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THE EFFECTS OF STOCKING DENSITY AND FEED ON THE GROWTH PERFORMANCE OF *Oreochromis niloticus* IN SUSPENDED CAGE IN LAKE BABOGAYA, ETHIOPIA

BY

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ABSTRACT

The effects of stocking density and supplementary feeding on growth performance of Nile tilapia, *O. niloticus* in cage culture in Lake Babogaya were investigated for five months from February 2007 to July 2007. Juvenile of *O. niloticus* having a mean body weight of 30 gm and mean length of 12.5 cm were stocked in duplicates of five cages, with stocking densities of 50 (with and with out feed), 75, 100 and 125 per meter cube. The feed treatments were providing supplementary feeds with a composition of 60% sweeping meal, 20% crushed seed cotton and 20% pea flour, with a feeding rate of 2% of the body weight. The feed was divided equally into two and was fed twice a day. Growth change and feed conversion ratio of the stocked fish were studied for the sampling periods.

The survival rates of the stocks were high in all treatments and were not affected by difference in stocking density. The results of this experiment indicated that significantly higher mean weight (MWT) and daily growth rate (DGR) were obtained from the lower stocking densities with feed (50 fish/m^3), than those from the higher stocking densities (125 fish/m^3) and the control stock (50 fish/m^3) ($P < 0.05$). This result revealed that growth performance was negatively affected by stocking density. Moreover; feed had a strong positive effect on growth performance. The gut analysis result indicates the importance rank of natural feed (phytoplankton: *Microcystis aeruginosa,* Bacileariacaea and dinoflagellates) were 1st, 2nd and the 3rd respectively. The biodynamic of the Lake changed after April; dinoflagellates became more dominant and *Microcystis aeruginosa* became more decreased, but the importance rank remain the same throughout the sampling periods, which indicated *O. niloticus* is selective feeder and *Microcystis aeruginosa,* and Bacileariacaea are the preferred natural feed in Lake Babogaya.

The least growth performance coincided with the decline of primary production, the change in biodynamic of the Lake and the vertical shifting of the natural feed to metalimnetic region. The negative growth of the control stock in May and June indicates that extensive cage culture practice is impossible while the primary production is decreasing and the natural feeds (phytoplankton and zooplankton) are shifted to the lower depth (metalimnetic region) from April to September unless the size of the cage is big enough to reach to the feed richer site of lower depth, but this has to take the DO concentration into consideration.

A nematode parasite worm *Contracaecum sp.* with length of 2.6 to 4.5 cm and 5 to 7 in number per fish were identified in the gill cavity of the stocked fishes with size of 60 –100 g; however, frequent longer sized worms were not common in natural wild fishes of comparable size. But these parasites rarely occurred in bigger sized wild fish. The competition for feed of the wild fishes was very high which bring stress and competes for feed and space; during sampling and harvesting times between 17 – 89 % extra wild fishes were identified. Relatively improved growth was observed in those cages that were fixed toward shore side and in shallow water than the front lined cages that were hanged in deeper position which indicates the position of the cages has effect on growth performance.

Key words / phrases: Cage culture, Lake Babogaya, stocking density

1. INTRODUCTION

The world population is on the rise, as is the demand for aquatic feed products, but production from capture fisheries at the global level is leveling off and most of the main fishing areas have reached their maximum potential. Meeting basic human needs for protein feeds in the future will be a difficult challenge. Approximately 1.3 billion people live on less than a dollar a day and half of the world's population lives on less than 2 dollars a day (Watson, 1999). For this, aquaculture not only addresses the challenge efficiently but also gives an alternative means in giving job opportunity and reducing poverty.

Aquaculture production is highly dominated by Asian countries, China accounted over 90% of world production, but aquaculture activities are not well developed in Africa. According to Aguilar-Manjarrez and Nath (1998) Africa has big potential for fish farming with 37 percent of its surface area suitable for artisanal fisheries and 43 percent suitable for commercial fish production. Africa has suitable bio-physical resources for aquaculture activities, i.e. the warm tropics with elevated temperatures and abundant rainfall, unutilized or under utilized land and low-cost labor as well as high demand for fishery products (Aguilar-Manjarrez and Nath, 1998). Between temperate (23°–67°) and tropical (23°N–23°S) zones, there is a considerable increase in the range of production values and thus tropical water bodies offer better opportunities for extensive and semi-intensive cage and pen culture (Le Cren and Lowe-McConnell, 1980).

Despite the favorable conditions in most parts of the continent, the contribution of Africa to global aquaculture products is low and the contribution of sub Saharan African (sSA) counties are very low. The contribution of Africa to global aquaculture products is less than 1% and the contribution of sSA in 2003 was a mere 13.6 percent to the African total or 0.13 percent of the world total (FAO, 2006; FISHSTAT Plus, 2005). However, in Africa aquaculture production has increasing as increasing world aquaculture production. Although Africa contributed less than 1 percent to global aquaculture production (251 000 t in 1999) the production has been expanding since 1984 at a rate equal to or greater than the global rate, albeit from a much smaller base (FAO, 1997).

Tilapia represents a major fish protein source in many countries of the world, and has been transplanted to and stocked in waters of nearly every country of the world (Eknath *et al*., 1993). According to Popma & Lovshin (1996) tilapia is currently ranked second next to carps in global production of the major producing countries like China, Egypt, Indonesia, Philippines, Mexico, Thailand, Taiwan and Brazil and is likely to be the most important cultured fish in the 21st century. According to Fitzsimmons (2004), in 2003 the global production of tilapia reached 1.5 million metric tones, the Nile tilapia, *Oreochromis niloticus*, L. is currently considered to be the most important and commonly cultured tilapia species around the world, and constitutes over 70% of the cultured tilapia. Among the 70 species of tilapia, nine of them are used in aquaculture farming, but Nile tilapia (*Oreochromis niloticus*) is the main cultured species and responsible for the significant increase in global tilapia aquaculture production (FAO, 2006). Besides *Clarias gariepinus* and O*. niloticus* show promise of being a suitable species for cage culture. In sub-Saharan African countries Nile tilapia, *O. niloticus,* contributes 12 percent by weight to total regional production but makes up 43 percent of total cichlid production in the region. The data also revealed that the contribution by *O. niloticus* to total production has increased from 7 percent in 1994 to 12 percent of total production in 2003 (FAO, 2005).

According to Delgado *et al.,* (2003) and NEPAD (2005), the current per capita fish consumption of World and Africa is 14 Kg and 8 Kg /person/year, respectively, however, the fish consumption per capita of sub-Saharan African countries is lower, 6.6 kg /person/year and only 175 g/person/year in Ethiopia. To maintain the current per capita fish supply in Sub-Saharan African countries requires a 20 percent increase in production within 10 years and a 32 percent increase by the year 2020.

Most commercial and artisan capture fisheries in SSA countries are declining or are optimally exploited (FAO, 2004). Juxtaposing the declining capture fisheries of the region, the high population growth rate in SSA and the current shortfall of fish emphasizes the need for rapid growth of the aquaculture sector. It is fact that aquaculture as the primary means of achieving increases in fish supply to overcome constraints that capture fisheries are confronted with. However, the situation in SSA is far from this. According to Kapetsky

(1994) the contribution of aquaculture to fish supplies is only 0.7% that is less than 5% of the potential. This justifies the need for the development of alternative aquaculture in such areas so as to avoid over fishing and to meet the consumer demands.

Ethiopia, which belongs to sSA, is called a water tower of Eastern Africa in a continent. According to Wood and Talling (1988) the inland water body of Ethiopia is estimated at about 7,400 km^2 of lake area and about 7,000 km total length of rivers. A conservative estimated potential yield of fish in Ethiopia is between 30,000 - 40,000 tons per yea. This huge potential is not exploited properly although the country is faced with acute feed shortage.

Tilapia sp. in general and *O. niloticus* in particular is the important cultured fish worldwide, in Africa as well as in the region. It is important species both ecologically and economically in Ethiopia and is among the six economically important fish species in Ethiopia, with the most ecologically adaptive exploited species and it has high reproduction potential. The six family species, Centropomidae (*L. niloticus*), Cichilidae (*O. niloticus*), Claridae (*Clarias gariepinus*), Bagridae (*Bagrus docmack*) and Cyprinidae (*Labeobarbus sp*. and *Labeo sp*.) are the most important economically (JERBE, 2006). *O. niloticus* is the most exploited species and represents about 80% of the total fish capture in Ethiopia (Breuil, 1995). Among the local species, *O. niloticus* has a good breeding potential (FAO, 1997).

In Ethiopia, aquaculture production as well as fish-consumption compared to other SSA countries is very low. The present production in most water bodies is far below the estimated yield and the pattern of production is by no means uniform. The rift valley lakes that are situated near to urban center and along the main asphalt road are heavily fished than others. For instance, Lakes Awassa and Ziway are near to being heavily exploited as evidenced by the smaller size of fish handed in these lakes (FAO, 1995). Ethiopia needs much more effort in the production process not only to maximize fish production but also to tackle the problem associated with poverty, increased family income and better nutrition, because fish culture activities increase job opportunity. Consequently, there is a need to look for less expensive technology and simple methodology that is feasible to economic background of the country and cage culture practice is one of such activities in countries like Ethiopia

Worldwide, cage culture has been receiving strong attention in recent years; cage culture of fish utilizes existing water resources, encloses the fish in a cage or basket that allows water to pass freely between the fish and the water body. Culture of fish in cages was attempted in Africa in Lake Victoria, Tanzania; and in Lake Kainji, Nigeria (Agbebi and Fagberno, 2006). Successful culture of O. *niloticus* in cages was demonstrated in Lake Kossou (Ivory Coast), in recent years with average production of up to 17 kg/m^3 of cage per month, with stocking densities up to 50 – 150 fish/m^3 and feeding with locally prepared diets (Ouattara *et at*., 2003).

Cage culture activity can be practiced in extensive, semi-intensive and intensive methods. In extensive farming system, there is no use of fertilizer or supplementary feed in the culture, in semi-intensive farming system supplementary feed or fertilizer is applied to some extent but in intensive farming system the cultured organism is totally dependent on supplementary feed. Therefore, intensive farming system is costly; it needs higher investment and well-developed market. The most appropriate system for Ethiopia should be extensive and semi-intensive methods, which are feasible with the economy and the marketing demand of the country.

Extensive and semi-intensive methods that involve enclosures are suitable for fishes which are planktivorous, or which feed on benthos, detritus or drift, but carnivorous species, such as the salmonids and many of the catfishes (e.g. *Ictalurus punctatus*, *Pangasius sutchi*) cannot be successfully grown without recourse to intensive methods, using largely fish protein based diets (Cowey, 1979).

According to FAO (1975), the following suggestion is noteworthy: "Experimental and limited pilot scale operations have demonstrated that small or large scale fish farming using indigenous species and feed material can be highly productive and profitable". Therefore, identification of an appropriate species for aquaculture in general and for cage culture in particular is necessary. Rapidly growing species, disease resistance, market demand, lower trophic level are some of the criteria for selecting species for aquaculture.

Tilapia intensive culture would require the formulation of efficient feed with optimum potency to meet the protein requirement in fish culture during grow-out period. Juvenile and adult Nile tilapias are reported to filter phytoplankton (Moriarty and Moriarty, 1973). Since Nile tilapia use algal protein, raising tilapia for feed at a lower trophic level can be a cost efficient culture method. In cage culture feed selection is important because caged fish are not able to forage for insect and other feed items that are available in the water bodies. Since caged fish cannot feed on the bottom, the feed used should float.

Plant protein is used as the main protein source for carp and tilapia without need for additional animal protein components (FAO, 1995). Particle size in the diet of tilapias seems at first glance to be less important. Many of the cultured species, such as *O. niloticus* and *O. aureus* are microphagous feeders (Bowen, 1982), and according to Miller (1979) and Pullin and Lowe-McConnell (1982) powdered feeds produce as high yields from pond culture as pelleted feeds, without the added expense of pelleting. Whilst the above findings may apply to tilapia culture in ponds and pens, they do not apply to cage culture. Losses of feed from cages have frequently been observed and are due both to passive water currents as well as to currents induced by the fish during feeding (Collins, 1971; Loyacano and Smith, 1976; Hoelzl and Vens Cappell, 1980; Penczak, 1982; Phillips *et al*., 1983).

Oreochromis niloticus feed on large variety of natural feed organisms found in fertilized ponds (Binh *et al.,* 2006). However, supplementary feeding in Tilapia culture is important to get good growth performance and to increase yield. According to Dikel *et al.,* (2005) supplementary feed resulted in higher yields and growth rates as compared to the controlling cages. According to Khattab *et al.,* (2004), the feed should be rich in protein, carbohydrate and fats, and should also contain growth promoting substances like vitamins and minerals. The feeds can be prepared from locally available feed items. According to Diana *et al.,* (2004) among the feeds employed in Asia and Africa are rice bran, broken rice, oil cakes, flour, corn meal, kitchen refuse, rotten fruit, coffee pulp, and a variety of aquatic and terrestrial plant. As a principle the added feed should aim in compensating the scarce nutrition in natural feed.

Focus should be given to eliminate or reduce feed loss, for different techniques must be used, like automatic feeder or feeding ring. According to Yi *et al.,* (1996) feeding rings are usually used in smaller cages to retain sinking feed and prevent wastage. The rings consist of small-mesh (3 mm or less) screens suspended from the cover to a depth of 152 to 457 mm. Feeding rings that are too small will allow the more aggressive fish to control access to the feed. Feeding rings should enclose only a portion of the surface area because rings surrounding the entire cage perimeter may reduce water movement through the cage. However, it should be reminded that any high quality that floats could be used in cage culture (Khattab *et al.,* 2004) Feed may be also lost due to wild fish competitions. Wild fish have been observed in comparatively high densities in the immediate vicinity of fish cages (Collins, 1971; Eley *et al.*, 1972; Loyocano and Smith, 1976; Hays, 1980). Fish can learn to come to a feeding station in response to an acoustic signal, and it may be that the feeding response of the enclosed fishes acts as a signal to the wild fish that food is available(Phillips1982; 1983)

Research is needed for tilapia nutrition, not only to determine what feeds are best but also what rate of feeding are most effective in accordance with the type and abundance of natural feed available. According to Chapman (2006) *Oreochromis niloticus* grew well at 2% but best at 3% feeding rate, using a mixture of 35% peanut meal, 35% soybean meal, 20% ground beef liver, 15% fish meal. Growth of *Oreochromis niloticus* improved in each increment of feed. Feed conversion rate were best at 2% and 1% respectively (Bardach *et al.,* 1972). In this study it is assume that 2% of body weight feed is considered as optimal amount.

The composition of supplementary was prepared with the combined mash dry weight of 60% mill sweepings, 20% crushed cottonseed and 20% pea flour, which contains 40% carbohydrate, 9% fat and 20% protein. The correct amount of feed must be weighed daily. Feeding rate tables or programs are required to make periodic increments in the daily ration. Feeding adjustments can be made daily, weekly or every 2 weeks (Cruz, 1997). The fish should be sampled every 4 to 6 weeks to determine their average weight and the correct feeding rate for calculating adjustments in the daily ration.

Fish productivity is strongly associated with primary production and algal biomass. According to Aquino (1982), Sampaloc Lake in the Philippines was related both to gross primary production and to visibility (i.e. related to algal biomass). The primary productivity of Lake Babogaya is lower compare with other lakes of Ethiopia. The chlorophyll “a” concentration of 29-33 μl^{-1} in Lake Babogaya (Zinabu Gebremariam, 1994) and in Lake Hora 28 - 49μl^{-1} (Zinabu Gebremariam and Taylor, 1997) confirms the lesser productivity of the Lake.

For the deeper lakes like Babogaya, the thermal stratification show significant biodynamic change. The spatial distribution of biodynamic especially the vertical distributions of phytoplankton have strong effect on natural feed consumption potential of caged fish. Because the cage restricts the free movement of the caged fish to feed on natural feed exhaustively. According to Yeshimebet (2006) phytoplankton biomass varied in time in the months of March to June the concentration of Chlorophyll a (which is an indicator of phytoplankton biomass) was higher at the depth of 1-2 meter. According to Denbere Belay (2007) because of higher euphotic depth measurement about 7 meters, there is a tendency of increasing density of zooplankton towards the metalimnetic region.

In fish farming practices, stocking density is considered as one of the important factors that affect fish growth, feed utilization and the gross fish yield (Liu and Chang, 1992). In tilapia, experiments on the effect of stocking density have been conducted on different fish sizes including fry and juveniles (El-Sayed, 2002), sub-adults (D’Silva and Maughan, 1995) and large tilapia (Yi, Lin and Diana, 1996). Studies were also conducted using different culture systems such as tanks (Bailey *et al.,* 2000), ponds (Diana *et al.,* 2004) and net cages (Cruz and Ridha, 1991; Yi *et al.,* 1996; Ouattara *et al*., 2003).

According to Diana *et al*. (2004) the lower growth performance of higher stocking density; Yi and Lin (2001), increased fish biomass of Nile tilapia in cages had a significant negative effect on the final MWT; Diana *et al*. (2004), that sex-reversed Nile tilapia stocked in ponds at a low density of 3, fish/m^2 had higher growth than at a higher density of 6 and 9 fish/m^2.

In general, different results demonstrate an inverse relationship between stocking density and growth. According to Ouattara *et al.*, (2003), this could have been caused by voluntary appetite suppression, more expenditure of energy competition for feed and living space and intense antagonistic behavioral interaction increases stress. But according to Khattab *et al.,* (2004) that fish intensification by increasing stocking density was a suitable method to increase fish yield and used to overcome the problem of land shortage. Therefore, studies on stocking density and feeding are fertile areas of research, in countries like Ethiopia where there exists no cage culture practice. This preliminary research was designed to evaluate stocking density and feeding on growth performance of *O. niloticus* in Lake Babogaya.

2. LITRATURE REVIEW

Aquaculture is defined as rearing aquatic organism under more or less controlled conditions (Stickney, 1979). It is the aquatic counterpart of agriculture (Reay, 1979). According to FAO (1988), aquaculture is also stock enhancement (enhanced fisheries or culture-based fisheries). Aquaculture is the cultivation of aquatic organisms such as fish, shellfish, algae and other aquatic plants and animals. Cage culture involves the rearing of animals in a structure enclosed on all or but the top sides by wooden, mesh or net screens, whilst maintaining a free movement of water.

The use of cages for rearing fish and other aquatic animals is thought to have begun in China nearly one thousand years ago (Beveridge and Stewart, 2002). The first documented cages were used in Southeast Asia in the 1800s as a means of growing fish for feed and were made of bamboo. These early cages were constructed of wood or bamboo, and the fish were fed trash fish and feed scraps, modern cage culture began in the 1950^{s} with the advent of synthetic materials for cage construction. In Europe and America, cage began to be widely used in the 1960's in the emerging trout and catfish farming industries (Beveridge and Stewart, 2002). Many countries in Southeast Asia and Europe use cages to grow fish, in the U.S., cage culture is mainly limited to freshwater ponds and lakes; however, in other countries, fish are grown in freshwater as well as in the ocean. Large cages, called net pens, are placed into the ocean and used to grow marine fish.

Culture of fish in cages was attempted in Africa in Lake Victoria, Tanzania; and in Lake Kainji, Nigeria (Agbebi and Fagbermo, 2006). Successful culture of *O. niloticus* in cages was demonstrated in Lake Kossou (Ivory Coast) in recent years, with average production of up to 17 kg/m^3 of cage per month, with stocking densities of 50 - 150 fish/m^3 and feeding with locally prepared diets (Quattara *et al*., 2003).

Tilapia cage culture involves growing of tilapia in cages made of nylon nettings and bamboo frames that are floated, submerged or fixed at the bottom. It utilizes bodies of water such as dams, rivers, lakes, bays, reservoirs and coves. Cage production of fish is possible for producers who are interested in utilizing ponds that may be unsuitable for typical pond aquaculture; however, extreme care and hard work is required to produce fish in cages. In cage culture, landownership is not required, investments are generally small, cage culture system is relatively cheap, easy to construct and use existing water bodies (Beveridge, 1984).

Comparisons of energy and production efficiencies of aquaculture confirm that aquaculture is the efficient mass producer of animal proteins for a crowded, coastal planet (Costa-Pierce, 2002). Production efficiencies of edible mass for aquaculture range from 2.5 to 4.5 kg dry feed/kg edible mass compared with 3.0 to 17.4 for conventional terrestrial animal production systems (Costa-Pierce, 2002). Aquaculture also has a comparable advantage in water efficiency, since a comparatively smaller amount of water is required. For example, catfish ponds managed using multiple harvest strategies that use 1.50 m^3 of water per 1 kg of product while conventional soybean production takes 1.63 m^3 of water to produce 1 kg of product (Costa-Pierce, 2002).

Cage culture is one of the effective technologies used in raising tilapia. Tilapia is widely used as fish stock because it grows fast, takes only four months for fingerlings to reach an average weight of 100 grams. According to Beverage and Haylor (1998), table sizes of 80 – 120 gm and FAO (1997) commercial-size tilapia of 200-250 gm weight could be produced in four to five months' time. Cage culture encourages production by decreasing reproduction cost. Though the culture of all-male tilapia would be advantageous to increase the production, even un segregated population would do well in cages, as breeding will be greatly reduced and even when breeding takes place, there is little likelihood of survival of fry in the cages (Beverage and Haylor, 1998).

Cage components consist of a frame, mesh or netting, feeding ring, lid, and flotation. The frame of the cage can be constructed from wood (preferably redwood or cypress), iron, steel (galvanized), aluminum, fiberglass, or polyvinyl chloride (PVC) (Fitzsimmons, 2004). Similarly, bolts or other fasteners used to construct the cage should be of rust-resistant materials. The design of fish cages is determined by the behavior of the culture species (Rakocy and McGinty, 2005). For *Tilapia niloticus*, which is less active and sometimes territorial in habitat, the shape of the cage does not affect its mobility. In this case, design rectangular cages for easy assemblage and management (Alferez, 1977). Cage size depends on the size of the pond, the availability of aeration, and the method of harvest. Therefore, cage size may vary from 1 to more than 1,000 cubic meters. As cage size increases, costs per unit volume decrease, but production per unit volume also decreases, resulting from a reduction in the rate of water exchange (Eng and Tech, 2002).

Mesh or netting materials that can be used include plastic coated welded wire, solid plastic mesh, and nylon netting (knotted or knotless). Mesh size has a significant impact on production; a larger mesh size can be used if large fingerlings are stocked. According to Dikel *et al*., (2005) mesh size should be no smaller than 12.5 mm to assure good water circulation through the cage while holding relatively small fingerlings (100 – 130 mm) at the start of the production cycle; but mesh size of 20 mm is the preferred (Bocek, 1996). These mesh sizes provide adequate open space for good water circulation through the cage to renew the oxygen supply and remove waste. The use of large mesh size requires larger fingerling size to prevent gill entanglement or escape. For example, a 20 mm plastic mesh will retain 9-gram tilapia fingerlings while a 25 mm mesh requires a fingerling weighing at least 25 grams with plastic netting and 50 to 70 grams with nylon netting (Silva *et al.,* 2000). Larger mesh size facilitates the entry of wild fish into the cage and these fish will grow too large to swim out of the cage, but they do not grow large enough to reach marketable size, thereby representing a waste of feed. Cages should be equipped with covers to prevent fish losses from jumping or from bird predation. Covers are often eliminated on large nylon cages if the top edges of the cage walls are supported 30 to 60 cm above the water surface (McGinty, 1991).

Location of the cage in the water body can be critical to success of cage production; two factors to consider in cage placement are access to the cage under almost any weather condition for daily feeding, cage management and good water current circulation. Water current circulation throughout the area gives a continuous flushing of water inside the cages, making dissolved oxygen highly available to fish and wash out metabolites. According to Coche (1982), good water circulation in the cage is more critical to success. Cage culture requires at least 60 cm depth of water under the cage for waste to get out of the cage (Bardach *et al.,* 1972).

The ideal range of dissolved oxygen concentration on the water must be at least 3 ppm (parts per million) (Lin and Diana, 1995). According to Dikel *et al*., (2005) optimal fish growth occurs where oxygen levels are maintained above 6 ppm for cold water species and above 5 ppm for warm water species. Temperature is one factor that plays a major role in the growth of the fish stock. The suggested range of temperature by Popma and Masser (1999) is from 20°C to 30°C for normal growth and the lethal temperature levels are below 12°C and above 42°C. The pH range between 6.5 and 9.0 suitable for fish culture, but does best with pH range of 6.8 to 8.0 (Coche, 1982).

Tilapia tolerates adverse water quality and other stressors better than most other commercial aquaculture species. Because of stress and environmental quality play such important roles in the disease process, tilapia is labeled as being very "disease-resistant." This basically means that in the presence of pathogens, tilapias are the last to break with disease. However, all the indications are that tilapia is no longer a disease-resistant species. There are a number of bacterial and viral diseases and some of them are devastating. Among the parasites found on tilapia are Tricodina, Chilodon, and Saprolegnia. At least in marginal climates, tilapia would be subjected to ichthyophthiriasis, the precondition for which is usually chilling.

Tilapia also acts as carriers of catarrhal enteritis the clinically significant tilapia pathogens fall into the general categories of viruses, bacteria and protozoa; Mycotic (fungal) diseases are only significant if the tilapias are under constant stress. (Bardach *et al.*, 1972). In certain systems, metazoan ecto-parasites and endo-parasites cause problems, but do not significantly affect the tilapia industry. The occurrence of disease outbreaks in fish farming is usually associated with bad husbandry, since the disease-causing organisms are often ubiquitous and causes few problems until the fish are stressed through inadequate dietary or environmental conditions (Wedemeyer, 1970; Snieszko, 1974; Roberts and Shepherd, 1974; Shepherd, 1978).

The effect of disease is more serious in cage-cultured fish than in wild fish populations. In wild fish populations, mass mortalities are rare and linked to external stress factors, since the fish and the disease causing organisms are usually in a state of balance. For example, although many parasitic infections are known in wild tilapias, there is little evidence of clinical effects and thus it would seem that the presence of parasites is a normal occurrence of little significance (Roberts and Sommerville, 1982).

The advantages for using cage culture system include:

- Reduces the cost of reproduction
- Higher yield per acre than other crops
- Lower production costs per kilogram than any other meat protein
- Compliments rather than competes with agriculture for land and water use and on a year-round basis
- Cage culture increases pond production 100% as the fish loose in the pond eat wasted feed.
- Receive a premium price for cage-grown fish; Customers are able to observe fishes before buying
- Produce quality fish for a society who demands high quality, cage grown fish are easily observed examined and treated, therefore cost is less to treat fish confined in cages rather than loose in pond
- Eliminates expense of draining ponds and seining to harvest fish, whether it is a large or small order and keeps predators from eating fish and feed

The limitations for using cage culture include:

- Feed losses possible through cage walls
- Sometimes important interference from the natural fish population, i.e. small fish enter cages and compete for feed
- Natural fish populations act as a potential reservoir of disease and increased difficulties of disease and parasite treatment
- Increased labor costs for handling, stocking, feeding and maintenance
- Higher risks of theft
- Interference with public services such as recreation and transportation

3. OBJECTIVE

3.1.General objective

To enhance cage culture practice that would contribute to increase fish production and poverty alleviation in Ethiopia.

3.2.Specific objectives

The specific objectives are to:

- assess the effect of different stocking densities on growth performance,
- evaluate the final yield of different stocking densities,
- compare the effect of natural and supplementary feeding on the growth performance,

- The results from this study will provide basic information upon which rational exploitation and management of cage culture activities will be based.
- They could also provide base-line information for future aquaculture development in the country and for further research.

4. DESCRIPTION OF THE STUDY LAKE

4.1. Lake Babogaya (Bishoftu-Guda)

Lake Bishoftu-Guda is one of the Bishoftu explosion crater lakes found in and around Debre-Zeyit (formerly known as Bishoftu), which is a town located 47 km South East of Addis Ababa.

Lake Bishoftu-Guda is a small, roughly circular and fairly deep lake found at an altitude of 1870 m and at about 9^0N and 39^0E latitude (Prosser, *et al.,* 1968; Wood, *et al*., 1984). The Lake has a surface area of 0.58 Km^2 with 71 m maximum depth, 38 m mean depth and with water volume 0.022 Km^3, (Prosser *et al*., 1968). It is a closed system, surrounded by very steep and rocky hills. The vertical distance from the lake's surface to the crater rim is 20 m and affords moderate protection from wind (Baxter, 2002). The lake is fed primarily by precipitation falling directly on its surface and run-off from its small catchment's area (Prosser *et al*., 1968), which was formed from volcanic rocks of basalt (Mohr, 1961).

Previous limnological studies made on Lake Bishoftu-Guda described its bathymetry, water chemistry (Prosser *et al*., 1968; Wood et al., 1984; Rippey and Wood, 1985; Zinabu Gebre-Mariam, 1994; Baxter, 2002; Zinabu Gebre-Mariam *et al*., 2002), thermally stratified and mixing (Baxter and Wood, 1965; Baxter *et al*., 1965; Wood *et al*., 1976) chlorophyll a and phytoplankton, (Wood and Talling, 1988; Zinabu Gebre-Mariam, 1994) bacterial abundance, (Zinabu Gebre-Mariam and Taylor, 1997) and zooplankton associations (Green, 1986).

The lake's region is characterized by moderate rainfall, varying around 850 mm per annum (Rippey and Wood, 1985), high incident solar radiation and low relative humidity. The lake has two rainy periods, the minor one extending roughly from February to April and the major one beginning in June and ending in September.

The temperature of its surface water was frequently found to be about 22^0C with a maximum of 24.5°C and a minimum of 19.2°C, while the bottom temperature was almost constant

19.2^{0}C-19.4^{0}C (Wood *et al.,* 1976). (Baxter *et al. 1965* and Wood *et al.* 1976; 1984) have shown the frequent occurrence of pronounced and deep-seated thermal stratification, with a consequent stratification of various chemicals in Lake Bishoftu-Guda.

The salinity of the water is 0.928 (ppt) with Alkalinity of 10.80 (Mg per Liter) and pH of 9.20 (Wood and Talling 1988). Lake Bishoftu-Guda is a dilute lake with Na^+ as the dominant cation and carbonate-bicarbonate as the dominant anion. The lake water is alkaline, with the erosion of basaltic and hyper-alkaline rocks surrounding the lake playing an important role in increasing the alkalinity of the water.

The phytoplankton community is dominated by blue-green algae, particularly *Microcystis aeruginosa* (Wood and Talling, 1988), while the zooplankton is composed mainly of copepods [*Afrocyclops gibsoni* (Brady), *Lovenula africana* Daday] and rotifers [*Asplancha sieboldi* (Leydig), *Brachionus calyciflorus* Pallas and *Hexarthra jenkinae* (de Beachump) (Green, 1986). Cladocerea *Diaphanosoa eisu*m (Denbere, 2007). There is a small fishery based on *Tilapia* zilli, Nile tilapia and catfish (*Clarias gariepinus* B.).

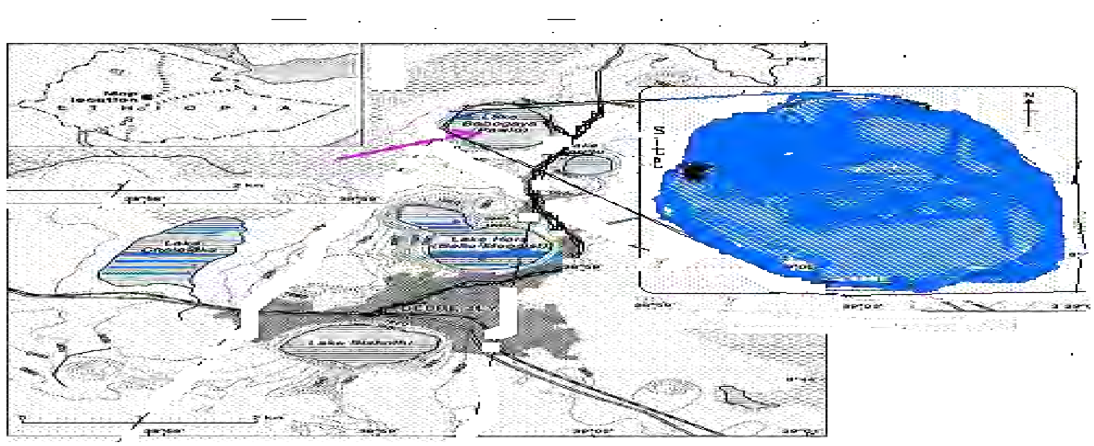

Figure 1: Location of Bishoftu-Guda (Babogaya), in relation to other Bishoftu crater lakes after Lamb (2001)

Table 1: Some morphological, physical and chemical characteristics of Lake Bishoftu-Guda (Babogaya)

Parameters	Values
Altitude (m)	1870[a]
Surface area (Km^2)	0.58[a]
Volume (Km^3)	0.022[a]
Maximum depth (m)	71 [b]
Mean depth (m)	38 [d]
Conductivity, K_{25} (μscm^{-1})	900[c]
Alkalinity (meq l^{-1})	10.2[b]
Ph	9.2[b]
Salinity (gl^{-1})	0.9[b]
$SiO\text{-}_2$ (meq l^{-1})	< .1[b]
Alkalinity (meq l^{-1})	10.80[b]
$Na+$ (meq l^{-1})	5.50[b]
Cl^- (meq l^{-1})	0.90[b]
Sum of cation (meq l^{-1})	11.7[b]
Sum of anions (meq l^{-1})	11.4[b]

Source ([a]Prosser, *et al*., 1968; Wood *et al.,* 1984) ([b] Yeshemebet Major, 2006; [c] Zinabu Gebre-Mariam, 1994; [d]Prosser *et al*., 1968)

4.2. Meteorological data

Temporal variations in mean monthly maximum and minimum air temperature, monthly rainfall and wind speed (2006 – 2007 data).of the lake region, were obtained from Ethiopian Institute of Agricultural Research (EIAR), Debre-Zeyit,

Mean monthly minimum air temperature ranges from 8.4 °C in November 2006 to 13 °C in June 2007, while the maximum mean monthly air temperature varied from 22 °C in September 2006 to 30.2 °C in March 2007. The average temperature ranged from 17 °C in December to 20.3 °C in June 2007. Monthly rainfall varied from 0.0 in November 2006 to 68 mm in June 2007. Wind speed range from 1.35 in September 2006 to 3.61 m/s, in March 2007.

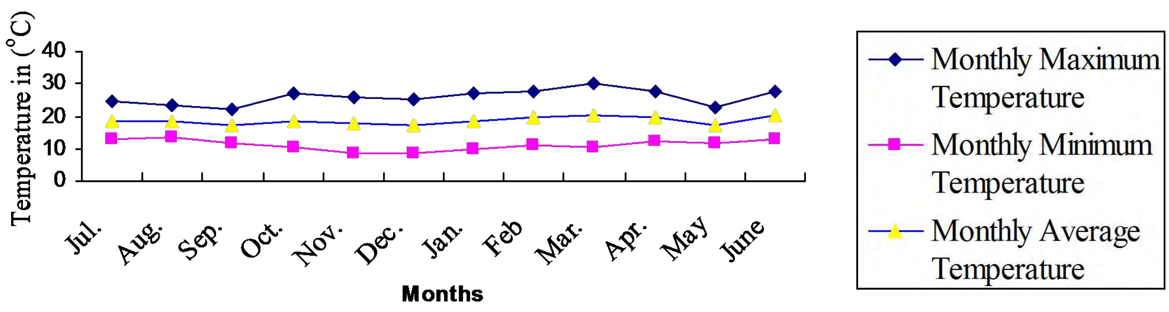

Figure 2: Annual monthly air temperature in °C, of the culture site (Source: EIAR, 2007).

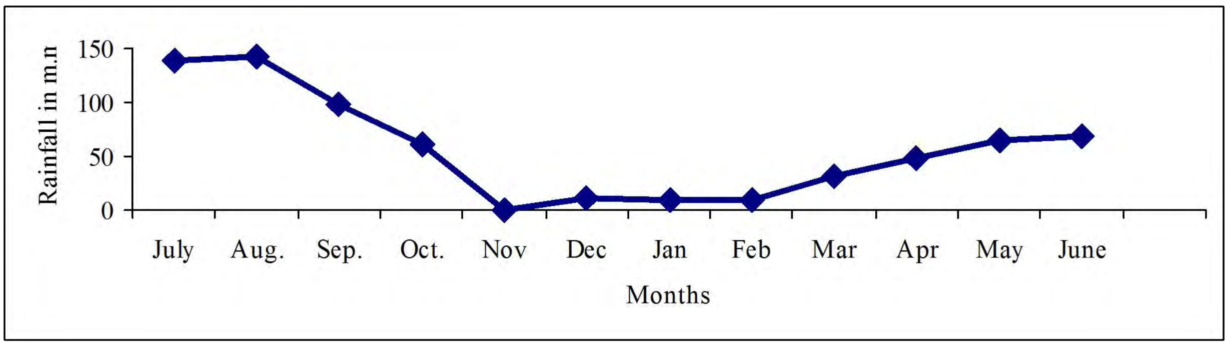

Figure 3: Annual monthly average rainfall in mm of the culture site (Source: EAIR, 2007).

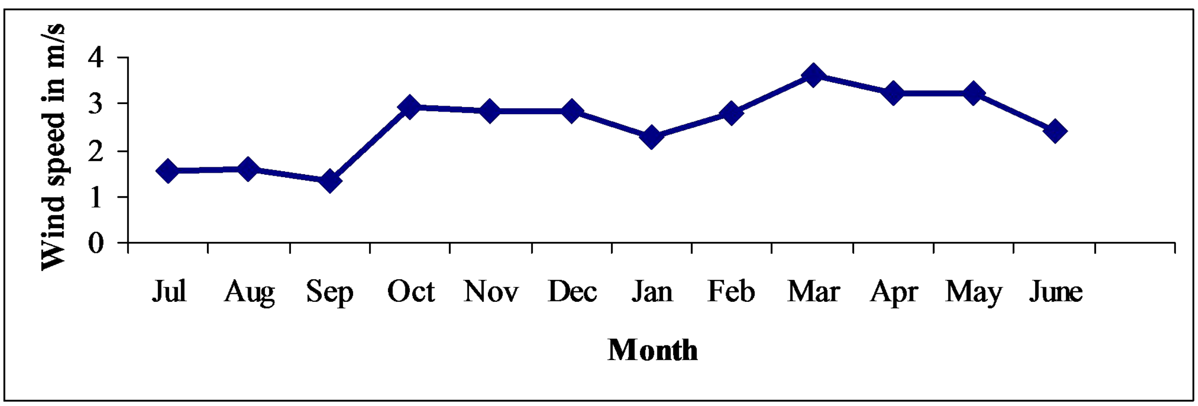

Figure 4: Annual monthly average wind speed m/s of the culture site (Source: EIAR, 2007).

5. MATERIALS AND METHODS

5.1. Jetty construction and placement

Jetty with fifteen meters long and one meter wide was constructed with local material at the selected site of 5 m off shore. The experimental cages were suspended at depth of 1½ -8 m of water under the cage. Treatment cages were laid ½ m apart from each other for easy waste removal and water circulation. The control stocks were suspended in separate place, contrary to wind direction to prevent them feeding uneaten feed from feed other treatments.

Figure 5: Picture showing the jetty construction and cage anchoring site

5.2. Structural design and construction of cages

Ten rectangular design cages with a volume of 1 m³ each, with feeding rings with 1⁄16 m² width and a mesh size of 0.32 cm were constructed, as suggested by (Alferez, 1977). The upper and the lower bottom were constructed with PVC frame and nylon (polythene) netting (with a mesh size of 1 cm² at the side and mesh size of 2 cm² at the top and bottom). These mesh sizes provide adequate open space for good water circulation through the cage to renew the oxygen supply and remove waste. The underlined PVC frames were perforated to allow water to enter into a tube and to enable it sink, but the upper PVC frames were sealed with PVC gum and rubbed with plaster at the joint to prevent the entrance of water into the tube and enable to float.

5.3. Source of Juveniles

The *Nile tilapia* juvenile fishes which had a weight range of 26 - 39 gm and size of 12 to 14 cm, were collected from the lake (Babogaya) by using beach seine hauls (with stretched mesh size of 80 mm). Because of lack of nursery at Sebeta Fishery and Other Aquatic Life Research Center the same cohort or a uniformly sized, weight and aged juveniles were not available. During transportation, the juvenile fishes had been kept in oxygenated water barrel until they were introduced into the cage.

5.4. Stocking

Nile tilapia juveniles with mean weight of 30 g and mean length of 12.13 cm were stocked on. 800 juvenile fishes (24 kg total weight) were stocked, with stocking density of (50, 75, 100 and 125 fish per m³) and control (50 fish per m³) with two replicates.

Table 2: Stocking density, initial mean weight and length of the stock

Treatment	Stocking density (fish per m³)	average weigh (gm)	average length (cm)
1	50	30.06±2.75	12.44±0.49
2	75	30.11±2.83	12.44±0.50
3	100	30.03±2.75	12.4±0.48
4	125	29.59±2.82	12.38±0.48
Control	50	30.06±2.75	12.46±0.51

5.5. Feed and feeding rate

The stocks were given 2% its weight of supplementary feed prepared locally with a composition of sweeping meal, crushed cottonseed and pea flour. Feed loss was prevented by making combined mash and using feeding try. The combined mash composition was prepared with dry weight of 60% mill sweepings, 20% crushed cottonseed and 20% pea flour. The composition contains 40% carbohydrate, 9% fat and 20% protein from the major feedstuff; (the details are given in Table 2 and 3). The fishes had also free access to the natural feed**.**

A supplementary feed at rate of 2% of the stock weight was given in each day, at two different times, half of the feed early in the morning at 8 am and the remaining half in the after noon at 4 pm as suggested by Chapman (2006). The feed was given by hand feeding method on feeding ring size of 0.0625 m^2 situated at the center of the cage, 30 to 40 cm depth. Feeding rate increases as the stocked fish weight increase. Feeding program was adjusted every two weeks based on their weight change. The feeding rate of the first 2 weeks of each month after sampling were adjusted based on the obtained sample data but the remaining 2 weeks of each month was adjusted based on expected weight gain.

Table 3: Percentage of carbohydrate, fat and protein found in each feed item

Feed Item	% Carbohydrate	% Fat	% Protein
Mill sweepings	58.0	14.0	12.5
Cotton Seed	29.6	18.8	22.8
Pea flour sweeping	64.8	1.4	20.1

As out lined by Bardach *et al.,* (1972)

Table 4: Composition of feed (%)

Feed composition	Carbohydrate (g)	Fat (g)	Protein (g)
Mill sweepings 600 g. (60%)	348 g	84 g	75 g
Cotton Seed 200 g. (20%)	59.2 g	37.6 g	45.6 g
Pea flour sweeping 200 g. (20%)	129.6 g	2.8 g	40.2 g
Total = 1 Kg	536.8 g (40%)	124.4 g (9%)	160.8 g (20%)

N.B. Weight and percent of the thee major feedstuff = 822 gm or 82.2%

The expected weight change was estimated based on the obtained data of feed conversion ratio (FCR) and weight of feed consumed by each stock at the sampling time. This is done as follow:

Amount of daily feed = Total weight of the stock * 2%, but the expected total weight of the stock (after 2 weeks of sampling) were calculated as

$$FCR = \frac{\text{Feed wt. consumed}}{\text{Wt. Gain}}, \text{ Therefore, Expected Wt. Gain} = \frac{\text{Feed Wt}}{\text{FCR}}$$

Total weight of the stock (after 2 weeks) = the previous weight + Expected Weight Gain

5.6. Physicochemical parameters

At the beginning, middle and end of the experiment measurements of the following physical and chemical parameters were made:

- Dissolved oxygen, pH and temperature of surface water were determined continually starting from stocking time and in each successive sampling month with an oxygen meter (YSI model 58), with a portable and digital pH meter (Hanna 9143) and thermometer, respectively.

- Secchi depth ($\mathbf{Z_{SD}}$) values were estimated with a standard Secchi disc to determine Lake's transparency (vertical visibility) and thus the approximate euphotic depth ($\mathbf{Z_{eu}}$)

5.7. Identification and estimation of phytoplankton and zooplankton species

5.7.1. Estimating the biomass of phytoplankton

Samples were collected with smaller mesh size net of approximately 20 micrometer and preserved with Lugol's iodine. Preserved samples were used for taxonomic analysis of phytoplankton and estimation of their abundance, focus was given to the dominant natural feed for *O. niloticus* in the lake. This was done by comparing with results of gut analysis; the higher proportion in number or volume considered as the major natural feeds (Appendix 2).

5.7.2. Estimating the biomass of zooplankton

Samples were collected by net with mesh size of 64 micrometer and 30 cm mouth diameter. The samples were preserved with 5% formaldehyde solution, and used for taxonomic analysis and estimation of the abundance of zooplankton.

For counting, 20-25 ml of sub sample was taken using pipette with wider mouth and poured into a girded Petri dish, after allowing the sample to settle and checking the uniform distribution throughout the girded Petri dish.

For estimating number of zooplankton, three girds were counted out of the total fifteen girds. Counting was done with stereoscope microscope (magnification of 50 X) and focus was given only to the dominant natural feed species by comparing with gut analysis result and with the result obtained by Denbere Belay (2007). Zooplankton species were identified using standard methods and references, mainly keys in Vogit and Koste, (1978); Van de Velde (1984); Defay (1988) and Fernando (1988).

5.8. Gut analysis

Gut analysis was done by taking representative samples fish from each pair of replicates of each stocking density. The same sample specimens were also used for disease inspection. The extracted stomach content was preserved in 5% formaldehyde solution. Larger feed items were identified by eye, whereas small sized zooplankton feed items were examined using a WILD type stereoscope with magnification of 50X. Each feed item was identified to the lowest taxon possible using description, illustrations and keys in the literature (Macan, 1959; Borror and Delong, 1964; Harding and Smith, 1974; Edington and Hildrew, 1981; Defaye, 1988). Very small feed items, such as phytoplankton, were examined at high magnifications (100X to 400X) under a compound research microscope.

The relative importance and contribution of each feed item to the diet of *O. niloticus* was determined by using the frequency of occurrence method and percentage proportion of numbers i.e. numerical analysis (Hynes, 1950; Windell and Bowen, 1978; Hyslop, 1980) and relative volume proportion. Brief description of each method is given below.

To identify the major natural feed of the stock, gut analysis was done in each sampling month. The samples were taken in the morning between 8 – 11 am before supplementary feed was given and compared with the control stock gut analysis result. The gut content was highly concentrated, because of this; it was too difficult to identify each feed item and count properly with higher magnifications power compound microscope. To make clearly visible, solution with high power compound microscope, the 1ml of the crude stomach content was diluted with 29 ml water, which makes it easy to identify the stomach content. Then 1 ml of the diluted solution was taken by using pipette and poured into a girded slide. Only three girds were taken for estimating volume proportion or relative number proportions.

The total number or volume was calculated based on the relative proportion of numbers in the sample or estimated relative area proportion occupied by each feed item on the girded slide. Each item was counted whenever appropriate and a list of items found in the stomach content was prepared.

All number of feed items that were found in all stomachs was recorded, but focus was given to major feed items. Each major feed item was counted separately and its percentage proportion was calculated with the total number or volume. Both percent composition by number and the volume proportion was used to estimate the relative importance of the feed item. The minor numbered phytoplankton were counted as a group only for calculation of the relative proportion but were not identified. The total number of individuals of each feed item was then expressed as a percentage of all feed items (Bagenal and Tesch, 1978).

5.9. Duration of the experiment

The experimental fishes were stocked for 5 months (150 days) starting 7 of February to June 8/ 2007. Data of physical parameters of the lake and growth measuring parameters (MWT, DGR, SGR swell as FCR) of the stocks were collected during sampling times. The final data were collected during harvesting time.

5.10. Data collection and analysis

Mean Weight (MWT), Daily Growth Rate (DGR), Specific Growth Rate (SGR), defined as the percent increase in body weight per day and Mean Length (ML), Fulton Condition Factor (FCF) used to determine the well being of fish (Bagenal and Tesch, 1978), Length-Weight relation the relationship between total length and total weight was calculated using least square regression analysis by Bagenal and Tesch (1978) for both fed and non-fed stocks, Feed Conversion Ratio (FCR) for experimental group were evaluated every month for five months by taking 25% samples with replacement. Brief description of the methods is given below:

I. $$\text{MWT (gm)} = \frac{\text{Weight Total}}{\text{Number of Fish}}$$

II. $$\text{DGR (gm)} = \frac{\text{Total Weight Gain}}{\text{Number of fish X culture days}}$$

III. SGR =100 (ln Final Weight _ln Initial Weight) / Number of Culture Days.

IV. $$\text{FCR} = \frac{\text{Total Weight of Dry Feed Given}}{\text{Total Weight Gain}}$$

V. Total production = Natural Production + Production with Feeding; (natural production was determined from the control non-feed treatment).

VI. . $$\text{FCF (\%)} = \frac{TW}{TL^3} \times 100;$$

Where FCF- Fulton condition factor, TW; total weight in gram, TL - total length in cm.

VII. $TW = a^* TL^b$; Where TW - total weight in gm

TL - total length in cm, a and b are intercept and slope of the equation, respectively.

VIII. Initial and final numbers of the stocks were recorded and percent of survival rate was determined as, survival rate =100 (Final total fish number/Initial total fish number).

IX. Disease inspections took place in each sampling period by direct observation and by dissecting sample of the fish from the stocks, the same sample specimens were used for gut analysis.

X. The effects of feeding and stocking density on growth performance, survival and gross yield were determined using one-way analysis of variance (ANOVA) and (SPSS, 1999). All statistical tests at 5% significance level as indicated in Sokal and Rohlf (1981).

6. RESULT

6.1. Physico- chemical parameters

The four months recorded sampling result of water temperature, dissolved oxygen and three months Z_{SD}, and pH result of the station is presented in Table 4. The surface water temperature ranged from 19 °C in April, to a higher value of 27.4 °C in May (See Fig. 6). The recorded range of dissolved oxygen (DO) concentration of surface water at the site was between 6 mg l^{-1} in April to 6.8 mg l^{-1} in February. The Secchi depth (Z_{SD}), an estimator of lake transparency was higher than 3.2 m throughout the stocking period. The lake had pH values at the range of 8.91 and 9.12. The higher value was recorded in February and March and the lowest value was recorded in May.

Table 5: Physical parameters result at the culture site of Lake Bishoftu-Guda

Sampling date	Temperature (°C)	DO (mg l^{-1})	pH	Z_{SD} (m)	Euphotic depth (m)
February 7, 2007	22	6. 8	9.12	4	12
March 7, 2007	22	6.5	9.12	3.2	9.6
April 8, 2007	19	6		4.2	12.6
May 7, 2007	27.4	6.5	8.91		

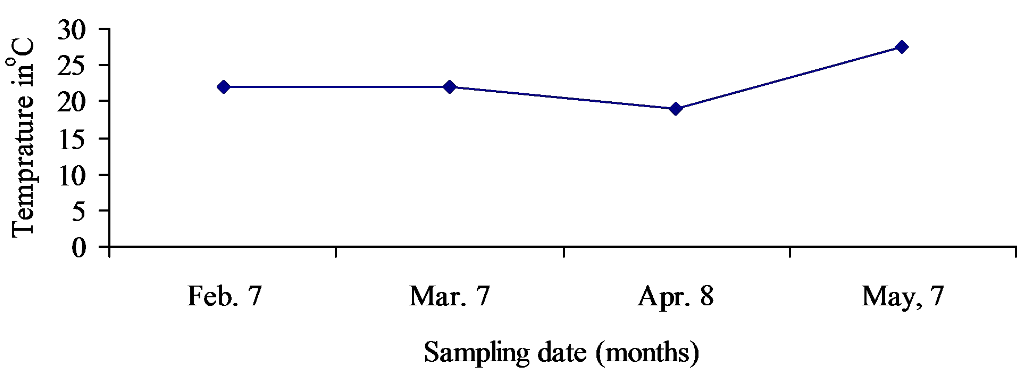

Figure 6: Surface water temperature result of culture site

6.2. Major natural feed at the culture site

From water analysis result *Dinoflagellates, Bacillariophyceae* and *Cyanophyceae* (haptophytes) were the common phytoplankton identified during the stocking periods. With some fluctuation of percentage proportion however, Dinoflagellates was the dominant in most of the time of stocking periods, especially after April.

The proportion of Dinoflagellates reached up to 57% in April and 35% in February and March. The percentage of Bacilariacaea (diatoms) more or less remained above 30% in average. However, the proportion value varied from 26.8% in April to 37% in February. The percentage proportion of *Microcystis aeruginosa* was below 21% average; but the maximum value reached up to 30% in March and the minimum value dropped to 13% in May (Appendix 3 and Fig. 7).

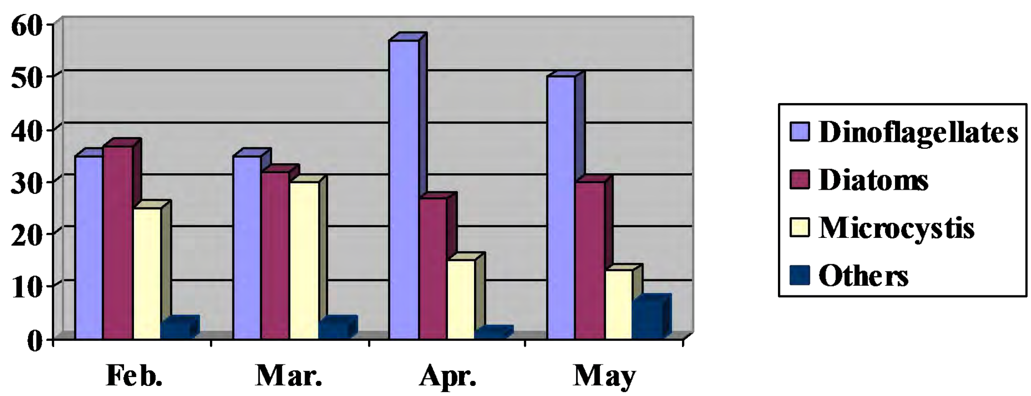

Figure 7: Proportion of major natural feed (from water analysis of the culture site).

Rotifers were the only zooplankton species that were identified in all water samples that were collected during the entire stocking period as well as in the gut analysis of specimens. From 4-meter depth of water samples, a maximum number of, ($4.1X\ 10^5$) ind/m^3 were obtained and minimum value of ($2.9X10^4$) ind/m^3 rotifers were obtained in March in June respectively. This number is less than the reported result of $9.9X10^5$ by Denbere Belay (2007). Copepods were identified in the water analysis, but not identified in gut analysis. The number of copepods obtained 750/lit in June from water analysis was much less than the reported result of

51941/litby Denbere Belay (2007) in the same month. However, cladocera were not identified both in the water analysis as well as in the gut analyses of the specimens (See Table 5).

Table 6: Identified zooplanktons of the culture site of Lake Bishoftu-Guda

	Feb	Mar	Apr	Jun
Rotifers	**893,839**	**4,117,411**	**33,746**	**29,391**
Copepods	**0**	**0**	**0**	**750**
Cladocera	**0**	**0**	**0**	**0**
Total	893,839	4,117,411	33,746	30,141

6.3. Gut contents.

The gut analysis of the stocked fish indicates three species of phytoplankton; blue green algae (*Microcystis aeruginosa)*, Bacileariacaea (diatoms), Dinoflagellates and rotifers from zooplanktons were the common natural feed. Among phytoplankton, *Microcystis aeruginosa* contributes the highest percentage composition and *Bacileariacaea* (diatoms) were the second and Dinoflagellates were third natural feed items throughout the stocking period. However; the percentage proportion value fluctuated to some extent in time. *Microcystis aeruginosa* decreased from 60% in February to 40% in May; Bacileariacaea (diatom) increased from 20% in February and March to 27% in June and dinoflagellates increased from 10% in February to 13% in May (Fig. 8 and Appendix 2).

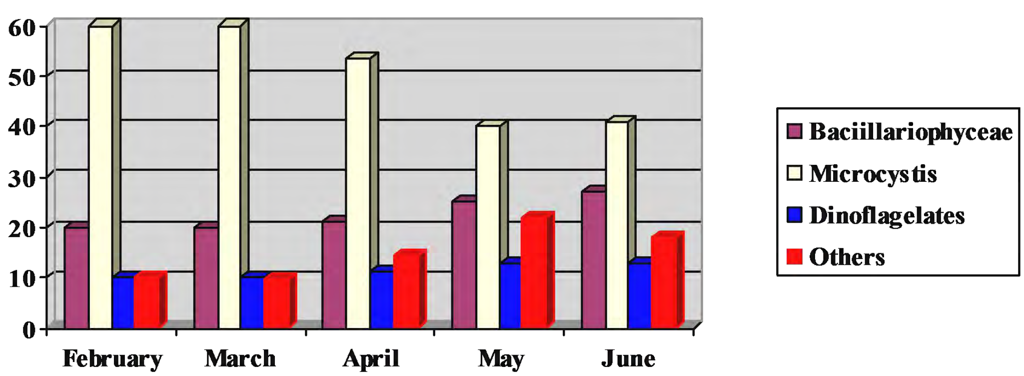

Figure 8: Volumetric proportion of major natural feed (in the gut part).

6.4. Growth performance

The data pertaining to process from stocking to harvesting period covering 150 days are presented in Table 8. The mean weights (MWT), daily growth weight (DGR), specific growth rate (SGR), Fulton condition factor and feed conversion ratio (FCR) were used as measuring parameters to analyze growth performance. The values of MWT, DGR and SGR decreased as the stocking time increased. However, in all growth parameters the lowest values were recorded, in May than in June. On the other hand, the FCR was increasing as the stocking density is increasing; the highest value was also recorded in May than in June especially for ST/100 and ST/125 stocks.

6.5. Mean weight

The average MWT values of all feed treatment stocks at different stocking densities in all months were greater than the control stocks (50 fish m^{-3}) (Table 7). The one-way ANOA test confirms a significant, ($p < 0.05$) negative relationship, ($r = -0.520$) in mean weight values and stocking density (G). The growth performance difference between control and the supplemental stock (50 fishes m^{-3}) is significant, ($p < 0.05$) and the relation is negative, $r = -0.982$ (Table 6 and 9).

The lowest stocking density ST/50 feed treatment group showed better growth performance in all parameters than the other higher stocking density feed treatment and control stocks. The minimum and maximum weight range of 80 to 180 gm fish was obtained from ST/50 feed treatment, with mean weight of 129.91± 3.35 gm. However, the maximum and mean weight value decreased as the stocking densities increased. The mean weight of lower stocking density (50 fish m^{-3}) feed higher by 62.45% than the mean weight value of (79.85 ± 2.21 gm).of the higher stocking density (125 fish m^{-3}). However, the difference decreased from 60.44% to 34.02% in ST/100 and in ST/75, respectively. The feed stock (50 fish m^{-3}) had 155.66% higher mean weight than the control stock (50 fish m^{-3}) with mean weight of 48.86 ± 3.09 gm. The mean weight value of control stock (50 fish m^{-3}) was less than the mean weight value of highest stock (125 fish m^{-3}) by 36.46% (Table 8).

Table 7: The T – test values and statistical relations of Feed and Control Stocks

X (Dependent Variable)	Y (Independent Variable)	R	R^2	P	Regression equation
MWT ST/50 (control)	MWT ST/50 feed	-0.982	0.97	P= 0.000	CI of MWT ST/50 feed = 103 – 70.1 MWT (control)
One way ANOA – test values for MWT, DGR, SGR Vs stocking density (G)					
Stoking Density	MWT	-0.520	0.44	0.017	
	DGR	-0.568	0.43	0.020	
	SGR	-0.200	0.11	0.678	

Linear increase in the mean body weight with time was observed in ST/50 and ST/75 feed treatments and the growth pattern of ST/100 and ST/125 is similar and less than ST/50 and ST/75. Moreover, the growth pattern of control stock shows negative trend after April (See Fig. 9 and Appendix 7).

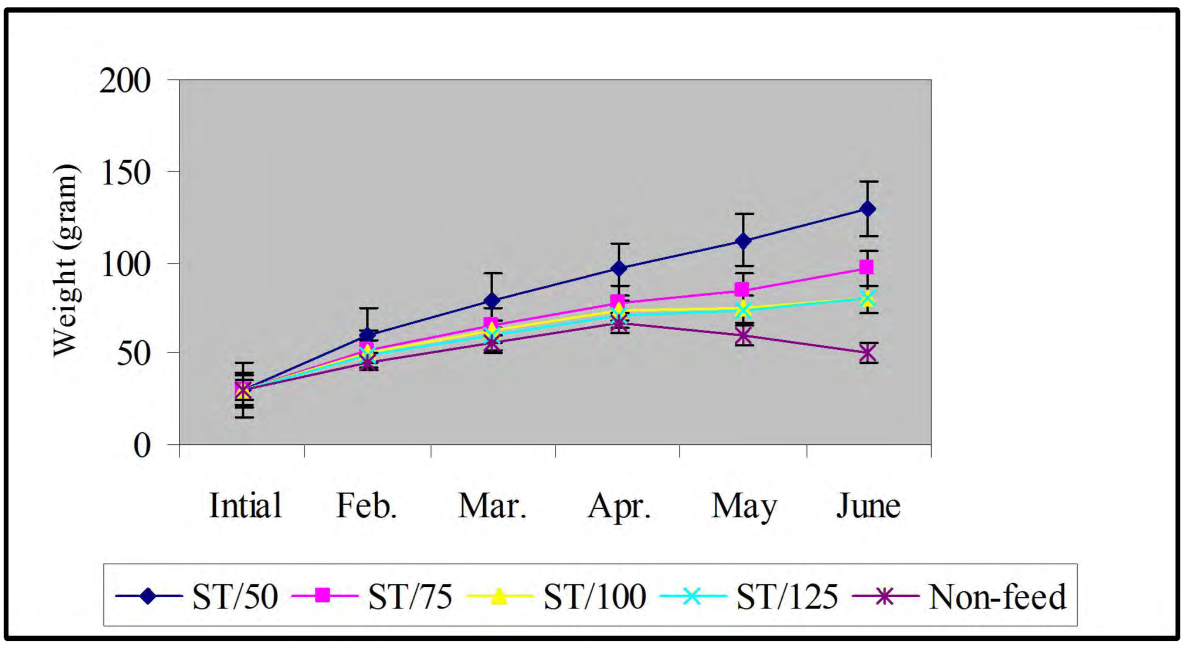

Figure 9: Growth pattern of different stocking densities and control stock

6.6. Daily growth rate

The one-way ANOVA - test result shows stocking densities has significant ($p < 0.05$) negative effect $r = -0.568$ on daily growth rate (DGR). The DGR values of all stocks decreased with increasing stocking densities and stocking period, but the DGR difference between ST/100 and ST/125 were not significant (Table 9). The growth pattern of ST/100 and ST/125 were similar and control stock ST/50 showed negative growth after April (Fig. 10).

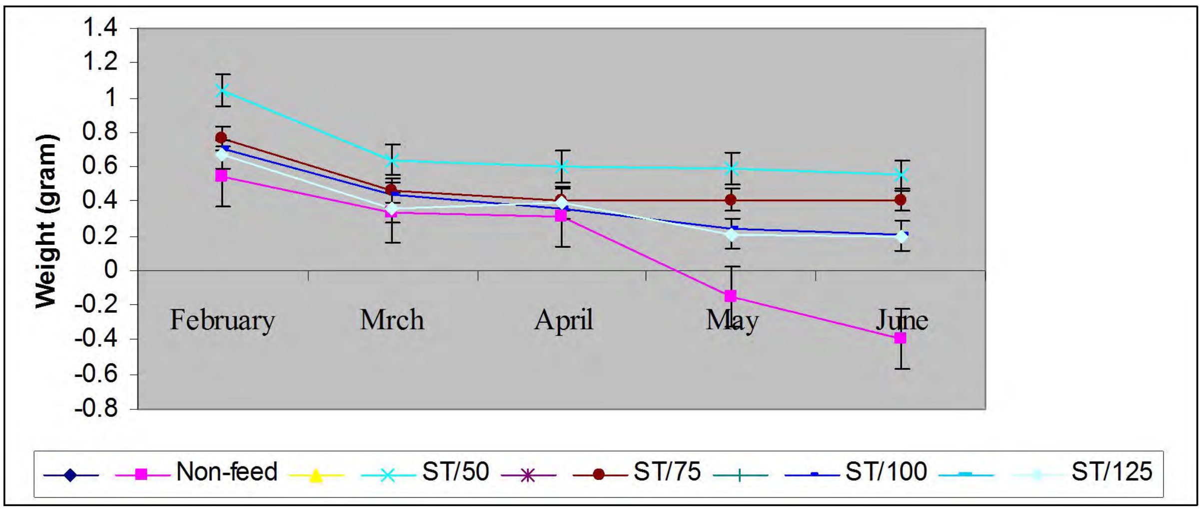

Figure 10: DGR change pattern of different months of stocks in relation to control

The higher average daily growth rate (0.67 g $fish^{-1} day^{-1}$) was seen in the lower stocking density ST/50 feed than the higher stocking density ST/125 with average daily growth rate of (0.33 g $fish^{-1}$ day^{-1}). This means the average daily growth rate decreased by 50.75% in higher stocking density (ST/125). However, this percentage difference in daily growth rate value decreases from 49.25% with ST/100 to 38.84% with ST/75. The highest average daily growth rate percentage difference 79.1% was seen between ST/50 feed and ST/50 control with average daily growth rate value of 0.14 g $fish^{-1}$ day^{-1} (Figure 11).

The difference between ST/50 feed and ST/50 non-feed is highly significant with Regression equation value $r^2 = 0.97$ and $p = 0.000$.

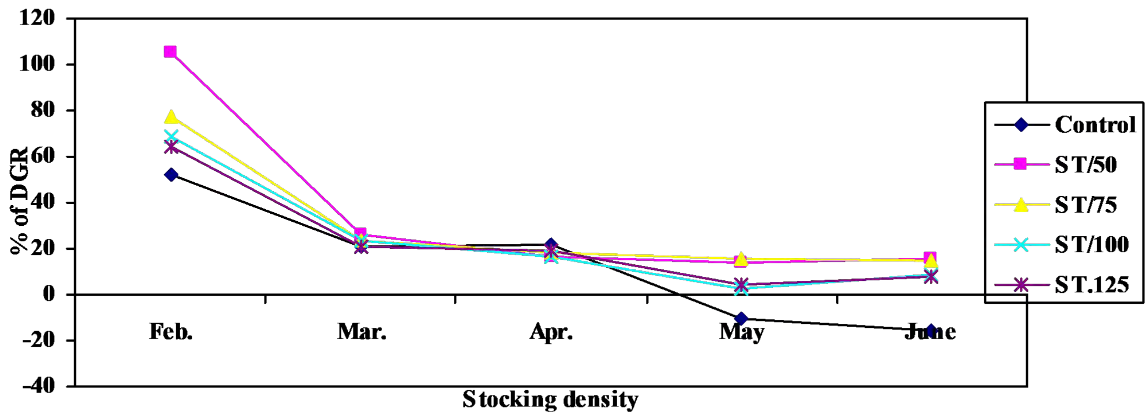

Figure 11: The monthly percentage DGR of different stocks

6.7. Specific growth rate

The SGR have inverse relationship with stocking density, but the relationship of SGR and FCR with stocking density was not significant ($p > 0.05$). The range of 65 – 98 % day$-^{1}$ SGR were obtained in higher and the lower stocking density ST/125 and ST/50 feed treatment respectively, and the lowest average value of 35% day $^{-1}$ was from the control stock (ST/50) (Table 8). Like other growth measuring parameters, MWT and DGR, the SGR value dropped in May and June (Figure 12), but the T-test value indicates that the relation between SGR and stocking density is not significant ($p > 0.05$) (Table 6).

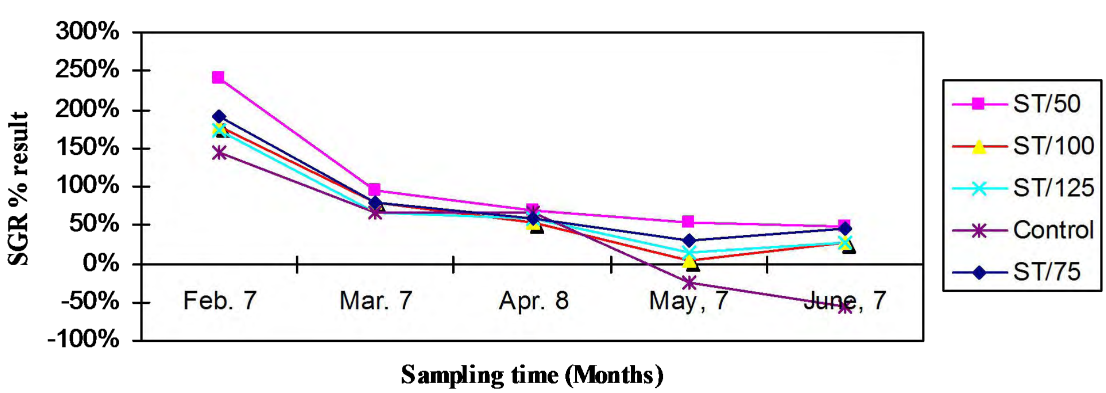

Figure 12: Monthly SGR of different stocks in relation to control

Table 8: Five-month summary data of different stocking densities

Stocking density	Month	MWT (gram)	TWT (gram)	∆WT (gram)	WFC (gram)	FCR	DGR (g/day)	SGR (%day⁻¹)	DFR ½	¾
ST/50	F	60.06	3003	1503	1122	0.75	1.04	2.39	30	48
	M	78.78	3939	936	2076	2.22	0.65	0.94	60	84
	A	96.1	4805	866	2445	2.82	0.60	0.69	79	90
	Ma	112.22	5611	806	2924	3.63	0.56	0.53	96	106
	J	129.72	6486	875	3510	4.1	0.58	0.48	112	122
ST/75	F	52.09	3907	1657	1683	1.02	0.76	1.9	45	72
	M	65.52	4914	1007	2584	2.57	0.46	0.79	78	101
	A	77.45	5809	895	3010	3.36	0.41	0.58	98	110
	Ma	84.55	6341	532	3518	6.61	0.41	0.30	116	127
	J	96.79	7259	918	3900	4.2	0.41	0.45	127	133
ST/100	F	50.22	5022	2022	2244	1.11	0.70	1.78	60	96
	M	63.07	6307	1285	3278	2.55	0.44	0.79	100	127
	A	73.43	7343	1036	3864	3.73	0.36	0.52	126	141
	Ma	74.56	7456	113	4431	39.2	0.24	0.05	147	159
	J	80.86	8086	630	4485	7.12	0.21	0.27	149	150
ST/125	F	49.41	6177	2427	2805	1.16	0.67	1.72	75	120
	M	59.85	7481	1304	4044	3.1	0.36	0.66	124	156
	A	71.08	8885	1404	4546	3.24	0.39	0.59	150	164
	Ma	73.88	9235	350	5386	15.39	0.21	0.13	178	194
	J	79.85	9981	746	5595	7.5	0.2	0.26	185	188
N-F/50	F	45.54	2277	777			0.54	1.44		
	M	55.23	2762	485			0.33	0.67		
	A	67.07	3354	592			0.41	0.67		
	Ma	60	3000	-212			-0.15	-0.24		
	J	50.74	2537	-463			-0.23	-0.56		

N.B: **MWT** mean weight; TWT, total weight; ∆**WT**, change in weight; **WFC**, weight of feed consumed
FCR, feed conversion ratio; **DGR**, daily growth rate**;** **SGR**, specific growth rate; **DFR**, daily feed rate
DFR ½, daily feed rate of the first 2 weeks; **DFR ¾** daily feed rate of the second 2 weeks
ST/, stocking density, the number indicates the number of stocked fishes; **N-F**, non-feed stocks
F, February; **M**, March; **A**, April; **Ma**, May; **J**, June

Table 9: Summary data of the stocks after five months

Parameter	ST/50	ST/75	ST/100	ST/125	Non-feed	Total
MWT (gm) (initial)	30.06±2.75	30.11±2.83	30.03±2.75	29.59±2.82	30.06±2.75	
ML (cm) (initial)	12.44±0.49	12.44±0.50	12.4±0.48	12.38±0.48	12.46±0.51	
Biomass (initial)/ cage	1.5 Kg	2.25 Kg	3.0 Kg	3.75 Kg	1.5 Kg	12 Kg
After Five Months						
MWT (g)	129.72±2.66^{a}	96.79±**1.59**^{b}	80.86±**1.27**^{c}	79.85±**1.07**^{d}	50.74± **1.4**^{e}	
Range (Wt. in g)	80-180	65-158	48-119	56-120	33-86	
% MWT < 80 g	0	11.13	57.9	47.5	90	
Waste product in Kg	0	0.81	4.68	4.74	2.29	12.25
ML (cm) (final)	19.12	17.56	16	16.47	15.85	
DGR (g fish^{-1} day^{-1})	0.67±**.078**^{a}	0.45 ± **.016**^{b}	0.3 4±**.078**^{c}	0.33±**.08512**^{c}	0.14±**.15524**^{d}	
SGR (% day^{-1})	0.98±**.35517**	0.78 ±**.2856**	0.66±**.30105**	0.65±**.28006**	0.35±**.35767**	
Total biomass in Kg per cage (m^{3})	6.49	7.26	8.09	9.98	2.54	34.37
Net product in Kg Per cage (m^{3})	4.99	5.0	5.09	6.23	1.04	22.35
Production Per Month	1 Kg/m³	1 Kg/m³	1.02 K g/m³	1.43 Kgm³	0.21 Kg/m³	0.89 Kg/m³
Net production With feed/ month	1 K g/m³	1 K g/m³	1.02 K g/m³	1.43 K/gm³	-	1.07 Kg/m³
Consumed feed Weight in Kg	24.15	29.4	36.61	44.75	-	135
FCR	2.42^{a}	2.93^{b}	3.6^{c}	3.59^{c}		3.17

In each raw mean with different superscripts are significantly different (ANOVA, $p < 0.05$)

6.8. Feed conversion ratio

The FCR value varies from 2.42, in the lower stocking density ST/50 to 3.6 and 3.59 for the higher stocking densities ST/100 and ST/125, respectively. Regardless of their stocking densities, the values of FCR were fluctuating in some months, for example lower FCR value, 3.24 was recorded in the higher stocking density of ST/125 than 3.36 in ST/75 in April. Another lower FCR value of 15.39 was recorded in ST/125 than 39.2 in ST/100 in May (Table 7). However, the general trend of FCR was increasing as stocking density and stocking period increased. But, the one way ANOVA - test value indicates the increment of effect of FCR with stoking density is not significant ($P > 0.05$) in group, but the increment in ST/75, 100 and 125 was significant (Appendix 4 and Table 8).

6.9. Production

The total net production includes production with natural and supplementary feed. A total of 68.69 Kg was harvested from 10 stocked cages, out of which 24 Kg is the initial weight. Therefore, the obtained net weight gain was 44690 g (44.69 Kg). The 42.62 Kg yield is contributed by feed treated 8 stocks (ST/50, ST/75, ST/100, and ST/125) and their replicates, while the remaining 2.07 Kg was obtained from control stocks of (ST/50) replicate.

The yield of 6.49 to 9.98 Kg $m-^{3}$ was obtained from the lower and the higher stocking density (50 and 125 fish $m-^{3}$), respectively. Additional yield of 3.49 Kg (53.78%) was obtained from the higher stocking density (125 fish $m-^{3}$) than the lower stocking density (50 fish $m-^{3}$). All of the harvested fishes from the lower stocking density (ST/50) were with in weight range of 80 and 180 gm. But in the higher stocking density (ST/125) up to 47.5% of the yield was less than 80 gm. The percentage of harvestable fishes less than 80 gm increased from 11.3% to 57.9% in ST/75 and ST/100 respectively

From ST/50 feed treatment the harvested fish size ranged from 80 -180 g with MWT of 129.72 g. but the harvested size continued to decrease as stocking densities increased. The range of 65 -158 g with MWT of 96.79 g harvested; from ST/75, the range of 48 - 119 g with MWT of 80.85 g was harvested; from ST/100 and range of 56 - 120 g with MWT of 79.85 g was harvested; from ST/125 and from the Control stock range of 33 - 86 g with MWT of 50.74 g was harvested and 90% of the yields were below 80 g (Table 8).

6.10. Length of different stocking densities during the sampling time

In ST/50 the harvested fish size ranged from 17 – 21 cm with average value of 19.17 cm, but in the higher stocking density ST/125, length range value of 15 – 19 cm with average value of 16.31 cm. The lowest length size range 14 – 17 was recorded from the control stock ST/50

(Table 9), but the T-test value p > 0.05 indicates stocking density and feed has no significant effect on length change (Appendix 5).

Table 10: Average length values of different stocking densities of sampling period

Sampling time	ST/50	ST/75	ST/100	ST/125	Non-feed
February	14.78	14.28	14.19	14.12	13.77
March	16.28	15.43	15.36	15.12	14.77
April	17.47	16.4	16.19	16	15.77
May	18.5	16.91	16.33	16.31	15.8
June	19.17	17.55	16	16.63	15.61

6.11. Fulton condition factor

The Fulton's condition factor for the stocking periods was calculated, and the result lies in the range of 1.55 and 1.85 for ST/50 feed and 1.31 to 1.92 for ST/50 non feed, 1.56 to 1.77 for ST/75, 1.57 to 1.72, for ST/100 and 1.56 to 1.72 for ST/ 125. The lower stock of ST/50 relatively has higher value of 1.85 in February than the higher stocking density value of 1.72 in the same month. The condition shows some decreasing order in all stocking densities up to May. Relatively a better value was seen in June than in May, especially in stock ST/50 and ST/75 (Figure 13). The lower range of Fulton condition value 1.44 to 1.56 was obtained from the control treatment. This value continually decreased and reached to the lowest value of 1.44 at end of June (Figure 14).

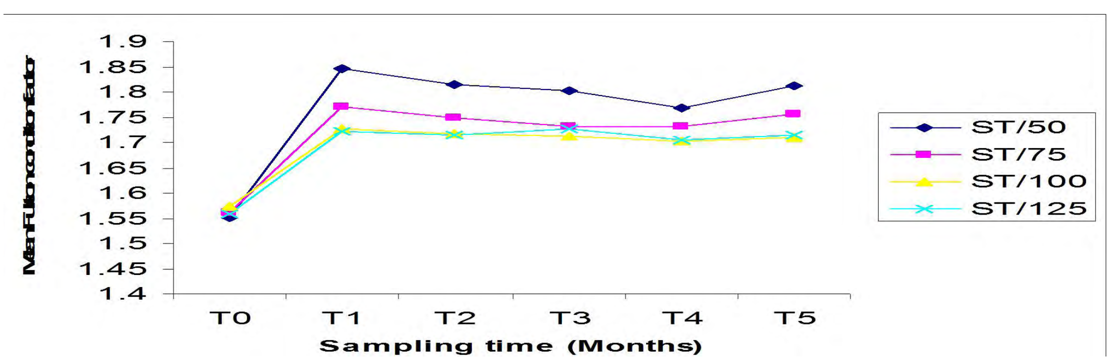

Figure 13: Fulton condition factor of the four feed treatments

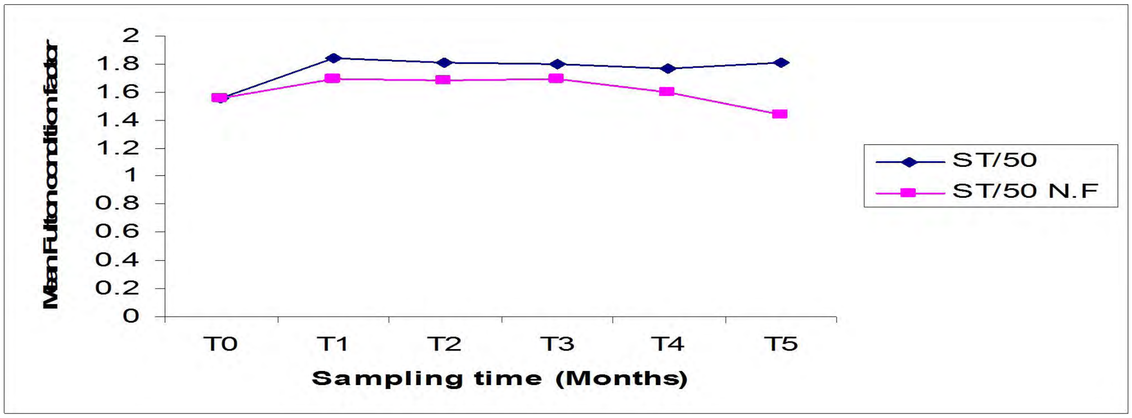

Figure 14: **Fulton condition factors of the ST/50 feed and ST/50 non-feed treatments**

6.12. Length - weigh relationship

The relationship between total length and total weight was curvilinear and statistically significant ($p < 0.05$).

Table 11: Length weight relationship of the stocked fishes after five months

Treatment	Equation	r^2	n	P
50 F	$TW = 0.0322TL^{2.8037}$	0.8459	40	0.000
75 F	$TW = 0.0211\ TL^{2.9352}$	0.8244	63	0.000
100 F	$TW = 0.0136\ TL^{3.0823}$	0.8579	77	0.000
125 F	$TW = 0.0357\ TL^{2.7382}$	0.8854	85	0.000
NF	$TW = 0.0017\ TL^{3.7927}$	0.8010	22	0.000

Table 12: Percentage of stocked and wild fishes (obtained from each stock at harvesting time)

	ST/50	ST/75	ST/100	ST/125	Control
Stocked fish	93	94.66	93.5	94.4	76
Wild fish	42	89.03	37	15	0

N. B the % of wild fish was computed based on their number proportion of wild fish to stocked fishes

The percentage of survival rate of feed stock raged from 93 and 94.66, but the lowest percentage of 76% was obtained from control stocks. Minimum percent of 15% to 89% of wild fishes were obtained from ST/25 and ST/75 feed stocks respectively, no significant number of wild fish were obtained from control stocks (Table 11).

7. Discussion

The physical parameters of Lake Bishoftu-Guda which is with water temperature of 19.2 °C in April to 27.4 °C in May favor tilapia production. As Popma and Masser (1999) suggested the temperature range between 20°C to 30°C is good for tilapia production, however temperature levels of below 12°C and above 42°C are lethal. The surface water temperature range recorded in this study is comparable with the reported result by Wood, *et al.* (1976). However, the maximum temperature, 27.4 °C, obtained in May in this study is greater than the maximum temperature (24.5 °C) reported by Wood, *et al.* (1976) whereas is comparable with maximum temperature (26.3 °C) reported by Yeshimebet (2006).

The recorded dissolved water oxygen concentration was between 6 mg l^{-1} and 6.8 mg l^{-1} in April and in February respectively, which is normal range for tilapia growth. The ideal range of dissolved oxygen concentration in the water must be at least 3 ppm (parts per million) (Lin and Diana, 1995). According to Dikel *et al*., (2005), optimal fish growth occurs where oxygen levels are maintained above 6 ppm for cold water species and above 5 ppm for warm water species. The obtained result for dissolved oxygen (DO) in this study is similar with that reported by Yeshimebet (2006). In most of the study periods the concentration of dissolved oxygen was below 8 mg l^{-1}. However, the maximum value of 6.8 mg l^{-1} in February in this study was lower than the reported value of 12.64 mg l^{-1} by Yeshimebet (2006). The pH value recorded between 8.91 in May and 9.12 in February is slightly greater than the recommended pH of 6.8 to 8 for better growth of tilapia and a range of 8.91 to 9.12 is the accepted pH value (Coche, 1982).

The higher value of secchi depth (Z_{SD}) at a range of 3.2 to 4.2 m indicates the higher euphotic (Zeu) depth of Lake Bishoftu-Guda. The euphotic (Zeu) depth ranged from 12 to 12.6 meter in February and in April respectively. The possible explanations for the higher euphotic (Zeu) depth of Lake Bishoftu-Guda might be due to low concentration of suspended solids and low phytoplankton biomass because of stratification and nutrient deficiency.

Results indicate that dinoflagellates were the dominant phytoplankton in Lake Bishoftu-Guda. This may be linked to the water column stability; the thermal stratification causes the decline of nutrients in the upper part of the water column. The concentration of nitrate-nitrogen remained at relatively low level throughout the period (Yeshimebet, 2006). This condition gives a competitive advantage to dinoflagellates over other algal group, because of their motility and ability of luxury consumption. The apparent success of these organisms is attributed to a number of features that improve their ability to compete with other phytoplankton (Pollingher, 1987; 1988), which include luxury consumption of phosphorus (Serruya and Berman, 1975), vertical migration that maximizes nutrient uptake from nutrient-replete hypolimnetic waters (Cullen and Horrigan, 1981; James *et al*., 1992).

The dominancy of Dinophyceae (dinoflagellates) and the fair proportion of Bacileariacaea (diatoms) obtained in this study is in agreement with the reported result by Yeshimebet (2006). The phytoplankton community of Lake Bishoftu-Guda was dominated by two classes of algae namely Dinophyceae (dinoflagellates) (annual mean = 52%) and Bacileariacaea (diatoms) (annual mean = 32%). After March, the percentage composition of phytoplankton (dinoflagellates) of the lake changed (Yeshimebet, 2006).

In the case of zooplankton abundance, commonly identified zooplankton in all stocking periods were rotifers, but copepods were also identified in June, but no cladocera were identified throughout the whole stocking period. The maximum number of rotifers, $4.1X\ 10^5$ ind/m^3, in March and copepods 750/lit in June obtained in this study was much less than the number of rotifers $9.9X10^5$ and 51941/lit reported by Denbere Belay (2007) in the same months. This may be because of the position shift made by the zooplanktons to escape from prey fish or to search for phytoplankton feed. According to Denbere Belay (2007), the major zooplanktons in Lake Babogaya were Rotifers, Copepods; Cladocerans did exhibit normal an evening ascent and morning descent movement pattern. Predator avoidance is commonly accepted as the ultimate reason for daily vertical migration (Lampert, 1993).

The gut analysis result indicates percentage composition of *Microcystis aeruginosa*, diatoms and dinoflagellates that were ranked 1st to 3rd, respectively, as the major natural feeds for the stocked Nile tilapia in Lake Bishoftu-Guda. Although the phytoplankton biodynamic composition of the lake was changed after March and dinoflagellates became more dominant while *Microcystis aeruginosa* were decreasing the feeding habit of the stocked fish was shifting to Bacileariacaea (*Nitzschia sp.*) to same extent than to dinoflagellates but with out changing the rank order. This confirms that *O. niloticus* is selective feeder and *Microcystis aeruginosa* and Bacileariacaea (*Nitzschia sp.*) were the most preferred natural feed than dinoflagellates.

The MWT value of the lower stocking density (ST/50) and the rest of higher stocking densities of (ST/75, ST/100, ST/125) feed treatments was moderately negative ($r = -0.520$) relationship with significant ($p < 0.05$) difference whereas, relationship between ST/50 feed and control treatments was strongly negative $r = -0.982$ and significant ($p < 0.05$) different. The average DGR (0.67 g/day) of the lower stocking density ST/50 feed treatment was greater than the DGR values of 0.45 g/day, 0.34 g/day, and 0.33 g/day for ST/75, ST/100 and ST/125, respectively.

The statistical one way ANOVA T- tests value indicates that stocking density has significant effect $p < 0.05$ on DGR and inversely related, $r = -0.568$. This indicates that growth performance and stocking density have inverse relationship. The insignificant difference between ST/100 and ST/125 (Table, 6 and 9) may be because of favorable condition for growth due to lower stocking density. The result of this study, agrees with the reported result by Yi and Lin (2001). Increased fish biomass of Nile tilapia in cages had a significant negative effect on the final MWT, Diana *et al*. (2004) stated that sex-reversed Nile tilapia stocked in ponds at a low density of 3 fish m^{-2} had higher growth than at a higher density of 6 and 9 fish m^{-2}. The reason for this relationship between stocking density and growth performance may be because of high stress created in higher stoking density due to competition for feed, space and more expenditure of energy due to their antagonistic behavior.

The continual growth pattern of stock ST/ 50 and ST/75 indicates that the favorable condition for growth is not reached at the maximum carrying capacity point. On the other hand the lower and similar growth pattern of stock ST/100 and ST/125, indicates that the maximum carrying capacity of the lake was reached at 100 fish m^{-3} cage size, with a given feed composition and feeding rate (Figure 9).

The growth performances of all higher stocking density were better than the control stock ST/50Which indicate feed has strong positive effect on growth performance. The lowest growth pattern and continual decline in weight or negative (MWT) results in May and June and the lowest DGR value of 0.14 g/day of control stock ST/50 may be due to starvation because of lack of enough amount of natural feed in the epilemnetic region where the stocked fishes were confined.

The DGR value of 0.14 g/day for the control ST/50 stock in this study is less than the DGR result of 0.45 g/day in control ST/50 reported by Ashagrie Gibtan (2007) in Lake Kuriftu The DGR range 0.33 – 0.67 g $fish^{-1} day^{-1}$ of the higher and lower stocking densities of ST/125 and ST/50 in this study is lower than the reported DGR range of 4.01–4.59 g $fish^{-1} day^{-1}$ for 141–152 g Nile tilapia stocked in cages at densities ranging from 30 to 70 fish m^{-3} by Yi *et al*. (1996). The lower DGR values of this study may be associated with constrain in feed quality and quantity or the lower abundance of natural feed in Lake Bishoftu-Guda.

The specific growth rate value decreased as stocking density increased, the range of specific growth rate value of 0.98 day^{-1} to 0.65 day^{-1} was obtained in the lowest and highest stocking densities of ST/50 and ST/125, respectively. The average specific growth rate SGR value of control stock ST/50 was 0.35 day^{-1} which is the lowest result. This indicates specific growth rate value was affected negatively by stocking density. And feed available also but the statistical the one way ANOVA – test value ($p > 0.05$) indicates that the effect of stocking density on SGR is not significant. Like other growth performance measuring parameters (MWT and DGR), the values of specific growth rate (SGR) decreased after March up to May. This may be because of the declining of natural feed.

The lowest SGR value (0.35 day^{-1}) recorded in control stock (ST/50) indicates that feed has strong effect on SGR. Unexpected lower specific growth rate results were recorded in stock ST/75 than the higher stocking density ST/125. This may be because of the position of the cages ST/75 and ST/100 were fixed in front line position at higher depth of 9 meters, whereas ST/125 was fixed at the shore side at 2.5 meter depth. Therefore, the shore sided stock or

ST/125 might have obtained an advantage of available natural feed than the front line caged stocks (ST/75 and ST /100), but further study is needed to proof effect of cage position on growth performance.

The lower stocking density (ST/50) showed better performance than the other higher stocking densities and control treatments. This indicates stocking density has negative effect on FCF and the superior role of feed in growth performance. The decreasing trend of Fulton condition factor through time in all stocking densities indicates the condition were not good for the stocked fish from April to May and some improvement was seen in June, this is may be due to the declining of primary production of the lake in those months and the inability of the supplementary feed to compensate the natural feed deficiency, this is may be the supplementary feed is low in quantity, poor in quality or both. Better condition obtained in June than in May due to less feed loss as wind speed decreases in June or some increasing in primary production especially diatoms

The lower Fulton condition value at the initial stocking time may be because of the younger juvenile age the fish or stress created at a time of collection and stocking. The average FCF value for the lower (ST/ 50), which is considered as low stressed, feed treated is 1.85. This value for the same species investigated in the same lake in natural condition is 2.00 (Fasil Dawit, 2007). Comparison between these two values indicates that the value obtained in this study is low. This can be explained simply by the very natural condition of the stocks in the previous study and that of a confined condition in this study. The stocks in caged condition are incapable to feed exhaustively on the naturally available feed. This is because of the vertical migration of the phytoplanktons from epilmnatic to metalimnetic regions

The study showed that the relationship between length and weight was curvilinear. The regression coefficient obtained for feed treatment; 2.8037, 2.9352, 3.0823, and 2.7382 for ST 50, ST 75, ST 100 and ST 125 respectively, was near the cube value. The b value obtained from this relationship for feed treatment is similar with 2.93 obtained by Fasil Dawit (2007) for the same species in the same lake. Whereas this value for those non feed stocks (3.7927) is by far grater than the value obtained for feed treated and the natural wild condition. This result seems paradoxical, the value for the natural (wild) condition is comparable with feed treatment, and whereas the value for the control treatment was greater than that value obtained for the wild fish. Therefore, this result confirms the unconditional stress might be due to starvation. This is because of their confined condition in the cage and hence lack of access to natural feed. The natural feed is concentrated beyond the cage length or in deeper position.

The food conversion ratio (FCR) of 2.42 and 3.59 were obtained from ST/50 and ST/125 of the lower and the higher stocking density respectively, but the feed conversion ratio value of 3.6 in stock ST/100 was slightly greater than the highest value for the higher stocking density ST/125. The higher FCR value indicates the inefficient utilization of feed and the higher feed loss and the lower FCR value indicates the inverse. Therefore, the lower FCR value of 2.42 in stock (50 fisf/m^3), indicates the efficient use of the supplementary feed than in higher stock (125 fisf/m^3) with higher FCR value of 3.59. Enhancement in FCR suggests efficient feed utilization through the extraction of more nutrients from the feed and converting it into flesh (Bhijkajee and Gobin, 1997).

However, the statistical one way ANOVA- test value indicates effect of stocking density has no significant ($p > 0.05$) on FCR. The reason for this may be insufficient supplementary feed supply either in quality or in quantity for a normal body mass change. But significant difference was seen in ST/50 and ST/100, this is may be high feed loss due to cage suspended position. A similar insignificant relationship result between FCR and stocking density also was reported by Siddiqui *et al.,* (1989). The report indicated that there is no difference in growth of *O. niloticus* (40.3 g average weight) reared in brackish water of (3.5 – 3.9 ppt) tank for 164 days, fed on supplementary feeding at densities of 16.32 and 42.2 fish/m^3. Report by Watanabe *et al.* (1990) revealed that feed conversion of Florida red tilapia fed supplementary feed did not differ at stocking densities ranging from 100 to 300/m^3. This might be due to the variation in fish size and cage, stocking density, feed quality, hygiene and environmental condition or other unknown factors (Diana *et al,.* 1996).

The higher FCR value was recorded in all stocking densities in May than in other months, especially value of 39.2 and 15.39 recorded in ST/100 and ST/125 respectively. This may be because of more feed lost in May by water tide than in other months, because of higher wind speed of 3.23 m/s recorded in May and April than other stocking period, but relatively lower FCR value in April regardless of the same higher value of wind speed as May. This may be because of the presence of better primary production or natural feed in April that masked the feed lost due to water current by lowering the FCR value. Some fluctuations were seen in FCR regardless of stocking density difference, as shown in ST/100 and ST/125 FCR of May.

On the other hand, the supplementary feed may be lost from front-lined cages and give an advantage to the shore side fixed cages. According to Talling (1965) and Melack (1979b) higher algal biomass is prevalent in shallow basins within a deeper lake. According to Collins (1971); Eley *et al.* (1972); Coche (1979); Muller and Varadi (1980); Beveridge and Muir (1982) and Penczak (1982), feed losses are dependent upon quality and type of feed (wet/dry, floating/sinking), method of feeding (hand/demand feeders/automatic feeders), enclosure design (cage/pen; presence/absence of feeding ring; solid/mesh cage bottom) species, site characteristics (lotic /lentic; sheltered/exposed, and stocking density high/low). Loss of feed to the environment is sometimes increased by the currents generated inside enclosures by feeding fish (Collins, 1971; and Coche, 1979).

The total yield of 6.49 and 9.98 Kg m^{-3} were obtained from the lower and higher stocking densities, ST/50 and ST/125 respectively. That means the yield obtained from the higher stocking density of ST/125 exceeded by 2.5 Kg (25%) but up to 5.9 Kg or 29.6% product of fishes were less than 80 g from the higher stock (ST/125). This means most of harvestable tilapia from the higher stocking densities ST/125 were stunt and better conditioned fishes was harvested from the lower stocking density ST/50. The result indicates that stocking density and yield have direct relationship, yield increases as stocking density increases but the quantity or quality of exploitable yield decrease. The obtained Gross yield (GY) ranged at 6.49 - 9.98 Kg m^{-3} in this study was lower than the range of production 15 – 23.6 kg m^{-3} reported by Yi *et al*. (1996)

The net product obtained from ST/50, ST/75, ST/100, and ST/125 stocking density feed treatment was 4.99, 5, 5.09 and 6.23 Kilograms, respectively, but only 1.04 Kg net product was obtained from the ST/50 control treatment. Only an excess of 10 gm net product was obtained from ST/75 than ST/50 feed stock, but 11.13% or about 810 g of the product of ST/75 stock was less than 80 g.

All of the total product of 6.49 Kg in ST/50 feed stock was with good performance, the exploitable product of ST/75 was only 6.45 Kg, but ST/75 consumed 5.25 Kg of more feed than ST/50. Like wise 57.9% or about 4.68 Kg of the product from ST/100 and 47.5% (4.74 Kg) of the product from ST/125 were stunt, the usable product was 3.41 and 5.24 Kg in ST/100 and ST/125 respectively, which was below the usable product of ST/50.

On the other hand all the higher stocks ST/100 and ST/125 consumed an excess of 12.46 and 20.6 Kg feed respectively than ST/50. Therefore for cage culture, the best stocking density for economical production and better quality yield in Lake Bishoftu-Guda is 50 fish m^{-3} in the given feed composition and feeding rate. The higher stunt fishes product of higher stocking density obtained in this study is in agreement with that reported by Mohammed (2006) in which highest percentage of fish (59.7±7.4%) smaller than 250 g was observed in the ST/200 treatment than in the ST/125 (46.7±6.5%).

The contribution of natural feed was estimated from the net product proportion result of control to feed stock ST/50, that is 1.04/4.99 or 0.208. Therefore, the contribution of natural feed is 20.8 % of the total net product weight. This implies that the maximum weight contribution potential product from natural feed to the obtained total net product of feed stock treatments would be 20.8% of the weight. Therefore, out of 42.62 Kg net product of feed treatments of the 8 cages, the possible maximum contribution of natural feed would be 0.208 X 42.62 Kg = 8.86 Kg, the rest 33.76 Kg (79.2 %) of the net product was obtained from supplementary feed only. The monthly net product of Lake Bishoftu-Guda with natural feed was 0.21 Kg m^{-3} cage $month^{-1}$ with stocking density (50 fish m^{-3}).

In addition 90% of the control stock product was less than 80g in weight; therefore the usable product should be 10% of 1.04 Kg/ cage m^{-3}= 0.11 Kg in five months. This indicates that Lake

Bishoftu-Guda is not productive lake for extensive tilapia cage culture, especially in the months of March to June, where the primary production of the lake decreased.

The monthly product result of 0.21 Kg/cage m^{-3} $month^{-1}$ obtained in control (ST/50) in this study is comparable to the reported result of. 0.07 - 0.18 Kg m^{-3} $month^{-1}$ by Mane (1979) in Lake Laguna de Bay with stocking density of 4 - 8 m^{-2}, and the reported result of 0.24 Kg m^{-3} $month^{-1}$ by Alvarez (1981), in Lake Bunot, but less than the reported result of, 0.4 Kg m^{-3} $month^{-1}$ by Oliva (1983) in Lake Buluan and much lower than reported result of 1.25 Kg m^{-3} $month^{-1}$ by Guerrero (1983) in Lake Taal and 1.90 Kg m^{-3} $month^{-1}$ by Oliva (1983) in Lake Bato.

From ST/50 control treatment of each cage a total of 2.54 Kg was produced in 5 moths, but 90% (2.29 Kg) of their was below 80 g. Negative growth seen in May and June may be, because of starvation of caged fish due to the confined restriction of the caged fish to reach to the site where abundant natural feed was available. Therefore, extensive farming in the lake is not advisable especially in the period of February to June where the primary production of the lake is low and the spatial vertical distribution of natural feed in the lake between the stocking periods of March to June was beyond the cage length of 1 meter long. But need further study to proof whether difference in production due to vertical set up of cages in accordance with vertical distribution of natural feed.

The declining in growth performance also coincides with the declining of the blue-green algae (*Mirocystis aeruginosa)* and the dominance of dinoflagllates sp. after April. This condition may be associated with the change in the quantities as well as the quality of natural feed. The assimilation efficiencies of *O. niloticus* on various diets are different. According to experimental result by Bowen (1982) through detects with 14_{C}, the assimilation efficiencies of *O. niloticus* feeding on *Microcystis sp*., is 70%, on *Anabaena sp*. is 75%, on *Nitzschia sp*., is 79%, on *Chlorella sp*., is 49%, and on suspended matter, is 43% in Lake George. The supplementary feed quality (i.e., the indigestible nature of cotton seed) may be also the other possible reason for low growth performance. However further study is need to identify the quality, quantity of supplementary feed as well as way of feeding.

Wild fish competition is may also the other reason for the poor growth performance of stocked fishes. Significant numbers of wild fish were identified in the cages during sampling time and final harvesting time, those wild fishes attracted to the cage may be for searching for food. For instance 67 extra wild fish were observed in a single cage ST/75, which is about 89.03 % of the stocked number. In the other cages, also wild fishes with 15 % to 43 % were observed (Table 11). This number includes only wild fishes that did not escape at the time of sampling and harvesting because of their growth after entering into the cage.

The T- test value shows no significant effect between stocking density and length ($p > 0.05$) (Appendix 5). The result obtained in this study is similar to the reported result by Mohammed (2006) in which it was shown that stocking density has no significant effect on the length of stocked. The survival rates of the stocked fishes were high in all treatments (93 to 94%) in feed stocks but the lowest 76% was obtained from control stocks. This indicates, survival rate was not affected by stocking density, but the continual decrease in MWT (figure 9 or Appendix 11) after April indicates the deterioration condition of control stock. This may be due to starvation because of confined condition of caged fish

8. CONCLUSION AND RECOMMENDATION

Human interference in Lake Bishoftu-Guda is growing rapidly. The lake is used for sanitation watering and for recreation purposes. The rapid growth of construction activities may cause greater catastrophic effect by changing the surrounding feature as well as polluting the lake unless authorized bodies check it. Therefore, there is urgent need of controlling measures to restore the beauty and the natural integrity of the lake.

Production of fish is strongly associated with primary product and visibility; therefore, aquaculture activities must be adjusted with the most productive season of the lake to get a maximum result. Moreover, the depth at which the cage is to be anchored is also to be considered according to the seasonal vertical migration of the phytoplankton and DO viability.

In this study, all the feed treatments including the higher stocking densities showed better growth performance than the control stock after April because of the shifting of planktons. Therefore, supplementary feed has significant effect on growth performance. Knowledge of natural feed helps to determine and prepare the appropriate quantity and quality of supplementary feed, therefore the qualities and quantities of natural feed should be studied.

The primary production of the lake is very limited; the fishing activities should adjust with the productivity, therefore fish management measures are needed to keep the lake from over exploitation. Further study should be needed to identify the appropriate composition and amount of supplementary feed needed for intensive and semi-intensive aquaculture. The prepared supplementary feed should aim at compensating the feeds that are deficient in the natural feed. Care should be given to feeding method and time to reduce feed losses. This is done by preparing an efficient feeding tray, by hand feeding system or preparing automatic feeder and by fixing the cage towards shallow shore side of wind direction.

To improve production need to use of better performing strains, adjusting production period with the productivity season of the lake. Selection of best sited of water body with minimum and uniform depth position

Therefore, further research is needed to analyze temporal and spatial variations of the main natural feed, the appropriate types and amount of supplementary feeds, appropriate feeding methods, and the type of disease and parasite, including other physico-chemical phenomena, which all have an impact on aquaculture production.

No detailed work is done on the environmental impact of cage culture on the lake, because of its complexity and it is beyond the objective of this study. However, cage and pen culture systems are much more open than land based systems, and must be considered as subcomponents of the lake watershed ecosystem in which they operate. Interactions between the environment inside and the environment outside the enclosure occur with little restriction, and so changes in one part of the ecosystem inevitably have an effect on all other parts, to a greater or lesser degree, so there is a need to conduct research on the environmental impact of cage culture.

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APPENDICES

Appendix 1: Correlations: Comparison of DGR, MWT, FCR, SGR, TIME and G

MWT G FCR TIME DGR
G -0.520
0.019
FCR 0.075 0.233
0.753 0.323
TIME 0.761 0.000 0.392
0.000 1.000 0.088
DGR -0.185 -0.568 -0.507 -0.683
0.435 0.009 0.022 0.001
SGR -0.558 -0.200 -0.498 -0.834 0.894
0.011 0.398 0.025 0.000 0.000

Cell Contents: Pearson correlation

P-Value, G = (ST/50, ST/75, ST/100, ST/125 and Non – Feed)

Appendix 2: Volumetric and relative number proportions of major natural feed of gut analysis.

Identified species	Feb.		Mar.		Apr.		May		Jun	
	%V	%N	%V	%N	%V	%N	%V	%N	%V	%N
Bacillariophyceae	20	3.2	20	3.2	21	3.73	25	5.74	27	6.06
Microcystis sp	60	95.7	60	95.69	53.4	94.94	40	91.9	41	91.98
Dinoflagellates	10	1.11	10.2	1.1	11.2	1.33	13	2.3	12.8	1.91
Rotifers	-	0.03	-	0.03	-	0.04	-	0.05	-	0.04
Other	10	-	9.6		14.3		22		18.1	

N.B %V = percentage result based on relative volume proportion

%N = percentage result based on relative number proportion

Appendix 3: Percentage proportion of number of major natural feed
(water analysis of culture site)

Identified species	Feb.	Mar.	Apr.	May
Algae Dinoflagellates	35	35	57	50
Bacileariacaea (diatom), *Nitzschia sp.*	37	32	26.8	30
Microcystis aeruginosa	25	30	15	13
Others	3	3	1.2	7

Appendix 4: T- Test comparison relationship of FCR value with stocking density

Source	DF	SS	MS	F	P
G	3	33.4	11.1	1.04	0.401
Error	16	171.0	10.7		
Total	19	204.4			
S = 3.269 R-Sq = 16.35% R-Sq(adj) = 0.66					

Individual 95% CIs For Mean Based on Pooled StDev

Pooled StDev = 3.269, G = Stocking Densities

Appendix 5: T- Test comparison of length relationship to stocking density

Source	DF	SS	MS	F	P
G	4	14.63	3.66	2.56	0.070
Error	20	28.58	1.43		
Total	24	43.21			
S = 1.195 R-Sq = 33.86% R-Sq(adj) = 20.63%					

Individual 95% CIs For Mean Based on Pooled StDev

G = Stocking Density

Appendix 6: Production of *O. niloticus* in cages and pens, without supplementary feeding*, in Cardona, Laguna de Bay, Philippines, 1982–83. Cages are 3–5 m deep.

Method of culture	Area (m^2)	Stocking density (fish m^{-2})	Stocking period (months)	Size at harvest (g)	Production (g m^{-2} $month^{-1}$)	Reference
Cage	138–2900	7.4	6.3	119	140	Lazaga & Roa, 1983
Pen	15000	20	4–6	170–250	833–850	Guerrero, 1983

Appendix 7: Mean weight of the stocks in different sampling months

	Jen.	Feb.	Mar.	Apr.	May	June
ST/50	30.06±0.47	60.06±2.3	78.78±3.09	96.06±3.07	112.22±3.37	129.72±2.66
ST/75	30.11±0.39	52.09±2.27	65.52±3.36	77.43±3.50	84.57±3.25	96.79±1.59
ST/100	30.03±0.33	50.22±2.39	63.07±2.66	73.39±2.57	74.57±2.06	80.86±1.27
ST/125	29.59±0.33	49.42±2.17	59.85±1.97	71.09±2.15	73.88±1.43	79.85±1.07
Control	30.06±0.47	45.50±2.81	55.22±2.67	67.06±2.77	60.00±2.18	50.74±1.40

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