so, receiving more attention in research. However, factors like increasing fish per capita, some declining wild fish stocks, and a weak farm economy produced great interest in fish production in cages by both researchers and commercial producers (Kartamihardja, 2012).

4. The advantages and disadvantages of the cage culture

The advantages of the cage culture of fish include several aspects. Many types of water resources can be used, including lakes, reservoirs, and rivers which could otherwise not be harvested. sometimes cage culture allows the use of the ponds for the culture of other species. A potential fish farmer can produce fish in an existing pond without destroying its sport fishing. No significant capital investment is required for construction or equipment; and can, therefore, practice fish culture without unreasonable risks (C.E. Boyd, 2005). Disadvantages of fish cage culture include the need that the feed is nutritionally complete; low dissolved oxygen syndrome (LODOS) requiring mechanical aeration. The incidence of disease can be high as diseases may

spread rapidly; stress due to overcrowding, vandalism, and poaching are potential problems that have to be anticipated and precautions are taken (Gopakumar, 1970).

5. The ecological benefit of Nile tilapia

Fish feeding habits can be utilized as an environmental management tool. In some middle east countries, they are taking the advantage of the detritivore's behavior of blue tilapia, a species that is stocked to control bad tastes and odors originating in sediments (Regidor et al., 2005). In Asian rice-fish farming, fish are viewed as a tool within an integrated pest management (IPM) system to make rice production more sustainable and environmentally friendly (Milstein & Hernández, 2017). The introduction of fish into the rice paddies has been shown to reduce the need for pesticides, increase farm household income, and diversify agriculture production. Omnivorous fish such as Nile tilapia can prey on rice plant pests and, as a result, the use of pesticides can be substantially reduced to rice monoculture. Blue tilapia, which can graze on cyanobacteria in the water column and on the pond bottom, has been used to prevent environment-derived off-flavors in channel catfish ponds. Nile tilapia can manage algae populations and improve water quality for channel catfish (Milstein & Hernández, 2017).

6. Steps to ensure the health of tilapia fish from its morphology

Firstly, the flesh of the fish should bounce back on touching it and the skin has a natural metallic glow and should not look dull. Secondly, fresh fish should have a mild scent of fish that is old or spoiled has a pungent and sharp smell of trimethylamine – an organic compound released from rotting fish. Thirdly, the eyes of fish should be bulging, shiny, and clear. They should be no cloudiness present. Even if the eyes are sunken into the head, it could suggest that the fish is old. Finally, the gills should be bright pink or reddish. They should also be slightly wet and not slimy or dry (Regidor et al., 2005).

7. Some Sciences related to fish pathology

Parasites in fish are a common natural occurrence. Parasites can provide information about host population ecology. In fisheries biology, for example, parasite communities can be used to distinguish distinct populations of the same fish species co-inhabiting a region. Additionally, parasites possess a variety of specialized traits and life-history strategies that enable them to colonize hosts (Halwart et al., 2012). However, understanding these aspects of parasite ecology,

need some knowledge from the other Sciences such as Ecophysiology, Ecology, Morphology, Limnology, Anatomy, and Taxonomy.

8. Fish Parasites

Parasites can be found in any fish species and within any type of aquatic system. They range from Protozoans (Flagellates, Ciliates, Apicomplexans, etc.) to Metazoans (Myxozoans, Trematodes, Cestodes, Acanthocephalans, Nematodes, and Crustaceans) (November 1991). The prevalence of some parasites seemed to be associated with water temperature and the level of dissolved oxygen (Ranzani, *et al* 2005). Paperna (1996) published a scientific manual that compiled both the personal observations and the published information from Africa on aspects of fish health, with particular reference to parasitology, except this, there is little work that has been done on fish parasites of *O. niloticus* under cage culture systems.

In general, the parasites reported being problematic in African aquaculture include ectoparasites like protozoans (*Ichthyophthirius multifiliis*, *Chilodonella spp.*, *Trichodina spp.*), monogeneans (*Dactylogyrids* and *Gyrodactylids*), leeches, crustaceans, and larval bivalve mollusks, and endoparasites such as protozoans (*haemoflagellates*, *apicomplexans*, *microspores*), myxosporeans, larval trematodes (*Diplostomatids*, *Bolbophorus spp.*, *Clinostomatids*), cestodes, acanthocephalans and nematodes (Hecht & Endemann, 1998).

9. Protozoan's parasites

Protozoans are most of the commonly encountered fish parasites (Martins et al., 2015). The identification of these parasites with practice can be the easiest to control. Protozoans are single-celled organisms, many of which are free-living in the aquatic environment (Paladini et al., 2017). Typically, an intermediate host is not required for the parasite to reproduce (direct life cycle). Consequently, they can be existing to very high numbers when fish are crowded causing debilitation, weight loss, and mortality (Florio *et al.*, 2009). There are five groups of protozoans namely: Ciliates, Flagellates, Myxozoans, Microsporidians, and Coccidia. The last three parasitic protozoans can be impossible or difficult to control (Paperna 1968).

a. Ciliated protozoa

Most of the protozoans identified by aquarists were ciliates. These organisms have tiny hair-like structures called cilia that are used for moving and/or feeding. Ciliates have a direct life cycle

and pond-reared fish are common inhabitants of them (Bruno *et al.*, 2006). Not all species seem to bother host fish until numbers become excessive. Ciliates should be eliminated in aquaria because they are usually closed systems. Uncontrollable or recurrent infestations with ciliated protozoans are indicative of a husbandry problem (Paperna 1968). Many proliferations of the parasites occur in organic debris accumulated at the bottom of aquaria. Ciliates are easily transmitted from one place to another by nets, hoses, or caretakers' wet hands. Typical symptoms of ciliates include gill and skin irritation displayed by rapid breathing, flashing, and rubbing. The most important species in the ciliated protozoan include the following: *Ichthyophthirius multifiliis*, *Chilodonella*, *Tetrahymena*, *Trichodina*, *Ambiphyra*, *Apiosoma*, *Epistylis*, and *Capriniana*. And they are causing many diseases to the fish (Trewavas, 1983).

i. Treatment of Ciliated Protozoan Infections

Most ciliate infestations respond to one chemical treatment; however, fish that still do not improve as expected should be rechecked and retreated if necessary. Overdose with chemicals can cause harm to fish. One of the excellent compounds for use in ponds to control external parasites and algae is copper sulfate; however, it is toxic to fish. Its killing action is directly proportional to the concentration of copper ions (Cu^{++}) in the water. As the alkalinity of the water increases, the concentration of copper ions in the solution decreases (Trewavas, 1983).

Consequently, a therapeutic level of copper in the water of high alkalinity would be lethal to fish in the water of low alkalinity. For this reason, the alkalinity of the water to be treated must be known to determine the amount of copper sulfate needed. The amount of copper sulfate needed in mg/L is the total alkalinity (in mg/L) divided by 100. For example, the concentration of copper sulfate needed would be $100/100$ or 1 mg/L if the total alkalinity in a pond is 100 mg/L. Never use copper sulfate in water that has total alkalinity of less than 50 mg/L. Because of its algicidal activity, copper sulfate can cause dangerous oxygen depletion, particularly in warm weather (Trewavas, 1983).

Emergency aeration should always be available when copper sulfate is applied to your system or ponds. In the biofilter on a recirculation system, Copper sulfate should not be run as it will kill the nitrifying bacteria. Potassium permanganate is effective against ciliates, fungus, external columnaris bacteria, and it can be used in a pond. Multiple treatments with potassium permanganate are not recommended as they can burn gills. Aeration should be available when

potassium permanganate is used because it is an algicide and can cause oxygen depletion. the dosage (2 mg/L) of potassium permanganate does not seem to affect the nitrifying bacteria in a biological filter; however, some parameters such as ammonia, nitrite, and pH should be Formalin is an excellent parasiticide for use in small volumes of water such as vats or aquaria. Formalin is a strong algicide and chemically removes oxygen from the water because of this it is not recommended for pond use. Vigorous aeration should always be provided when formalin is used (Trewavas, 1983).

Salt is used in proper amounts, salt effectively controls the protozoans on the fins, skin, and gills of fish. This is an effective treatment for small volumes of water such as aquaria or tanks. Use in ponds as a treatment is generally not recommended due to a large amount of salt and the high cost of treatment that would be needed to be effective. Salt should never be used on fish that navigate by electrical fields such as elephant nose fish (Nedić, *et al* 2018). When using any fish treatment, a bioassay should be conducted on some fish before large numbers of fish are exposed. Fish species can react differently to various concentrations of the chemical; therefore, fish under treatment must be monitored closely for adverse reactions. If the fish negatively react to treatment, the chemical should be flushed immediately from the system, or the fish should be moved to freshwater (Trewavas, 1983).

b. Flagellated protozoa

Flagellated protozoans are small parasites that can infect fish in internal organs or on external organs. flagellates are characterized by one or more flagella that cause the parasite to move in a whip-like or jerky motion. Because of their small size, their movement, observed at 200 or 400x magnification under the microscope, usually identifies flagellates. Common species of flagellates that infest fish are *Hexamita/Spironucleus*, *Ichthyobodo*, *Piscinoodinium*, and *Cryptobia* (Nedić, *et al* 2018).

10. Common Protozoa Parasites that Infecting the Nile tilapia

A study from Mitiku et al. (2018), indicated that the protozoan parasites comprise one of the foremost vital groups of pathogens negatively influencing the farmed fish especially Nile tilapia and this group has not received much attention due to the technical difficulties inherent in their study compared to the other parasites. Molnar et al. (2019), indicated that the ectoparasitic

protozoa are ubiquitous in the aquatic environment and can cause great economic loss in fish farms as a result of host mortality. Another study from Arguedas et al. (2017), showed the presence of protozoa like *Ichthyophthirius multifiliis*, *Trichodina*, *Chilodonella*, *Ichtyobodo necatrix*; Monogenic: *Cichlidogyrus*, *Gyrodactylus*, *Dactylogyrus*; Nematodes: *Contracaecum* sp. Parasitic crustaceans like *Argulus*, *Ergasius*, and *Lerne*a on Nile tilapia.

A study from Suliman & Al-Harbi. (2016) indicated that the parasite infestation increases in intensive culture systems due to the high density of fish and in different cases, if the parasites do not reach the level or amount necessary to cause an epidemic, the host fish can become weak and a path for infection of other fish. Biu et al. (2014) mentioned that the protozoan parasites are among the foremost pathogenic that infect fishes while they are not usually considered to be a problem in the wild fish, but many of these species cause extensive losses under conditions of intensive fish culture and poor environmental conditions. Pantoja et al. (2012) indicated that the *Trichodina* spp. is the most common protozoan affecting cultured Nile tilapia. A similar study conducted by Indahsari et al. (2019) in Indonesia on farmed Nile tilapia showed that the protozoa *Trichodina* spp. was the most common parasite observed among the other parasite species in the study. Based on a study by Arguedas et al. (2017) indicated that the protozoa *Apiosoma* spp. affects the skin and gills of Nile tilapia, and the infection is associated with the seasons, as the infection was higher in the rainy season than it was in the dry season. The protozoan *Ambiphrya* spp. infects the gill and skin of Nile tilapia and causes a serious problem in fish culture. (Salem & Reda, 2011).

The study from Bruno et al. (2006) indicates that the parasite *Ichthyophthirius multifiliis* is one of the causes of economic losses to the fish culture around the world. It infects the gills and skin of Nile tilapia causing 'Ich' or white spot disease, following by high mortality rates in cultured and wild fish. A study from Martins et al. (2015), indicated that the flagellated protozoan *Cryptobia* spp. can infect the gills, fins, skin of fishes. In the study conducted by Kohn et al. (2016); the ciliated protozoan *Tetrahymena* spp. is an important pathogen for freshwater ornamental fish and tilapia as it may cause severe mortality. The parasite infects the epithelium of the host fish (especially when there are wounds), reaches the blood, and intrudes on the gills, kidneys, brain, and eyes.

11. Factors Influencing Fish Parasitism

a. Farm or/ and Cage Management Practices

Intensification of densities in tilapia aquaculture, lack of biosecurity plans, and deficient management practices have led to the spread establishment of non-native parasitic diseases. they are many factors associated with reports of parasitic and bacterial diseases under poor management conditions such as fish source, high stocking density, high concentrations of nitrates, and low frequency of water exchange in cultured tilapia have been identified in both pond and cages (Paredes-Trujillo et al., 2016).

The study by Paredes Trujillo *et al.* (2016) suggested that the high and low technology Nile tilapia farms in Yucatán Mexico depending on their management and environmental variables have specific suites of ectoparasites. In Brazil at the Aquaculture center between 1993 to 1998, 393 fish parasites were diagnosed cases brought by fish farmers, comprised of various parasites whose occurrence was attributed to high stocking densities, high organic matter content, and farmers' failure to clean the fishnets (Martins, *et al.* 2000).

Trade of fishes, and embryos as a result of fish farming and restocking of wild populations and ornamental fish exert a high risk for transmission of protozoan parasites. Therefore, good management measures of the brood stock in hatcheries can prevent the transmission of these parasites. also, the source of water for fish farming an important factor in parasite transmission (Iyaji, *et al.* 2010). Fish farmers faced several pond management problems including; high cost of feeds (33.6%), drying up of ponds during drought (18.5%), lack of fingerlings (13.8%), flooding (10.9%), and siltation of ponds (8.9%), pond maintenance (8.6%) and poor security (5.7%) (Shitote, *et al.* 2013).

High stocking densities cause stress and facilitate parasitic transmission. It is much easier for the parasite to find a host in high-density populations and this also allows the parasite to reproduce more rapidly and effectively. In a study by (Pavlou, *et al.* 2019) the high prevalence of *Trichodina spp.* was shown to be correlated with the high stocking density of fish and with the physicochemical parameters of the water.

b. Age of the host, Size, and Body Weight

Prevalence and/or intensity of parasitic infestation are positively associated with the fish size and age. Older fish have a longer time to accumulate parasites than younger ones and may provide more internal and external space for parasite establishment. The occurrence of negative correlations has also been reported. This was attributed to changes in the feeding habit or to the development of the immunity reaction that occurs in older fish or premature mortality of infested older individuals (Indahsari, *et al* 2019). In a study by Ibrahim. (2012) on parasite info communities of *Tilapia zillii*, there was a positive significant correlation of prevalence and mean parasite intensity with total host length indicating that larger hosts harbored more parasite species and more parasite burden than smaller ones. This was attributed to the fact that larger (older) fish had longer to accumulate parasites than the smaller (younger) ones.

Relationships between weight and *Lernaeid* ectoparasites showed a negative correlation. *Lernaea* spp. had the very best prevalence (25.9%) within the weight group of 1000g its prevalence was 20.6% and 13.4%, respectively (Khalil, *et al.* 2014). Pantoja *et al.* (2012) found that the intensity of protozoan *Ichthyophthirius* multi-files was positively correlated with both the weight and length of the Nile tilapia (*Oreochromis niloticus*). This indicates an increase in parasitism according to the growth of fish. Mwita and Lamtane. (2014), reported fish in lower size classes and upper classes had few parasites while fish within the middle class (160 - 189 mm) had a better prevalence of infestation. All fish in higher size classes or older fish had a low intensity of infestation. This was attributed to ontogenetic change that's considered because the main factor determining parasite abundance within the alimentary canal due to changes in feeding behavior as a fish grows.

c. Host Diet

In parasites acquired by ingestion, the host diet is that the main factor determining the number of parasite species and individuals to which a host is exposed. Ingestion of larval helminth parasites by fishes could be a frequent event because of the abundance and variety of those tropically transmitted parasites in aquatic ecosystems. Differences in trematodes (*Coitocaecum parvum*) infestation levels observed among fish species within the Lake Waiholo community by Lagrue *et al.* (2011) in New Zealand were attributed to interspecific differences in host diets. However, prevalence and abundance of *Acanthocephalus galaxii* and nematode *Hedruris*

spinigera weren't, or only weakly correlated with fish host diets. Cirtwill *et al.* (2015) found no obvious link between individual fish host diet and helminth infestation levels. This was attributed to the relatively low richness of freshwater helminth parasites in New Zealand and high host-parasite specificity.

d. Host Sex

Differences in immunocompetence may result in Sex-biased parasitism. Males are predicted to grips a greater cost of sexual selection and immunosuppressive effects of testosterone production thus becoming more at risk of parasitic infestation than females. Differences in parasitic infestation between genders may additionally arise ecologically. as an example, niche partitioning involving habitat or diet may end up in differential exposure to parasites with either males or females exhibiting excess parasitism dependent on their probability of encountering the parasite (Iyaji, *et al.* 2010).

Studies on helminth parasites in largemouth bass, *Micropterus salmoides* from Lake Naivasha showed female fish were heavily infested than males (Biu *et al.*, 2014). Mwita and Lamtane. (2014), in lakes, Uba and Ruwe in Tanzania reported overall prevalence (88.5%) and mean intensity (21.6%) of parasites was higher in males compared to females though the differences weren't statistically significant ($P > 0.05$). This was attributed to the inactivity of females since most had ripe gonads indicating a spawning period. Ibrahim. (2012) reported that the prevalence and intensity of most parasite species were higher in females than in male fish. The sex difference in infestation was attributed to the immunologic response of the host due to the difference in endocrine glands activities between the host male and female fishes.

e. Seasonality of Parasite Transmission

Rainfall and temperature are important factors controlling the seasonal prevalence of parasites. As warm temperature would hasten the generation time, the absence of seasonal fluctuation in temperature would suggest a dynamic equilibrium of the parasite population with constant infestation and maturation (Mwita & Lamtane, 2014). Ali, *et al.* (2014), attributed the high prevalence of *Lernaea cyprinacea* and *L. polymorpha* in some fish species cultured in some nurseries and hatcheries in Pakistan to the hot climate within the area.

In a study on helminth parasites in fish from Niger delta creek in Nigeria by Ogbeibu, *et al.* (2014) parasites had the very best densities in the dry season, corresponding with the influence of season, particularly salinity, improved availability of food prey, and change in physicochemical conditions. A report by Martins, *et al.* (2003) showed sea bass reared in cages to be more likely to develop monogenean parasitism in autumn. This was due to the lower overall temperatures, specific wild fish fauna, and climate conditions present. Lower temperatures may affect the system rendering fish more liable to infection with parasites.

Kayis *et al.* (2009) showed that the mean intensity of the *Microcotyloides* spp. was positively correlated with water temperature where their mean intensity appeared to increase with the increase in water temperature resulting in a seasonal cycle of the parasite. Rainfall affects water quality by diluting nutrients, food remains, and other materials and increasing turbidity due to excess particles from sediments in the water (Pantoja *et al.*, 2012). Fish reared in cages in Greece showed an increase in the prevalence and intensity of the monogenean *Diplectanum aequans* in sea bass after heavy rainfall, a typical phenomenon during autumn (Martins-Bessa *et al.*, 2003). The increased load of suspended solids and turbidity within the water was also present. This was attributed to the mixing of the water during the storms which facilitate the transfer of the parasites to the hosts or the sudden decrease of salinity resulting in immunosuppression because of stress. Parasites' development and growth require high temperature, low humidity, and less rainfall (Dhole .2010).

f. Water quality

Poor water quality parameters such as high organic matter, high ammonia, low dissolved oxygen, and high bacterial load can create a suboptimal environment that is stressful for the fish leading to a higher incidence of parasitic outbreaks (Arguedas, *et al.* 2017). Salinity is an important factor influencing infestation with a specific parasite as some parasites only survive in brackish water and others only tolerate freshwater. For instance, dinoflagellates such as *Amyloodinium* spp. can only survive in brackish and marine water; therefore, it does not occur in freshwater. In contrast, some species of *Trichodina* can die with as little as 5ppt of salt in the water, and they only tolerate freshwater (Arguedas, *et al.* 2017).

During investigating parasitic infections in pond-reared Rainbow trout, *Oncorhynchus mykiss* in Denmark found that prevalence of some parasites such as *Ichthyophthirius multifiliis*

increased with temperature (Maximum at 16°C to 20°C) whereas diplomonad had the highest prevalence at 1 to 5°C, likewise, the *gyrodactylids* occurred more abundantly at lower temperatures (Buchmann & Bresciani, 1997).

12. Standard Water Quality Requirements for Nile tilapia Farming

International standards for optimum water quality (PH, DO, transparency, ammonia, conductivity, and temperature) required for the culture of Nile tilapia [see table1].

Table 1:Standard Water Quality Requirements for Nile tilapia Farming.

	Water Quality Criteria	Recommended Value (Range)	Source
1	PH	6,5 -9	(Claude E. Boyd, 1998)
2	Temperature	25 °C – 30°C	(Claude E. Boyd, 1998)
3	Transparency	65- 85 cm	(Claude E. Boyd, 1998)
4	Ammonia	< 0.1 mg/l of NH ₃	(Zweig, <i>et al</i> 1999)
5	conductivity	150 -500 µ S/cm	(Claude E. Boyd, 1998))
6	DO	5-8 ml/L	(Claude E. Boyd, 1998)

B. Conceptual framework of the study

The conceptual framework of this study has three major components that will investigate namely; first the host fish Nile tilapia (*Oreochromis niloticus*), second the environment, or physicochemical parameters (pH, DO, ammonia, conductivity, water temperature, transparency), and third the parasites (external protozoans' parasites ciliates and flagellates). As we know Nile tilapia fish like any organism that lives in water interacts with both abiotic and biotic factors in its environment, where Nile tilapia's survival, growth, and productivity rely upon its ecology. However, tilapia aquaculture Cages in those reservoirs are small and confined to a narrow place thereby presenting a significant stress factor to the fish.

Furthermore, some of those reservoirs being used are uncensored for parasites and pathogens as they were constructed without the intention of farmed Nile tilapia fish. as a result of the situation mentioned above, this causes significant stress factor to the farmed Nile tilapia due to water quality, quantity, circulation, stocking densities (biomass), re-stocking, handling, and other matters which disrupts the dynamics of equilibrium between the host (Nile tilapia fish) and the parasites

(external protozoans' parasites). That diseases or parasitic infections in the water environment develop as a result of fish being under stress by the biotic and abiotic factors (Koyuncu, 2009). The particular gaps which will fill during this study include: identifying the external protozoans parasites occurring on *Oreochromis niloticus* farmed in cages in those three reservoirs, establishing their mean intensity, prevalence, and mean abundance.

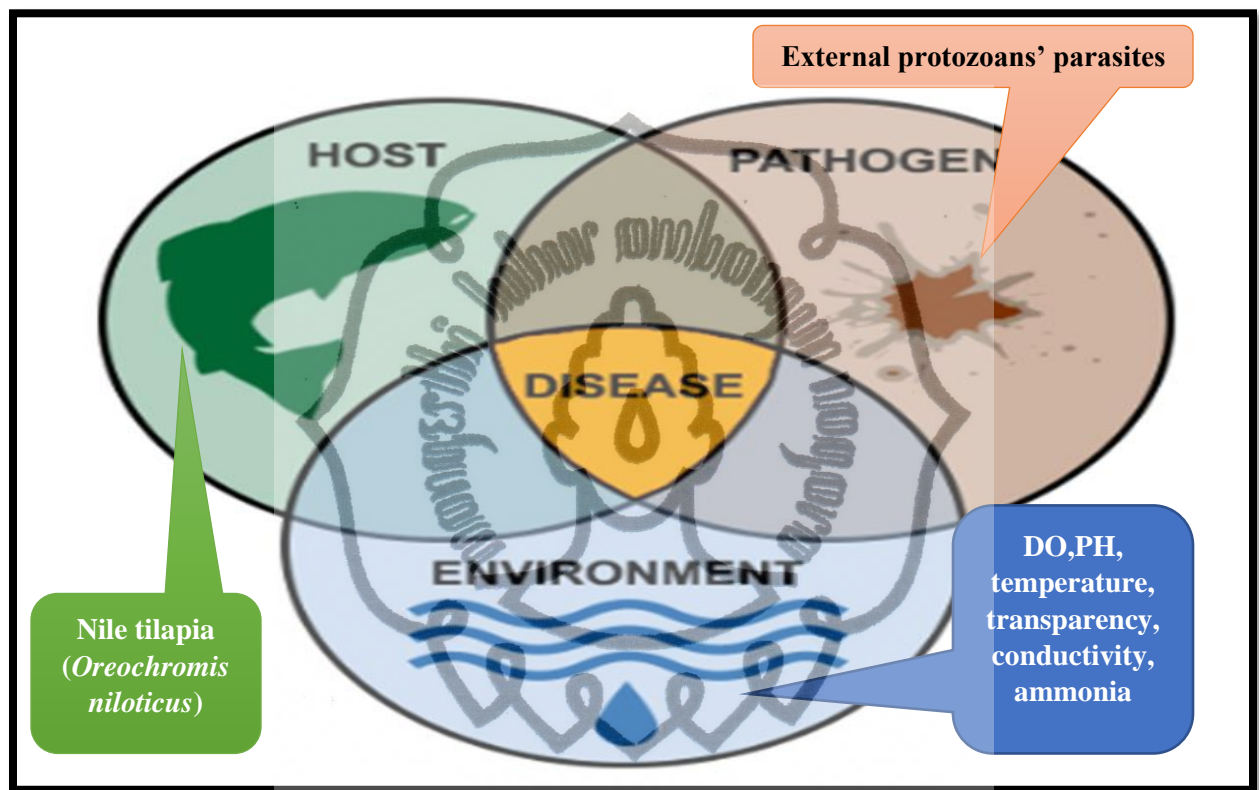


Figure 6: The conceptual framework of the study showing the interactions between three major components: Fish, Environment, and Pathogen.