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Full Length Research Paper

The abundance, distribution and diversity of benthic invertebrates of Lake Malombe

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The benthic zone of Lake Malombe was sampled for invertebrates, fungi and bacteria using an Ekman Grab measuring 15.2 cm by 15.2 cm. Thirty-six stations were surveyed for macro-invertebrates which were identified to the lowest taxa and enumerated to estimate abundance for the lake. Snails were the most dominant macro fauna, belonging to four genera *Melanoides, Bellamya, Bulinus* and *Lanistes* with the mean densities of 177.5, 34.7, and 4.3 and 0.1 m^{-2} individuals, respectively. Blood worms and *Tubifex* were also present. Although there are few such studies in Malawi, it was generally postulated that dominance of snails is a recent phenomenon following previous studies which showed that the invasion of a form of *Melanoides* of Asian origin; its success might be responsible for its proliferation. The benthic substrate was mainly composed of mud, clay granules, sand and bedrock. The biomass of macro-fauna is being reported here for the first time and coincides with a decline in fish catches on Lake Malombe. The prevalence of *Melanoides* species and other high pollution tolerance species suggests that there is high ecosystem modification due to anthropogenic activities including sediment and nutrient loading from agricultural practices in the surrounding area. Compared to Lake Malawi and Upper Shire, Lake Malombe is by far the most productive. There were significantly higher (P<0.5) densities of aerobic, anaerobic bacteria and fungi, demonstrating the importance of the detrital food chain. Therefore, future programs aimed at enhancing fish restoration in Lake Malombe would be advised to include a suite of bottom feeding fish species. The state of benthos found in Lake Malombe is an indication of confounding impacts of over-fishing, climate change and catchment-wide activities. Thus, use of QIIME software could unravel microbiome characteristics, including climate change signatures. Similarly, further studies on food webs could contribute to a better understanding of the Lake Malombe trophic functions.

Key words: Benthic invertebrates, aquatic snails, fungi, bacteria, ecosystems, food chain, Lake Malombe.

INTRODUCTION

Benthic studies have not been frequently conducted in conjunction with fishery related sciences, because there is little appreciation of the role benthic of organisms play in the sustenance of fisheries stocks. Scientists and ecologists who constructed ecosystem models long realised the important role the benthic zone plays in recycling of nutrients and in the provision of food for the bottom dwelling flora and fauna (Christensen and Pauly,

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1993; Strayer, 2009). The heterotrophic food chain contributes to primary and secondary production, although energy flowing through the aquatic system is normally modest. However, the same may not have been said about microbial contribution to primary and secondary production. Generally, as aquatic ecosystems develop and mature, the flow and exchange of matter between the aquatic and terrestrial systems becomes more complex (Pfannkuche et al., 1985; Weyl et al., 2010).

Depending on size of organisms passing through sieves, benthic invertebrates can be classified as macro-invertebrates once they pass through 0.5 mm mesh size and are retained by fine sieve of 0.05 mm mesh as meiobenthos if they pass through fine sieves (Strayer, 2009). Furthermore, the zoobenthos biomass usually includes macro-invertebrates and excludes large bivalves. The benthic animals depend on nutrients from phytoplankton, aquatic plants, animals, bacteria and detritus and facilitate biogeochemical cycles (Alexander et al., 2009). It has been reported that where suspension feeders like mussels, sponges and cladocerans are abundant, they reduce phytoplankton biomass and influence its composition (Reeder et al., 1993).

In Malawi, few studies have been devoted to the aquatic benthic habitats. Therefore, such ecosystem changes are not well understood. On the other hand, most of the scientific studies have been focused on the littoral and pelagic zones of Lake Malawi, because of the diversity of fish species and interest from evolutionary scientists. The Lake Malombe fishery has undergone complete cycles of utilization passing through four phases of development from undeveloped, developing, maturation, decline and senescent, hence to understand Lake Malombe's dynamics, all ecological niches needed to be investigated (FAO, 1993; Matiya and Wakabayashi, 2005; Dulanya et al., 2013; Singini et al., 2013;Hara and Njaya, 2016). This study therefore focused on determining the composition, quantity and contribution of benthic macro-invertebrates and their contribution to the functioning of Lake Malombe ecosystem. Unfortunately, the co-management approach has not produced desired results (Hara et al., 2002), hence fisheries management remain in dire need of fresh efforts.

METHODOLOGY

Study area

The study was carried out in Lake Malombe which is a natural impoundment of the Upper Shire River and is located approximately at 16 km downstream of the outlet of Lake Malawi. It lies between latitudes 14°30′S and 14°45′S and longitudes between 35°12′E and 34°20′E with the surrounding area of the south western part of lake being mostly for agricultural activities while the land-water interface is occupied by emergent aquatic vegetation (Dulanya et al., 2013). The lake is directly fed by waters from Upper Shire River and was known to have a total surface area of approximately 390 to 450 km^2. The lake runs 30 km long from and 15 km wide with an average depth of 5 to 7 m, showing steady declining in depth (Jamu et al., 2011; Maguza-Tembo, 2002; FAOa, 2018). The lake is polymictic, where the shallow depths permit complete mixing by wind and frequent recycling of nutrients from the sediments (Donda, 2011; FISH, 2015). Upper Shire River and south east arm of Lake Malawi were also surveyed to compare with the findings from Lake Malombe.

Sample collection and preservation

Field sampling of invertebrates was done in May and October, 2018 using an Ekman Birge grab to have a profile of species that are abundant both during high lake levels and low levels (Strayer, 2009). Part of the soil sample collected at each sampling station was put in sterilized bottle and sealed for microbial analysis and the rest was washed through sieves to separate macro-fauna from sand, silt and other sediments. Larger fauna including, gastropods and beetles were placed in a container while the rest of live aquatic organisms were placed in a separate container. All samples were stored in 70% ethanol to arrest post-mortem degeneration of tissues induced by autolysis and prevent microbial attack. The Garmin Etrex 10 GPS device was used to locate and record the sampling points. Measurements of depth and temperature were taken by a Fish Finder 140 Garmin equipment. Organisms were preserved using alcohol and sorted carefully based on physical characteristics into their lowest taxa possible using a dissection microscope and magnifying lens. All large organisms were placed in a tray and physically observed using a magnifying lens. The smaller organisms were spread onto petri dishes and examined under a dissection microscope.

Media preparation for microbiological analyses

Benthic soil samples were analyzed for total viable counts (TVC), aerobic and anaerobic bacteria, and fungi populations. The soil samples were cultured in an incubator for 18 h. Preparing the media involved adding 28 g of nutrient agar (NA), 15.5 g of malt extra agar and 15.5 g of Nutrient broth which were placed into conical flasks into which 1 L of ionized water was added. The media was then autoclaved for 15 min at 121°C and later cooled. The plates were prepared in duplicates on sterile petri dishes and dilutions of 0.1 mL were obtained by a micropipette and transferred aseptically into the pre-prepared agar plates by raising the upper lid sufficient enough to enter the tips of the pipette. Samples were spread homogenously and aseptically arranged by sterile flamed L-shaped glass rod throughout the surface of the media until the sample dried out.

The nutrient broth media was placed in a Bio-Bag system consisting of an air-tight plastic bag in which petri plates were sealed. A disposable hydrogen (H_2) gas container was made to react with oxygen (O_2) to form water in sealed bag; eventually, all oxygen in the bag was consumed. This created an anaerobic environment. This was followed with autoclaving the medium to drive off dissolved oxygen. Thereafter, the shake culture technique was used and a tube of Fluid Thioglycollate (FTG) medium held at 48°C was inoculated before the medium solidified. FTG medium contained a small amount of agar to increase viscosity and reduce diffusion of oxygen into medium. Finally, an indicator which turned colourless in the absence of oxygen was included to confirm that anaerobic conditions were achieved.

Soil sample inoculation into the media

For each sample, a subsample of 1 g of soil was transferred to a sample vial containing 9 ml of 0.1% sterile peptone water. The vial

Table 1. The macro-fauna found in Lake Malombe benthos.

Species	Individuals (m^2)	Weight (g/m^2)
Melanoides	178	88.75
Bellamya capillata	35	52.11
Lanistes	5.4	11.4
Bulinus	0.1	0.7
Chironomid larvae	0.1	0.06
Diptera larvae	3.5	n/a
Oligochaetes	2.6	n/a
Black fly larvae	1.2	n/a
Water beetle	0.1	n/a
Tubifex	0.1	n/a

Figure 1. From the right, Melanoides spp., Bellamya capillata and mussels found in Lake Malombe.

was closed, shaken thoroughly for 10 min and allowed to stand for 20 min. Thereafter, a 6-fold serial dilution was carried out in triplicates. The inoculated plates were used for Total Viable Counts (aerobic and anaerobic bacterial counts) after incubation at 28°C. The colony-forming units (CFU/g) were counted under a Quebec dark field colony counter (Leica, Buffalo. NY. USA) equipped with a guide plate ruled in square centimetres. Results were recorded as Colony Forming Units per gram (CFU/g).

Statistical analysis

Data were processed by Microsoft Excel. Mean distribution and abundance of micro-invertebrates were compared by One Way Analysis of Variance (ANOVA) at 5% level of significance using SPSS software version 16.0. Significantly different treatment means were separated using the Least Significant Difference. The Shannon index was used to calculate the diversity using the equation:

$$H = -\sum_{i=1}^{S} p_i \times Inp_i$$

where H = the Shannon diversity index, P_i = fraction of the entire population made up of species I, S = numbers of species encountered and ∑ = sum from species 1 to species S.

RESULTS

Benthic organisms in Lake Malombe

Data analysis from 35 sampling station in Lake Malombe revealed that snails dominate the zoobenthic invertebrates in the Lake and is shown in Table 1. This was followed by Diptera larvae, annelids and black fly larvae.

Overall, *Melanoides* registered average density of 177 m^{-2} followed by *Bellamya capillata* 35 m^{-2}. Although *B. capillata* (Figure 1) are larger in size (almost 4 times) as compared to *Melanoides*, their relatively smaller numbers were outnumbered by the smaller forms of *Melanoides*.

Other invertebrates including tubifex, water beetles and chironomids larvae, were especially present in water depths ranging from 2.5 to 3.5 m. These macro-invertebrates were mostly found in muddy bottom substrates.

Spatial distribution of snails in Lake Malombe

Geo-referencing results of the sampled stations showed that the snails *Melanoides* which dominated the benthic zones of Lake Malombe were more abundant in the north-western part of the lake (Figure 2).

In contrast, the distribution of *B. capillata* in Lake Malombe showed that the snail was highly concentrated in the south western part of the lake (Figure 3).

Substrate types and composition in Lake Malombe

The hard clay substrates were common in deeper waters (>3 m). These areas contained less live benthic fauna

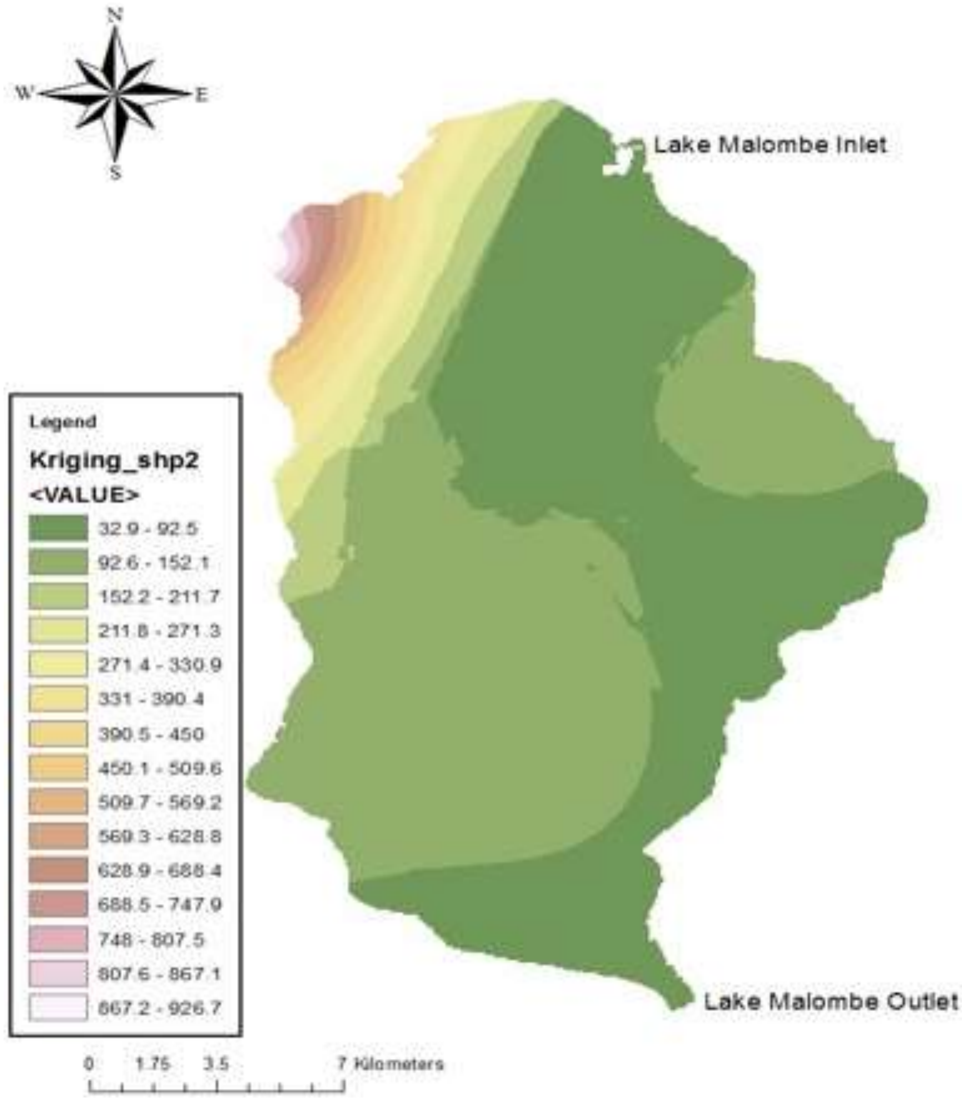

Figure 2. Distribution of Melanoides spp. in Lake Malombe.

and debris but contained considerable amounts of decaying snail shells. The composite substrate had a unique light greyish colour with very tiny particles making it very smooth to tough but not mouldable. The substrate was composed of weathered and decayed shells of snails and fine particles of clay soils (Figure 4).

Snails in Lake Malawi, Malombe and Upper Shire River

A comparative analysis of Lake Malombe, Upper-shire River and Lake Malawi benthic macro-invertebrates at depths ranging from 1.5 to 3.5 m showed remarkable differences in snail distribution and concentration. In Lake Malombe, the snail of the genus *Melanoides* are dominant making up 85% of the benthic macro-fauna (Figure 5).

The *B. capillata* was found to contribute 12% while chironomids larvae contributed only 1%. Thus, Lake Malombe showed great disparities of benthic fauna distribution and abundance.

The abundance of *Melanoides* in the Upper-Shire River was estimated at 48%, showing a 50% difference with Lake Malombe. *B. capillata* abundance is slightly higher than 15% compared to Lake Malombe at 12%. The Upper Shire River had a more diverse number of benthic fauna which included nymph stages of species of the order Coleoptera, Diptera and Trichoptera (Figure 6).

There was also an increase in the abundance of snails of the genus *Bulinus* and Annelids. The abundance of both *Bulinus* and Annelids in Upper-Shire River was 8% as compared to 1% in Lake Malombe. Results from Lake Malawi showed that the measures of abundance of

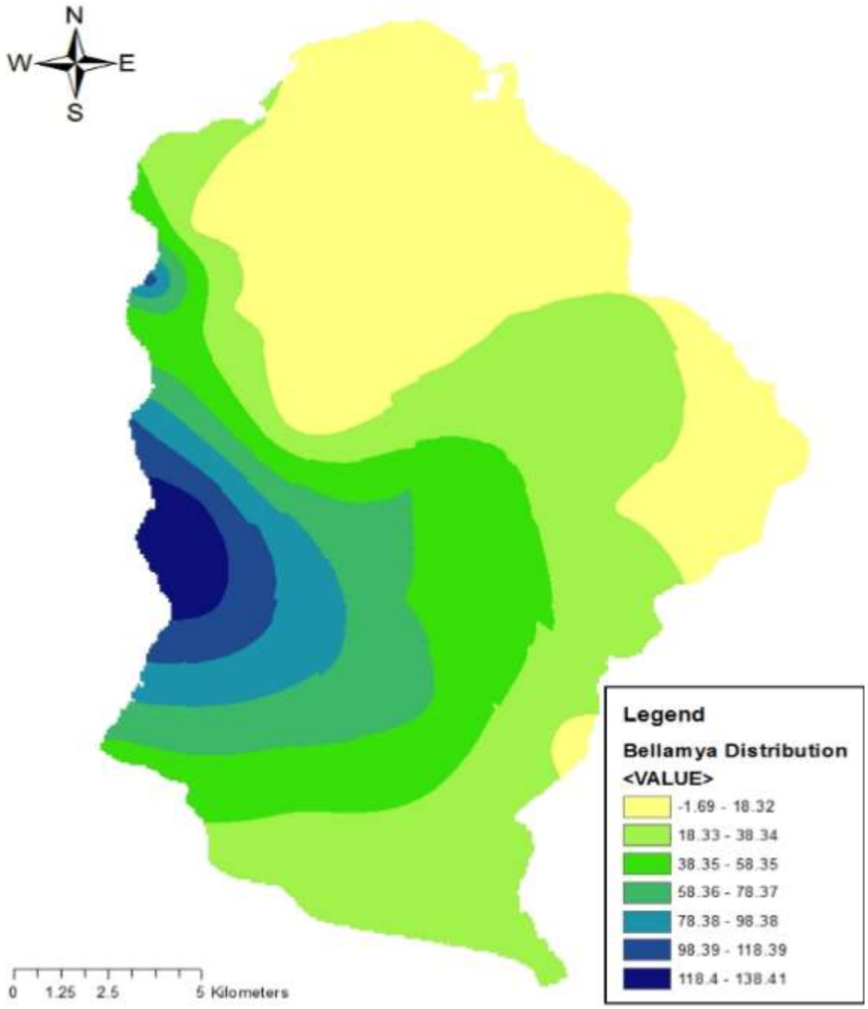

Figure 3. Distribution of Bellamya capillata in Lake Malombe.

Figure 4. Sand and mud substrate found in Lake Malombe.

Annelids, *Melanoides, Bellamya*, Chironomids larvae and bivalves were 31, 16, 4, 9 and 4%, respectively. In Lake Malawi, dominance is displayed Annelids and the community is more diverse (Figure 7).

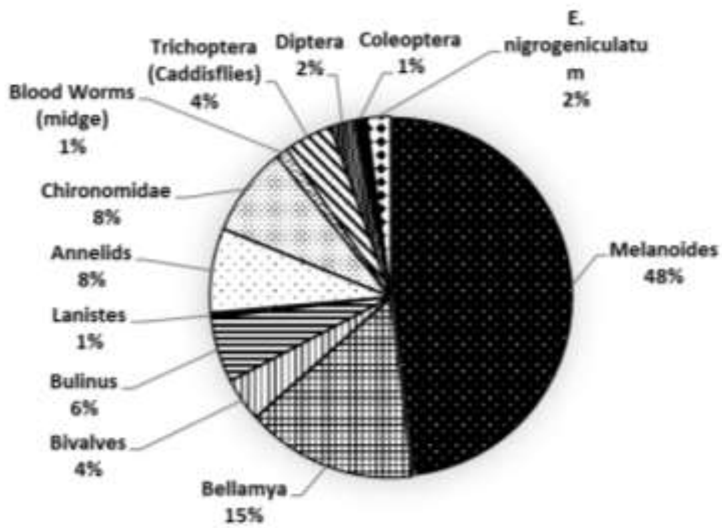

Figure 5. Composition and diversity of macro-invertebrates in Lake Malombe.

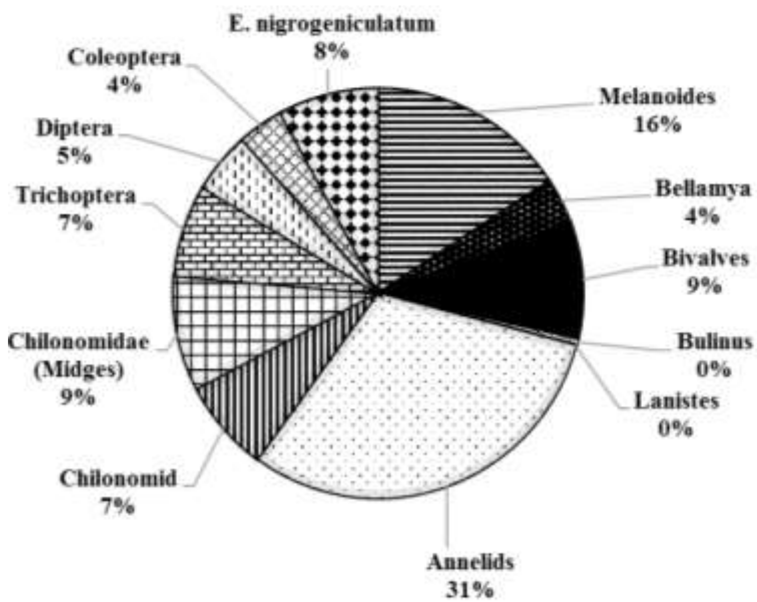

Figure 6. The composition and diversity of macro-invertebrates in the Upper Shire River.

Species richness in south east arm of Lake Malawi, Lake Malombe and Upper Shire River

Although the Upper Shire and southeast Lake Malawi were not as intensively sampled as Lake Malombe, comparisons can be drawn to aid future studies.

The Shannon index of species richness (Table 2) showed that the order of importance was Lake Malawi (1.64), Upper-Shire River (1.46) and Lake Malombe (0.64), respectively. The species richness of Lake Malombe were statistically different to that of Lake Malawi and Upper-Shire River ($P<0.05$).

Microbial population of benthic soils for the three lake sytems

Table 2 shows a summary of microbiological analyses results for the three ecosystems. Lake Malombe had significantly higher numbers of total plate count of

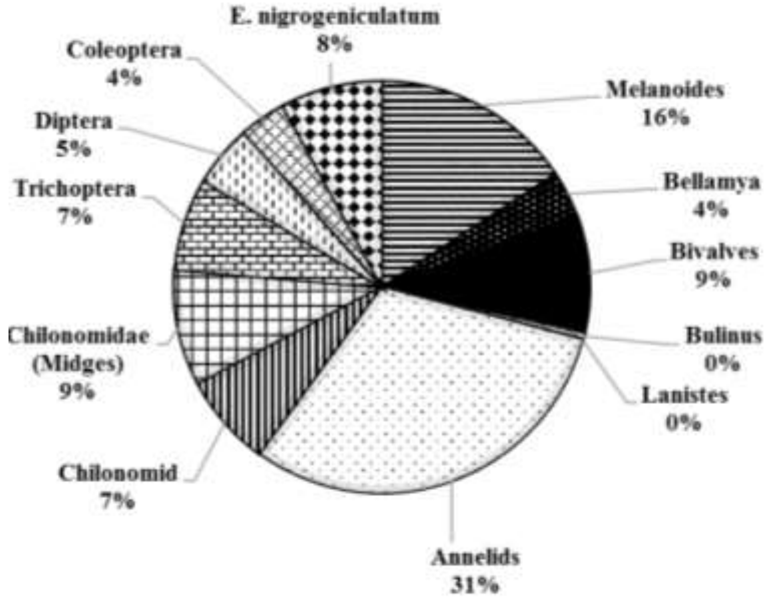

Figure 7. The benthic invertebrates in south-East Lake Malawi.

Table 2. Comparison of the benthic microbial communities of water bodies.

Bacteria (CFU/g)	Lake Malombe	Upper Shire	Lake Malawi
TVC	$1.4\times10^{7}{}_{a}$	$6.7\times10^{3}{}_{b}$	$8.9\times10^{3}{}_{b}$
Aerobic	$1.3\times10^{7}{}_{a}$	$9.0\times10^{3}{}_{b}$	$1.0\times10^{4}{}_{b}$
Anaerobic	$8.9\times10^{9}{}_{a}$	$2.6\times10^{2}{}_{b}$	$6.2\times10^{2}{}_{b}$
Fungi	$5.8\times10^{5}{}_{a}$	$2.6\times10^{2}{}_{b}$	$5.7\times10^{2}{}_{b}$

*Values with the same subscript along a column are not significantly different (p>0.05).

1.4×10^{7} CFU/g compared to Upper Shire and part of Lake Malawi which had the same order of magnitude; 6.7×10^{3} and 8.9×10^{3} CFU/g, respectively; these results were significantly different (P=0.001). Significantly higher populations (P=0.01) of fungi, aerobic and anaerobic bacteria were identified in Lake Malombe as compared to Upper Shire and Lake Malawi. The difference in microbiological populations of the benthic soil samples reveals productivity and comparative importance of the heterophic food chain of the three ecosystems.

DISCUSSION

Abundance and distribution of benthic macro-invertebrates in Lake Malombe

The macrobenthos fauna of Lake Malombe showed little diversity as compared to the Upper-Shire River or Lake Malawi. The most common gastropods in Lake Malombe belonged to the genus *Melanoides,* which are believed to be very tolerant to diverse environments, according to Berry and Kadri (1973) and Vogler et al. (2012). This genus has been found to occupy a variety of habitats, ranging from weakly saline close to sea-level to freshwater of higher altitudes and can thrive in a wide range of pH and hardness regimes and in distinct kinds of substrates, however, it is most common in the mud. This is in-line with current results where *Melanoides* were most abundant in muddy substrates. The diets of this snail comprise of several types of algae, bacteria, deposits of organic materials and decaying flora (Pointier et al., 1991; Ben-Ami and Heller, 2005; Raw et al., 2016); hence, the lake provided a perfect environment.

B. capillata was the second most abundant snail in Lake Malombe and is also a widely distributed gastropod in the Africa region. This species is also found in coastal Tanzania, north-eastern Natal, Democratic Republic of Congo and Lake Victoria Basin (Van Damme and Lange, 2016). The distribution of *B. capillata* is influenced by physico-chemical parameters notably water temperature and salinity, whose extreme values shows an inverse effect regarding distribution and abundance (Brown, 1994). Freshwater gastropods are regarded as bioindicators of water quality and play a vital role in purifying water since they are saprophytic, obtaining nourishment from dead and decaying organic matter. The other gastropods like *Bulinus* are of great medical importance for being intermediate hosts of infectious trematodes and other parasites of animals and human beings (Brown, 1994). One of the most important parameters being calcium salts are found in both food and influence the growth of gastropods (Dillon, 2000). The benthic ecosystem generally favours the growth and reproduction of gastropods, therefore, the success of gastropods to colonize and dominate Lake Malombe benthos can also be attributed to overfishing. Snail eating fish species such as *Trematocranus placodon* and *Synodontis njassae* have been over-fished in the lake, thereby removing the natural biological control (FAO, 2018c).

The presence of *Tubifex* worms and blood worms in Lake Malombe benthic ecosystem confirms the assumption made that deeper parts of the lake (>3 m) are eutrophic and are generally of low oxygen content. According to Pelegri and Blackburn (1995), *Tubifex* worms along with chironomids larvae are the most abundant macro fauna species in eutrophic lake sediments that occur in Lake Malombe. *Tubifex* worms feed in the ranges of 2 to 8 cm of the benthic sediments, primarily consuming microfauna composed of bacterial and fungi.

The benthic fauna of southeast arm of Lake Malawi and Upper Shire River

The benthic fauna of these two ecosystems were not significantly different; however, both were lower than in Lake Malombe. In Upper Shire River, *Melanoides* were dominant at 48% and *Bellamya* came second at 15%. In Lake Malawi, the benthic fauna was observed to be dominated by Annelids (31%) seconded by *Melanoides* (16%). The density of snails and other aquatic organisms in Lake Malawi and Upper Shire River was high in the littoral zone as compared to the middle of the lake or deeper waters. However, *Melanoides* were present in all the sampling stations, this confirms what Genner et al. (2004) had previously observed that *Melanoides* species showed rapid reproductive potential and spread to littoral habitats.

The reduction of the benthic fauna towards the middle of the two ecosystems (Lake Malawi and Upper Shire River) may be explained by the increase in silt content, indicating a reduction of suitable space. Martin et al. (1998) showed that the oxygenated layer in the sediment is reduced to the few first millimetres in shallow water and <1 mm near the anoxic layer. A limnology study conducted in the same Lake showed that dissolved oxygen levels did not exceed 7 mg/L throughout the Lake (FAO, 2018b). It has been observed elsewhere that the longer periods of very low oxygen content or anoxic conditions may prevent survival of aerobic species that are tolerant to low oxygen (Ott and Schiemer, 1973). Another probable reason for the density decrease of benthic invertebrates may be reduction of food availability. In deep water, benthic standing stock usually reflects food availability (Pfannkuche, 1993). In addition, there was relatively high water velocity at the middle of the lake as well as in the river (Giovanelli et al., 2005; Buss et al., 2004; Kloos et al., 2001).

It was observed that the benthic substrate of Lake Malawi had several submerged aquatic plants, which were scarce in Upper Shire River and especially at the area close to Lake Malombe. Most fishers use beach seine nets which drag the bottom, especially the “Nkacha” nets which are illegalised in Lake Malawi. This is likely to have affected growth of submerged aquatic plants in Upper Shire River contributing to reduction of benthic fauna that depend on aquatic vegetation for food, shelter and breeding (FISH, 2015). This association needs further investigation.

The role of microbial population in the ecosystems

The total viable counts for bacteria and fungi in Lake Malombe were shown to be higher than Upper Shire River and Lake Malombe. This suggests that benthic bacteria are essential food for invertebrates forming the base of the heterotrophic food chain in these systems. Regarding their trophic role, bacteria would be expected to play a vital role in mineralization of detritus, dead shells of snails and the recycling of essential nutrients. The microbial populations in the aquatic systems serve as a general indicator of nutrient recycling and health of the benthic system (Castelli et al., 2004; Weyl et al. 2010). Aerobic and anaerobic microbial populations in Lake Malombe were shown to be more abundant as compared to Lake Malawi and Upper Shire benthic systems. The slow movement of water in Lake Malombe, essentially a floodplain lake, meant that bacteria have sufficient time to establish themselves and to allow interactions that support multifunctional activities (Gamfeldt et al., 2008). The aerobic bacteria and fungi consume dissolved oxygen and leave anaerobic zones where the anaerobic bacteria conduct metabolic processes. Steele et al. (2001) reported that these bacteria constitute the foundation of all earth’s ecosystems, being responsible for the degradation and recycling of essential elements such as carbon, nitrogen and phosphorus. Alongi (1994) reported that the energetic power of microbes is greater than all other living organisms combined and is the powerhouse driving aquatic food webs. Fungi are saprobes and obtain substrates from the remnants of dead plants and animals in soil or other aquatic habitats (Sergeeva and Kopytina, 2014). Therefore, higher counts in the Lake Malombe benthos indicate a lot of decomposition of detritus and dead shells; this is evidence of high nutrient recycling as well as effects of anthropogenic inputs from catchment area of Lake Malombe. This was also evident in high concentrations of carbonates and bicarbonates (FAO, 2018b), which could be signature nutrients for the lake. Therefore, the biological processes in the benthic soils are exerting substantial effect on the aquatic environment of Lake Malombe through the heterotrophic food chain.

Evidence of role of substrate in the ecosystems

The substrate composition has been reported to be very closely linked to ecosystem functions, including microbial communities as they harbour microbial populations (Ylla et al., 2013). Lake Malombe is a rich source of established benthic communities which have been developed on the appropriate substrate (Gamfeldt et al., 2008). The study found that clay and composite substrates were highly prevalent in Lake Malombe, while sand, silt and fine sand were present in Upper Shire River. Only a small portion of Lake Malawi was sampled and had silt, mud and clay.

CONCLUSION AND RECOMMENDATIONS

Having demonstrated that the benthic community of Lake Malombe is potentially a rich source of a suite of food including bacteria, fungi and snails; finding fish species which will feed on these organisms should be considered for stock enhancement programs that will contribute to effective fisheries management. To further advance an understanding of Lake Malombe, studies using QIIME software are required to sequence the microbes and couple with climate change parameters including signature carbon species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Effects of feeding rates and feeding frequencies on growth performance, uniformity of the batch and survival rate of Amazon ornamental fish larvae

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The aim of this study is to evaluate the effect of different feeding rates and frequencies on angelfish (*Pterophyllum scalare*) and severum (*Heros severus*) larvae. For this purpose, two similar experiments were conducted in parallel. For each experiment, a total of 360 larvae were distributed in 36-1 L aquariums. The experiments were done using a factorial 3x3 completely randomized design, with four replicates. The feeding rates of 50, 100 and 150 artemia nauplii larvae^{-1} and the feeding frequencies of one, two and four meals day^{-1} were tested. Parameters of growth performance, uniformity of the batch and survival rate were determined at the end of both experimental periods. No interaction was observed between feed rates and frequencies in angelfish for all parameters evaluated; growth performance was higher in fish fed with 150 nauplii larvae^{-1}, which were divided in two and four meals day^{-1}. The severum larvae presented interaction between feeding rates and feeding frequencies; growth performance was higher in fish fed with two and four meals day^{-1}. Thus, in order to facilitate feed management and reduce manpower costs during ornamental angelfish and severum larvae production, it is recommended to supply 150 artemia nauplii larvae^{-1} divided in two meals day^{-1} to fish.

Key words: Angelfish, feeding practices, ornamental fish farming, severum.

INTRODUCTION

Angelfish (*Pterophyllum scalare*) and severum (*Heros severus*) are both freshwater cichlid fish, native to the Amazon basin and widely distributed in South America (Shukla, 2010). Angelfish has been classified as the most popular freshwater fish species in aquarium trade industry (Garcia-Ulloa and Gomez-Romero, 2005); it has

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high economic value due to its elegance, reproductive ability and adaptability to captivity (Karayucel et al., 2006; Ortega-Salas et al., 2009). Severum, on the other hand, has become widespread because of its predominantly yellowish color with shades of olive green. It presents relatively easy reproduction and good adaptation in captivity (Alishahi et al., 2014).

In contrast to the culture of edible fish, information on the dietary requirements and feeding practices of ornamental fish is limited (Jobling, 2012), especially on their first life stages. Larvae rearing is the most critical step in the aquaculture production chain (Herath and Atapaththu, 2013), as this period involves functional and morphological changes in internal organs, tissue systems and, particularly, in fish digestive tract (Korzelecka-Orkisz et al., 2012).

Nutrition is one of the most important factors influencing the ability of cultured fish to exhibit its full growth potential (Kasiri et al., 2011). In this context, some study has shown that formulated feeds can substitute the need for live feed in larviculture of some species (Maithya et al., 2017), although, for most ornamental fish larvae, live feed is generally considered as the most suitable feed (Conceição et al., 2010). Among live feed used in the aquaculture, artemia nauplii are the most common item (EL-Sebaie et al., 2014), being suitable and convenient food source for edible and ornamental fish larvae (Treece, 2000). Factors such as fish behavior, feed quality, water parameters and feeding practices also influence fish growth (Kasiri et al., 2011).

In aquaculture, failures on feeding practices can lead to weight loss, non-standardized growth and an inefficiency of nutrient absorption, impairing growth performance, as well as water quality of the growing environment (Veras et al., 2016a). Thus, it is important to assess an optimum feeding rate and frequency for fish larvae, since it directly influences the survival and growth of individuals, enabling food scheduling, optimizing manpower and consequently increasing productivity (Abe et al., 2016; Zuanon et al., 2011). Therefore, this study was designed to evaluate the effects of different feeding rates and frequencies and their potential interaction on growth parameters, uniformity of the batch and survival rate of angelfish and severum larvae fed with artemia nauplii.

MATERIALS AND METHODS

The experiments were approved by the local Ethics Committee for Animal Use (Protocol n° 7656100517). For each larvae specie, a 2-week feeding trial was conducted at the Laboratory of Ornamental Fish, of the Faculty of Fisheries Engineering, Institute for Coastal Studies, Federal University of Pará, Bragança *Campus*, Pará State, Brazil.

Fish and culture conditions

The angelfish and the severum larvae used for this study were hatched in the Laboratory of Ornamental Fish, under controlled environmental conditions. A total of 360 larvae were used for each experiment. The angelfish presented an initial body weight and length of 0.93 ± 0.13 mg and 3.95 ± 1.07 mm (mean ± SD) respectively, and the severum presented an initial body weight and length of 2.10 ± 0.14 mg and 5.23 ± 0.30 mm (mean ± SD), respectively. For each experiment, the larvae were randomly distributed at a density of 10 larvae L^{-1} in 36 aquariums (1 L) and kept under natural photoperiod of approximately 12/12 h light/dark condition.

For each experiment, larvae were fed only with newly hatched artemia nauplii, submitted to three feeding rates: 50, 100 and 150 artemia nauplii larvae^{-1}, in combination with three feeding frequencies: one meal at 08:00 h, two meals at 08:00 and 14:00 h, and four meals at 08:00, 11:00, 14:00 and 17:00 h. An hour after the last feeding, the aquaria were siphoned to ensure the maintenance of water quality, exchanging one third of the water volume. Fish were counted during the cleaning management for the adequacy of feeding rates, in case of mortality. During the whole trial no artemia nauplii surplus was observed, indicating that all artemia nauplii provided were consumed by the fish larvae.

Artemia hatching

For artemia nauplii hatching, 20.0 g of cysts was divided into twelve containers (1 L) and incubated for approximately 24 h with constant aeration. Water saline concentration was 30 g L^{-1} and temperature, 28°C. After hatching, aeration was withdrawn and the living nauplii were collected from the suspension of unhatched cysts by siphoning. A pipette was used to withdraw a 0.5 mL volume of nauplii, counted in triplicate through a stereomicroscope to obtain a mean value. Artemia nauplii were then filtered through a 120 µm mesh and washed twice with running freshwater to remove impurities, reduce salinity and ensure food quality. After estimating nauplii density, the volume of artemia nauplii to be supplied in each treatment for each experiment was calculated.

Water parameters

During both feeding trial water temperature, pH, and total ammonia were 27.51 ± 0.03°C, 7.50 ± 0.02, and 0.005 ± 0.01 mg L^{-1}, respectively. Oxygen was maintained at 4.82 ± 0.26 mg L^{-1} throughout the experiment. Temperature and dissolved oxygen were measured daily with a thermometer and a digital oximeter (Lutron DO -5510, São Paulo, SP, Brazil). Total ammonia and pH were measured every two days with a multi-parameter meter (HI 3512, Hanna Instruments, Barueri, SP, Brazil). There was no effect of the treatments on water quality parameters ($P > 0.05$).

Growth performance

At the end of each feeding trial, after 12 h of starvation, all fish from each aquarium unit were counted and weighed on a precision scale (model AG200 Gehaka® 0.0001 g) to evaluate the growth performance parameters of final weight, weight gain (final weight - initial weight), specific growth rate ((ln final weight - ln initial weight) days^{-1}) x 100) and the weight and length uniformity of the batch. To determine the batch uniformity, the following equation by Furuya et al. (1998) was used: $U = (N \pm 20\%)/Nt) \times 100$, where: U = the uniformity of the batch, that is, variation in weight or total length (%); Nt = the total number of fish in each experimental unit; and N ± 20% = the number of fish with weight or total length ± 20% of the mean for each experimental unit. Survival rate was evaluated every day. Individuals were considered dead when spontaneous movements or responses to mechanical stimuli were lacking. Dead fish were removed from the aquarium and counted to calculate the survival

Table 1. Growth performance, uniformity of the batch and survival rates of angelfish (*Pterophyllum scalare*) larvae fed with artemia nauplii at different feeding rates and frequencies.

Treatment	Performance indices					
	FW (mg)	WG (mg)	SGR (%)	WU (%)	LU (%)	SR (%)
Feed Rate						
50 Artemia nauplii larvae^{-1}	10.79±2.5^{c}	9.89±2.5^{c}	16.30±1.4^{c}	72.04±11.3	100.00±0.0	97.50±3.7
100 Artemia nauplii larvae^{-1}	15.41±1.5^{b}	14.41±1.5^{b}	18.90±0.6^{b}	71.15±15.4	100.00±0.0	93.33±8.9
150 Artemia nauplii larvae^{-1}	20.48±2.3^{a}	19.58±2.3^{a}	20.78±0.7^{a}	68.68±17.1	100.00±0.0	90.50±5.0
Feed Frequency						
One meals day^{-1}	13.30±3.7^{b}	12.40±3.7^{b}	17.55±2.1^{b}	66.53±13.2^{b}	100.00±0.0	91.67±6.9
Two meals day^{-1}	16.03±3.5^{a}	15.13±3.5^{a}	18.94±1.5^{a}	63.68±15.3^{b}	100.00±0.0	91.67±6.9
Four meals day^{-1}	17.35±3.9^{a}	16.45±3.9^{a}	19.49±1.5^{a}	81.66±10.4^{a}	100.00±0.0	92.50±7.5
Feed Rate	***	***	***	NS	NS	NS
Feed Frequency	*	*	**	*	NS	NS
Interaction	NS	NS	NS	NS	NS	NS

Final weight (FW); Weight gain (WG); Specific growth rate (SGR); Weight uniformity (WU); Length uniformity (LU); Survival rate (SR).
Each value is a mean ± SD.
Mean values in the same column, with different letters, are significantly different by Tukey test at 5% probability.
ANOVA: NS: non-significant (P>0.05); *P<0.05; **P<0.01; ***P<0.001.

rate.

Experimental design and statistical analysis

Both experiments were conducted using a completely randomized design with four replicates, testing three different feeding rates and frequencies in a factorial 3×3 design. Normality was assessed via the Shapiro–Wilk normality test ($P < 0.05$) and the Cochran test was used to establish the homogeneity of variance. Using the Statistic software version 7, data were evaluated by two-way analysis of variance ($P < 0.05$). If no interaction between feeding rates and frequencies was detected, one-way ANOVA ($P < 0.05$) of single factors was performed. In case of differences, the Tukey test at a probability level of 5% was performed.

RESULTS

There was no interaction between feeding rates and feeding frequencies on the growth performance of angelfish larvae ($P > 0.05$). Final weight, weight gain and specific growth rate were higher in fish fed with 150 artemia nauplii larvae^{-1}. Also, there was an improvement of growth performance of angelfish larvae fed with artemia nauplii divided in two and four meals day^{-1}. Weight uniformity was higher in angelfish larvae fed with four meals day^{-1} and was not affected by the feeding rates. Survival rate and length uniformity were not affected by the feeding rates or feeding frequencies (Table 1).

Results similar to the angelfish were observed for severum larvae, which presented highest final weight, weight gain and specific growth rate values when fed 150 artemia nauplii larvae^{-1}. Survival rate, weight and length uniformity was not affected by the feeding rates or feeding frequencies (Table 2). The interaction between feeding rates and feeding frequencies had also a significant effect; final weight, weight gain and specific growth rate were higher in fish fed two and four meals day^{-1} only in the highest feeding rate (Table 3).

DISCUSSION

In aquaculture industry, nutrition cost accounts for about 60% of the operating cost especially in intensive fish culture (Kasiri et al., 2011). Thus, improving feeding practices during fish production aims to increase the productivity and quality of aquaculture products. Ornamental fish are usually subjected to stressful factors during their management before reaching the end consumer. This process can cause high mortality rates and reducing profits (Zuanon et al., 2011). Therefore, estimating the optimum feeding rate and frequency for a particular fish species may reduce stress, improve fish development and quality of fish supply, especially in ornamental aquaculture production (EL-Sebaie et al., 2014; Kasiri et al., 2011).

In the present study, fish that received 150 artemia nauplii larvae^{-1} presented the best results of growth performance, regardless of the specie. Similar results were observed in pyrrhulina (*Pyrrhulina brevis*) larvae, another Amazon ornamental fish, which had the best feeding rate set at 150 artemia nauplii larvae^{-1} (Abe et al., 2015). Different results were found during the larvae

Table 2. Growth performance, uniformity of the batch and survival rates of severum (*Heros severus*) larvae fed with artemia nauplii at different feeding rates and frequency.

Treatment	Performance indices					
	FW (mg)	**WG (mg)**	**SGR (%)**	**UW (%)**	**UL (%)**	**SR (%)**
Feed rate						
50 Artemia nauplii larvae^{-1}	8.30±1.1^{c}	6.20±1.1^{c}	9.09±0.8^{c}	59.84±14.1	100.00±0.0	95.00±6.7
100 Artemia nauplii larvae^{-1}	13.98±1.3^{b}	11.88±1.3^{b}	12.60±0.6^{b}	68.70±15.3	100.00±0.0	95.00±5.0
150 Artemia nauplii larvae^{-1}	18.36±0.6^{a}	16.26±0.6^{a}	14.45±0.2^{a}	68.87±13.3	100.00±0.0	95.83±5.6
Feed frequency						
One meals day^{-1}	12.30±3.5	10.20±3.5	11.35±2.1	59.47±16.1	100.00±0.0	94.17±6.8
Two meals day^{-1}	13.40±3.7	11.31±3.7	11.95±2.1	67.59±16.3	100.00±0.0	95.00±5.0
Four meals day^{-1}	14.93±3.3	12.83±3.3	12.83±1.6	70.35±11.7	100.00±0.0	96.67±5.0
Feed Rate	***	***	***	NS	NS	NS
Feed Frequency	NS	NS	NS	NS	NS	NS
Interaction	*	*	**	NS	NS	NS

Final weight (FW); Weight gain (WG); Specific growth rate (SGR); Weight uniformity (UW); Length uniformity (UL); Survival rate (SR).
Each value is a mean ± DP.
Mean values in the same column, with different letters, are significantly different by Tukey test at 5% probability.
ANOVA: NS: non-significant (P>0.05); *P<0.05; **P<0.01; ***P<0.001.

Table 3. Splitting feeding rates and frequency interaction for final weight, weight gain and specific growth rate of severum (*Heros severus*) larvae.

	Final weight (mg)		
Feed frequency	**Feed rate (artemia nauplii larvae^{-1})**		
	50	**100**	**150**
One meals day^{-1}	7.15±0.29^{cB}	12.34±0.30^{bB}	17.41±0.36^{aB}
Two meals day^{-1}	7.80±0.37^{cB}	13.75±0.26^{bB}	18.69±0.23^{aA}
Four meals day^{-1}	9.94±0.33^{cA}	15.86±0.78^{bA}	18.98±0.47^{aA}
	Weight g^{a}in (mg)		
Feed Frequency	**Feed rate (artemia nauplii larvae^{-1})**		
	50	100	150
One meals day^{-1}	5.05±0.29^{cB}	10.24±0.30^{bC}	15.31±0.36^{aB}
Two meals day^{-1}	5.70±0.37^{cB}	11.65±0.26^{bB}	16.59±0.23^{aA}
Four meals day^{-1}	7.84±0.33^{cA}	13.76±0.78^{bA}	16.88±0.47^{aA}
	Spe^{c}ifi^{c} growth r^{a}te (%)		
Feed Frequency	**Feed rate (artemia nauplii larvae^{-1})**		
	50	100	150
One meals day^{-1}	8.16±0.27^{cC}	11.80±0.16^{bC}	14.10±0.14^{aA}
Two meals day^{-1}	8.74±0.32^{cB}	12.53±0.13^{bB}	14.57±0.08^{aA}
Four meals day^{-1}	10.36±0.22^{cA}	13.47±0.32^{bA}	14.67±0.16^{aA}

Different minuscule letters on the same line indicate difference by Tukey test at 5% probability.
Different capital letters in the same column indicate difference by Tukey test at 5% probability.

rearing of pacamã (*Lophiosilurus alexandri*). It is recommended to supply 1600 artemia nauplii larvae^{-1} divided in three feeds daily, for higher values of weight and total length (Santos et al., 2015). These different results indicate that, although the optimal feeding rate is specie-specific, more effort is needed to determine an optimum feeding practice (EL-Sebaie et al., 2014), especially in first life stages of ornamental fish production.

Determining the optimal feeding rate should be done aiming food utilization improvement and reducing production costs (Abe et al., 2016). Both, excess and lack of food can be harmful to fish health and may increase their susceptibility to diseases and parasites (Lee et al., 2000). The excess of live food also makes the activity more costly (Luz and Portella, 2005; Zuanon et al., 2011). In addition, excess supply of artemia nauplii may promote water quality reduction, since it presents rapid mortality in freshwater (Santos et al., 2015).

The appropriate feeding rate is directly related to feeding frequency. Thus, it is important to establish how many meals the defined amount of food will provide. When larvae of freshwater fish are fed with live marine organisms, such as artemia nauplii, optimal feeding frequency is critical to increase fish opportunity to consume live nauplii, improving nutrient uptake (Portella et al., 2000) and avoiding possible problems with water quality. In the present study, although no interaction was observed between feeding rates and feeding frequencies by angelfish, increasing of feeding frequency had an improvement effect on growth performance. Once higher weight gain was observed when angelfish was fed two or four meals a day. For severum, different from the results reported by Abe et al. (2016), the interaction observed between feeding rates and feeding frequencies reduced the feed frequency for two meals daily, when the larvae was fed with 150 artemia nauplii larvae^{-1}.

Feeding frequency has a significant effect on feed conversion ratio and growth (Kasiri et al., 2011). Normally, by using a reduced feeding frequency for fish in early developmental stages, the amount of food might exceed the intake capacity of the animal (Veras et al., 2016b). This excess consumption can lead to a rapid passage of food through the digestive tract and decrease the efficiency of digestion and absorption of nutrients (Luz and Portella, 2005). On the other hand, high feeding frequency increases manpower costs and can lead to a greater dispute between individuals, which may also affect the development of the animals (Hayashi et al., 2004). Dominant fish consume more of the provided food (Gonçalves Júnior et al., 2013) and are benefited by inadequate feeding frequency. Thus, an adequate feed frequency can lead to greater uniformity and survival, which facilitates the management and marketing of fish (Hayashi et al., 2004).

For ornamental fish a uniform development is important, as they are marketed individually (Abe et al., 2016). Although the weight uniformity of angelfish larvae was higher by fish fed four meals a day, there was no significant difference in the length uniformity. The length uniformity of the batch facilitates the handling of individuals within the production system, as well as the marketing of species. Thus, since ornamental fish commercialization usually takes the length of the animals and the unit value into consideration (Veras et al., 2016b), the lack of weight uniformity in angelfish fed two meals a day may not be a problem.

The survival rate of both specie larvae tested in the present study did not show significant differences. Similarly, severum larvae submitted to different feeding rates and frequencies also did not present differences in survival rates (Abe et al., 2016). The sociability of the fish larvae and its preference for living in shoals (Gómez-Laplaza, 2006) may have contributed to the observed survival rates, since the negative interactions of territorialism were not intense enough to justify a reduction of this parameter.

Conclusions

According to the results, the feeding rates of 150 artemia nauplii larvae^{-1} led us to obtain better growth performance in angelfish and severum larvae production. Moreover, as there was no difference in growth performance of angelfish larvae fed with artemia nauplii in two or four meals day^{-1} as well as severum larvae fed with 150 artemia nauplii larvae^{-1}, the feeding frequency of two meals day^{-1} is recommended. Thus, the supply of 150 artemia nauplii larvae^{-1} divided into two meals day^{-1} is recommended, for easy handling and manpower reduction costs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Identification of possible causes of fish death in Lake ‘’Lake Kabo’’

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Any adverse change in the environmental conditions affects the life of aquatic organisms in water. Fish death was suddenly observed in Lake Kabo. To investigate its cause and look for solution, a research team started to consider the Lake. The present study was conducted to identify the reason for the fish deaths that accidentally occur in the lake. To achieve the objective samples were collected from four different sampling sites on the lake from October 2017 to August 2018. The four sampling stations on the lake were selected based on criteria and were coded. Sample collection was made every month. Data were analyzed using SPSS version 23. Experimental activities were carried out both on the spot and in laboratory. The results analyzed were compared with permissible limits prescribed by WHO, FAO, BIS and other references. In this study, the pH (6.1-8.7), total dissolved solid (TDS) (60-251.3 mg/L) and total alkalinity (101-195 mg/L) of the lake followed the prescribed limits set by WHO (1993) and BIS (1991). Critical dissolved oxygen (DO) value (2.8-4.7 mg/L) and temperature (T°) (25-30°C) of the lake were found below the specified limit for tilapia Fish. In this study, the reasons for the sudden death of tilapia fish in the lake include: highly fluctuated values of T°, DO and pH value of the lake water especially in rainy season. The study concluded that tilapia fish could not tolerate the fluctuation of DO value which is less than 3 mg/L. The result from secchi-disk also supported the less value of DO. The mean nutrients values for Ca++, PO_4^{-3} and (Cl^-) of the lake were 7.6 ± 2.6, 0.1039±0.15 and 1.5102±0.7 mg/L, respectively. The reduced level of DO and extreme fluctuation of pH were the expected reasons for the sudden fish death in the lake during rainy season.

Key words: Lake Kabo, pH, dissolved oxygen (DO), total dissolved solid (TDS), Secchi-disk.

INTRODUCTION

This research was conducted in Majang Zone, Gambela Regional State, Ethiopia. The Lake ‘Bishan Waka’ is an alternative local name for Lake Kabo, a kind of natural lake created by volcano phenomenon. The name, Bishan Waka means the gift of God. The maximum depth of the lake was 20.5m during the study period. It is located about 651 km from Addis Ababa and is situated very far from the government. Local people benefit from the lake through traditional fishing activity. We encountered dead fish floating on the lake during preliminary survey and

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were interested in finding the reason for their sudden death. Water quality is the totality of physical, biological and chemical parameters that affect the growth and welfare of organisms. Quality of water is an indispensable factor to be considered when planning to produce fish (Mallya, 2007).

The chemistry of natural surface waters is complex, and is based on the equilibrium reached with the normal physical, chemical and biological characteristics of the surrounding (Bronmark and Hansson, 2005). The life and growth of fish depend on pH of the water. pH value of the water will rise during the day as the amount of carbonic acid is reduced; on the other hand dissolved oxygen concentrations rise during the day. At night, the level of carbon dioxide rises, leading to reduction in pH, and the level of dissolved oxygen also falls (Svobodová et al., 1993). Algae require a pH of about 7, and a slightly lower (alkaline) pH of 6.5 favors good zooplankton (tiny animals in the pond water on which fishes feed) and fish growth.

Fish have a limited ability to adapt to changes in these factors, if they occur sufficiently slowly; rapid changes can be harmful. Water pH also has a significant influence on the toxic action of a number of other substances (e.g. ammonia, hydrogen sulphide, cyanides, and heavy metals) on fish. The suitable water temperature for carp culture, for example, is between 24 and 30°C. In their natural environment, fish can easily tolerate the seasonal changes in temperature, e.g. a decrease to 0°C in winter and increase to 20-30°C (depending on species). Increase in temperature can cause stress and expose them to disease. Fish kill can be caused by a variety of factors including dissolved oxygen depletion, extreme water temperatures, fish diseases or introduction of pollutants. Most fish kills are natural events.

Secchi disc is an all white or a black and white metal disc which can easily be made by hand. The disc is attached to a cord that is marked every 5 cm along its length (Assiah et al*.,* 2004). Turbidity is the decreased ability of water to pass on light caused by suspended particulate matter and phytoplankton. Secchi disk transparency from 30 to 40 cm shows optimum productivity of lake and 50 cm is high. Algae, microscopic aquatic animals, water color, and suspended sediment interfere with light penetration and lessen water clarity. Hence, secchi transparency is considered an indirect measurement of how much algae and sediment is in the water (Tushar, 2012).

Cyprinids types of fish species have less demand than other fishes; they can succeed in water containing 6-8 mg/L DO and show signs of suffocation only when the oxygen concentration falls to 1.5-2.0 mg/L. Increase in water temperature from 10 to 20°C doubles the oxygen demand; a higher total weight of fish per unit volume of water can lead to increased activity and increased respiration as a result of overcrowding (Svobodová et al., 1993). Tilapia fish prefer >5 mg/l and tolerate 3-4 mg/L of DO level (Lloyd, 1992). Alkalinity is the total sum of ions reacting to neutralize hydrogen ions when an acid is added to water. The ideal value for fish is 50-300 mg/L (Santhosh and Singh, 2007). With low levels of oxygen in the water, lower concentrations non-dissociated ammonia can kill fish.

Fish populations are highly dependent on the variations of physicochemical characteristics of their aquatic habitat which supports their biological functions (Mushahida-Al-Noor and Kamruzzaman, 2013; Blaber, 2000; Furhan et al., 2004; Koloanda and Oladimeji, 2004; Ojutiku and Kolo, 2011). The availability of good water quality is important for all fish farming systems but water quantity is even of greater importance for fish farming systems. Right through the century’s fish has been vital element of humans’ food. The need to improve fish yield by farming became a critical matter (Carballo et al, 2008). Phytoplankton produces carbohydrate using sunlight and releases oxygen. This is the major source of energy and oxygen in the ecosystem. Zooplanktons living on the phytoplankton form major source of food for fishes (Santhosh and Singh, 2007).

In winter, fish are commonly killed by suffocation in polluted storage ponds and in summer this often happens in polluted water courses with high temperatures and low flow rates. Oxygen deficiency causes asphyxiation and fish will die, depending on the oxygen requirements of the species and to a lesser extent on their rate of adaptation. Fish exposed to oxygen deficient water do not take food, collect near the water surface, gasp for air (cyprinids), gather at the inflow to ponds where the oxygen levels are higher, become torpid, fail to react to irritation, lose their ability to escape capture and ultimately die (Svobodová et al., 1993). The dissolved oxygen (DO) is the most important source of the aquatic atmosphere and photosynthetic process for the green plants and also a determining factor of the water quality of an aquatic ecosystem (Rajeev and Ajay, 2010).

Generally, phytoplankton development in waters is determined by the same physical and chemical parameters like temperature, light availability, nutrients. Chlorophyll-a concentration is also determined as a measure of phytoplankton biomass (Hötzel and Croome, 1999). A Secchi disk is used to estimate phytoplankton density and the fertility of lake. This study aims to study the physicochemical characteristics of the Lake and provides reason for sudden fish death.

Physicochemical feature of water has direct effect on survival, growth, reproduction and distribution of fishes. Any improper environmental characters threaten the life of fish. Quality of water is, therefore, an indispensable factor to be considered when planning the production of fish (Mallya, 2007). The chemistry of natural surface waters is complex and is based on the equilibrium reached with the normal physical, chemical and biological characteristics of the surrounding (Bronmark and Hansson, 2005). Therefore, the present study was conducted to find out the information about the Physico-chemical parameters of Kabo Lake water for the first time and find out possible reasons for sudden fish death. So, the result of this study may provide primary data about the lake for further scientific study, help to extend sustainable lake management, monitoring of water quality, indicate the problem of the lake identified and recommend accordingly and point out possible solutions.

MATERIALS AND METHODS

Description of the study area

Lake Kabo is a small, circular and natural lake located in Ethiopia in Gambela Regional State, Majang zone, Godere worada, Gubeti kebele (Ethiopia). It is located about 651 km from Addis Ababa and 40 km far from Teppi town. It lies at Latitude: 7°18’10.36’’N and Longitude: 35°16’5.42’’ E, at an elevation of 1397 m above mean sea level.

Sampling technique and sample collection methods

Four sampling stations on the lake were taken to identify and analyze the problem of the Lake. These selected sites were according to the iterance of water to the lake, the exit site of water out of the lake and area mostly preferred by fish or traditional fishing activity performed. Samples were taken from all four selected stations every month starting from October 2017 to August 2018 in the morning by direct immersing of polyethylene vessels (PVC) just below the surface of the lake at the depth of 50 cm. Sites on the lake’s body coded SS1 for entering of small river into the lake, SS2 (exit site of the lake), SS3 (at the center of the lake) and SS4 (sites of fishery activities performed by local society traditionally).

Experimental methods and procedures

One liter of water sample from each sampling station was taken and placed in a polyethylene bottle, coded and transferred cold to the laboratory for analysis as per the standard methods suggested by APHA (1992). The samples were analysed in triplicate. Samples for pH, temperature (T°), transparency, TDS (total dissolved solid and electrical conductivity (EC) were analyzed *in situ* using a portable standard laboratory pH meter (pH 600, range 0.0/14 pH, accuracy + 0.1); electrical conductivity (EC) was determined by portable EC meter (conductivity meter cc–101, Elmron I P67 model). Water samples for DO and total alkalinity were analyzed in the Teppi National Soil Laboratory. All field meters and equipment were checked and calibrated according to the manufacturer’s specification. Total alkalinity was estimated titrimetrically using 0.02N, HCl with Bromocresol Green and DO was measured titrimetrically based on Winkler method/procedure. The transparency of the lake was determined with the aid of the Secchi disc. The disc was lowered into the water and the depth at which it disappeared was observed and recorded. It was there after gradually withdrawn from the water and the depth at which it became visible was noted and recorded. The transparency of the water body was calculated as the mean of the two readings.

The Lake water was analyzed for its minerals following AOAC (1990). Sample (0.5 L) was digested by using HNO_3 and perchloric acid at ratio of 7:3 on hot plate until solution turned colorless. Digested sample was diluted for mineral analysis. Sodium, potassium and calcium were calculated on Flame Photometer-410 (Sherwood Scientific Ltd., Cambridge); on the other hand, copper, iron, magnesium and phosphorus were determined through Atomic Absorption Spectrophotometer (Varian AA240, Australia).

Statistical analysis

Comparison of physicochemical characteristics of the lake water was made with WHO standards (1993), BIS standards (1991) and other related documents. The data were exposed to descriptive statistical analysis. Statistical package for social sciences (SPSS version 19) was used to govern the mean, standard deviation and range values. Pearson correlation was performed using simple Pearson correlation method. The results of water parameters were also compared with water quality standards to check whether the lake water is within the acceptable range to fish or not.

RESULTS

Monthly physicochemical analysis was made in different parameters. The maximum pH was registered in March (8.7), TDS (251.3 mg/L) in June, TA (195 mg/L) in August and February, EC (191 mg/L) in August, DO (4.7 mg/L) in June and the maximum temperature was 24.6°C in the month of April (Table 1). The annual mean temp., pH, TDS, total alkalinity, EC and DO of the lake were 23°C, 7.65, 205.64, 173.3 and 4.34 mg/L respectively (Table 2). The annual mean DO value of the Lake Kabo was 3.033±0.18 to 4.2 ± 0.24 mg/L. The least value was 2.8 mg/L while 4.7 mg/L was the maximum DO value (Table 2). The annual mean values of PO_4^{-3}, Chlorides and Ca^{++} were 0.1, 1.5 and 7.6 mg/L respectively (Table 3).

DISCUSSION

Most waters are suitable for fish production, although tolerance to different water quality parameters varies among fish species. The physiochemical characteristic of water is important determinant of the aquatic system. Their characteristic is greatly influenced by climatic vegetation and general composition of water. The lake was surrounded with larger natural forest trees and the location of the lake can be the reason for preventing sun ray to reach water surface.

pH regulates most of the biological processes and biochemical reactions. The pH showed fluctuation throughout the study period showing monthly range of 6.1-8.7 and annual mean of 7.65 ± 0.835) (Table 1). The maximum value of pH was recorded at sampling station SS4 (site from River entry, in the month of July) which is 8.7 and the minimum value of pH was recorded at sampling station S1, (recorded 6.1 in the month of August). The maximum mean value of pH was recorded at the SS1 (7.71 ± 0.9) and the minimum value was 7.6140 ± 0.9 at SS3. The result of this study revealed that the pH value for all analyzed samples was within the range of the acceptable limits set by BIS (1991) for different fish species. The pH showed strong positive

Table 1. Monthly value of physicochemical parameters of the Lake (0ct 2017-July 2018 G.C)

Par	T°				pH at 25 ºC				TDS at 180 ºC			
Month	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Oc	21	22	19	18	7.8	7.55	7.2	7.6	155	170	175	185
N	23.6	22.6	20	19	7.7	7.5	7.54	7.7	157	175	188	193
D	23	2	22	21	8.3	8.0	8.4	8.2	160	160	170	165
F	23.6	22.8	21	20	8.3	8.4	8.5	8.4	180	169	162	168
M	23	23	20	21	8.6	8.5	8.6	8.7	100	60	80	120
A	24.6	23.7	19	18	8.4	8.4	8.3	8.4	201	198	195	205
M	24	22	19	19	8.2	8.1	8.0	8.0	220	210	222	201
J	23	22.1	22.8	18.6	7.5	7.34	7.1	6.5	251.3	242	251	250
J	21	22.5	22	20	6.2	6.4	6.3	6.5	198	210	170	251
A	20	19	19	20	6.1	6.2	6.2	6.4	170	160	210	230
Month	Talk				EC at 25ºC				OD			
S	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Oc	178	169	183	179	98	103	120	155	2.9	3.0	4.0	4.2
N	182	101	182	192	101	119	132	139	3.0	3.5	4.5	4.0
D	180	172	184	172	107	106	110	104	2.9	3. 0	3.5	4.5
F	175	170	195	190	115	120	115	108	3.1	3.5	4.3	4.0
M	170	181	172	189	105	90	98	103	3.3	3.0	3.9	4.2
A	168	167	191	193	103	121	120	128	2.8	2.9	4.2	4.0
M	151	158	162	170	119	129	130	98	2.9	3.0	4.3	4.2
J	159	161	153	150	171	160	178	170	2.9	3.0	3.4	4.7
J	183	162	172	189	135	165	133	171	3.3	3.0	3.0	4.5
A	180	173	179	195	130	121	191	168	3.3	3.8	4.0	4.2

Table 2. The annual minimum, maximum and mean value of DO of the Lake **Kabo** based on sampling site (2017/2018)

Sampling stations	N	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Std. Deviation
SS1	10	2.800	3.300	3.033	±0.177525
SS2	10	2.900	3.800	3.1416	±0.287492
SS3	10	3.000	4.500	3.8416	±0.503548
SS4	10	4.000	4.700	4.2083	±0.239159

Table 3. Annual physicochemical value (mg/L) of Lake Kabo (2017/2018 G.C)

Parameter	Mean value	Minimum and Maximum Value (mg/l)
T (°C)	23± 1.57928	(19.00-25.10)
pH	7.6508±0.83468	(6.10-8.70)
TDS	183.43± 64.89287	(60.00-320)
TA	172.85±16.87693	(101.00-195.00)
EC (µS/cm)	127.22±41.01139	(90.00-191.00)
DO	3.5800± 0. 59191	(2.80-4.70)
Ca++	7.6112±2.59149	(2.00-11.80)
PO_4^{-3}	0.1039±0.14598	(0.02-0.99)
Chloride (Cl^-)	1.5102±0.67688	(0.89-3.00)

correlation with T° (0.727) p value < 0.01 and negatively correlated with EC (-0.601) and TDS (-0.832) significantly at 0.01. The range obtained in this investigation was in line with the value suggested by Assiah et al. (2004).

Table 4. Pearson Correlation statistics of different parameters of Lake water (Lake Kabo/ 2016/2017).

Parameter	pH	T^0	T.al	DO	EC	TDS
pH	1	0.727**	0.078	0.243	-0.601**	-0.832**
T^0	0.727**	1	-0.109	0.399*	-0.614**	-0.574**
T.al	0.078	-0.109	1	0.197	0.103	-0.087
DO	0.243	0.399*	0.197	1	-0.289	-0.184
EC	-0.601**	-0.614**	0.103	-0.289	1	0.569**
TDS	-0.832**	-0.574**	-0.087	-0.184	0.569**	1

**Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2 tailed).

In present study, the lowest value of water temperature was found in the month of August (19°C) and highest in May (25.1°C); while the annual average temperature was ~23 ± 1.6°C (Table 4). Sampling stations SS1 and SS4 scored maximum annual mean value (23.16°C) than the rest two sampling sites. The result was found below permissible limit for aquatic life as recommended by BIS (1991) (30-35°C) and Dennis et al. (2009) for tilapia fish (25-32°C) but it agreed with the report presented by Assiah et al. (2004) for fish (20- 30°C). However, the variations in water temperature may be due to different timings of collection, influence of the season and the effect of atmospheric temperature (Rajeev and Ajay, 2010).

Electrical conductivity estimates the amount of total dissolved salts (TDS), or the total amount of dissolved ions in the water. The conductivity is proportional to the amount of salts dissolved in water. In the present investigation, the lowest value of EC was obtained in October (98 μs/cm) and highest values (235 μs/cm) registered in July (Table 2), with the annual mean value of 150.59 μs/cm (Table 5). The maximum average result was registered in August (206 μs/cm and the lowest in February (108 μs/cm). The result of electric conductivity and total dissolved solid positively correlated with TDS (r=0.569). The increase in electric conductivity was completely associated with the amount of dissolved solid in the analyzed sample waters. The EC level annual mean of SS4 was significantly greater than the rest three sampling sites (158.60 ± 43.653). The result obtained during the study period was low when compared with the value specified by BIS (1991) permissible limit for aquatic life. The lower value of total alkalinity and TDS directly correlated with Na^+ and Ca^{++} concentration of the lake.

In natural water, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, Iron and manganese etc. (Esmaeili and Johal, 2005). Total dissolved solids indicate organic and inorganic matter in the sample. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. It is aggregated amount of the entire floating suspended solids present in water sample. The annual average TDS value registered in the lake was 183.43± 64.89287 mg/L and ranged from 60 to 320 mg/L (Tables 1, 3 and 5). The highest value was registered in August (320 mg/L) and the lowest was 60 mg/L in the month of March (Table 1). SS4 had the highest value and SS2 recorded the lowest annual mean value, 213.80+64.82935 and 199.7 ± 68.3 respectively. The TDS value of Lake Kabo agreed with the specified limit set by WHO (max 1000 mg/L) and BIS standard max 500 mg/L for drinking water quality standard. When the sample has low measurement of conductivity, the TDS is also consistently low at all stations.

Total alkalinity of water is the quality of water and kinds of components present in water such as bicarbonate, carbonate and hydroxide. Annual range was 101-195 mg/L with annual mean of 172.85±16.87693 (Table 3). The lowest value was registered in April (101 mg/L) and highest value obtained in the month of February (195 mg/L). The value obtained in this investigation agreed with the permissible limit set for aquatic life by BIS (1991) (max 200 mg/L) and with the document prepared by Dennis et al. (2009) for tilapia fish (100-250 mg/L). SS4 had the highest annual mean value (181.90 ± 14.25521 mg/L) and SS 2 registered the lowest value (161.40 ± 22.25 mg/L).

Fish obtain the oxygen that they require for their metabolic processes from the gas dissolved in water. The solubility of oxygen in water is low and depends on the temperature; at 5, 15 and 25°C the dissolved oxygen concentration is 12.8, 10.0 and 8.4 mg per litter respectively. Dissolved oxygen is an important limnlogical parameter indicating level of water quality and organic production in the lake. Fish exposed to deficient oxygen or fluctuation water do not take food, collect near the water surface, gasp for air (cyprinids), gather at the inflow to ponds where the oxygen levels are higher, become torpid, fail to react to irritation, lose their ability to escape capture and ultimately die (Svobodová et al., 1993).

Annual DO value ranged from 2.80- 4.70 mg/L with annual mean of 3.5800 ± 0.6 mg/L. The lowest DO value was observed in April (2.8 mg/L) at SS1 and the highest were 4.7 mg/L at SS4 in June (Tables 1 and 3). This result was found to be below minimum permissible limit set by BIS (1991) for aquatic life (5-7 mg/L). Largest DO

Table 5. Annual minimum, maximum and mean values of parameters at each sampling stations (2016/2017)

			Descriptive statistics			
Sampling	Parameter	N	Minimum	Maximum	Mean	Std. Deviation
SS1	T°	10	20.00	24.90	23.12	±1.59778
	PH	10	6.10	8.60	7.71	±.89001
	TDS	10	100.00	251.300	179.23	±4.1495
	T.al	10	151.00	183.00	172.60	±10.64790
	EC	10	98.00	171.000	118.400	±52.37907
	DO	10	2.800	3.300	3.03333	±0.177525
SS2	T°	10	19.00	24.90	22.791	±1.56678
	PH	10	6.20	8.50	7.6390	±0.81410
	TDS	10	60.00	242.000	175.40	+68.27729
	T.al	10	101.00	181.00	161.40	±22.2471
	EC	10	90.00	165.000	123.40	±36.53370
	DO	10	2.900	3.800	3.14167	±0.287492
SS3	T°	10	19.00	25.00	22.922	±1.66998
	PH	10	6.20	8.60	7.6140	±0.89204
	TDS	10	80.00	251.00	182.30	±70.43723
	T.al	10	153.00	195.00	177.30	±12.84134
	EC	10	98.000	191.000	132.700	±34.19231
	DO	10	3.000	4.500	3.84167	±0.503548
SS4	T°	10	20.00	25.10	23.16	±1.70633
	PH	10	6.40	8.70	7.64	±0.87331
	TDS	10	120.00	251.000	196.800	±64.82935
	T.alk	10	150.00	195.00	181.90	±14.25521
	EC	10	98.000	171.000	134.400	±43.65318
	DO	10	4.000	4.700	4.20833	±0.239159

value was recorded at sampling site coded as SS3 and SS4 (Table 2). These sites were identified as sites where fish are abundantly located on the lake. The annual DO mean value and monthly value of the Lake Kabo at SS1 and SS2 were below the minimum permissible limit for fish and aquatic life as suggested by WHO (1993)/BIS (1991). The only fish species inhabiting the lake was tilapia type of fish and other fish inhibit the lake not found at the time of study. Tilapia fish prefer >5 mg/L and tolerate 3-4 mg/L of DO level (Lloyd, 1992). Values lower than this can put fishes to stress and levels reaching less than 2 mg/L may result to death. The dissolved oxygen (DO) is the most important source of the aquatic atmosphere and photosynthetic process for the green plants and also a determining factor of the water quality of an aquatic ecosystem (Rajeev and Ajay, 2010). In this finding the less DO level registered (<4 mg/L) in 75% of lake sites was suggested problem for fish death on Lake Kabo. The reduced level of DO is due to the stirring effect of the in-coming flood towards the lake resulting in the mixing of surface waters to reduce pH (Figure 1).

Clarity of lake water is affected by algae, soil particles, and other materials suspended in the water. However, Secchi disk depth is primarily used as an indicator of algal abundance and general lake productivity. Although it is only an indicator, Secchi disk depth is the simplest and one of the most effective tools for estimating a lake's productivity. The Secchi disk values can help to estimate the low concentration of chlorophyll, algae and TSS present in the lake. The Secchi disk value obtained in this study ranged from 35-66 cm and annual average value was 48.32 cm which is above the specified limit (25-30 cm) proposed by Assiah et al. (2004).

Pearson Correlation was made among the parameters identified in the study. TDS has a strong negative correlation with PH and T^0 which were r = -.832 and r= -.574, respectively; positive correlation with EC and vs. EC have negative correlation with PH and T^0 while positive with TDS. Temperature has strong positive correlation with pH (0.727) at 0.01significance level (Table 4). Biological properties are essential to determine the lake's condition and in making informed lake management decisions. In this study direct measurement of Biological parameters (Phytoplankton and zooplanktons) was not studded instead indirect estimations were conducted. Algae, microscopic aquatic

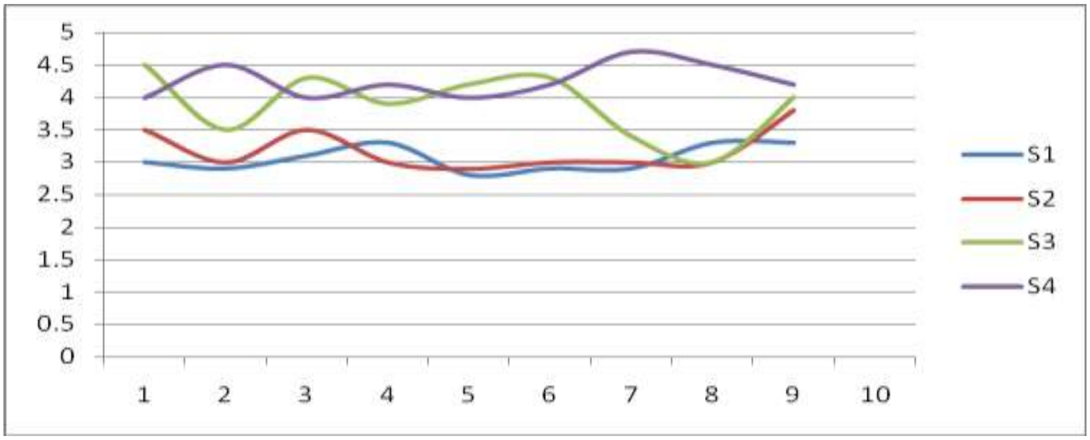

Figure 1. Fluctuation of dissolved oxygen (DO) in the Lake Kabo from the month of October to August 2016/2017 G.C.

animals, watercolor, and suspended sediment interfere with light penetration and reduce water clarity. Hence, secchi transparency is considered an indirect measurement of how much algae and sediment is the water. The water transparence of the Lake Kabo (Secchi depths ranged from 35-66 cm) which is the indication of very clear water deficient of microscopic organisms**.** The Secchi disc values obtained in this investigation indirectly showed us the low concentration of chlorophyll and algae, which can be indirect indicator for low level of DO in the lake due to their less abundance.

Calcium is an essential component for fish, and moderate calcium levels in water help in fish osmoregulation during stressful periods. The annual rage of Ca^{++} registered at the study time was 2.00 -11.80 mg/L with mean value of 7.6112 + 2.59149. Most results were under the desirable value (>20 mg/L) and similar with the acceptable range > 5 mg/L. PO_4 is a component of most waters; it recorded value obtained in this study ranged from 0.02-0.99 mg/L with annual mean of 0.1039 + 0.14598 mg/L, and for Chloride, it ranged from 0.89-3.00 mg/L with annual mean value of 1.5102 ± 0.67688 mg/L (Table 5).

Conclusion

From the result obtained during the study period, major conclusions were drawn. The Physicochemical water quality of Lake Kabo at the study time revealed that water dissolved oxygen (mg/l), temperature and pH level fluctuation were found as the reasons for the sudden death of the fish.

RECOMMENDATIONS

The critical problem of the lake was fluctuation of DO and pH level. So, it is recommended that the level of phytoplankton in the lake should be enhanced through wise use of minerals for their growth and farther production of oxygen. Forest canopy that prevents the penetration of sun light should be avoided.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Full Length Research Paper

Age, growth and mortality rates of round sardinella, *Sardinella aurita* (Valenciennes, 1810) from the Senegalese coasts (West Africa)

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***Sardinella aurita* is the main species exploited by small-scale fisheries in Senegal and represents an important source of low cost protein in the Senegalese market. The objective of this study was to determine the age, growth and mortality parameters of *S. aurita* obtained from the Senegalese coastal waters. Age, growth parameters and mortality rates of this species were estimated using FiSAT II (FAO–ICLARM Stock Assessment Tools) software. A total of 5104 specimens of *S. aurita* were collected monthly between March 2012 and February 2013 from commercial landings in three sites of Senegalese coasts (Joal, Mbour and Kayar). Mean growth parameters for the entire period were estimated as L_∞= 32.82 cm, K= 1.10 year^{-1} and t_0 = -0.14 year. Instantaneous total mortality (Z = 2.77 year^{-1}) coefficients per year were estimated using catch curves and methods based on the mean length of the fish caught. Natural mortality (M = 1.49 year^{-1}) was estimated using the Pauly's empirical equation and fishing mortality (F = 1.28 year^{-1}) by the difference between total and natural mortality values. The exploitation rate (E) of 0.46 indicated no over-fishing on this species.**

Key words: Round sardinella, age, growth, mortality, Senegalese coast.

INTRODUCTION

Senegal has one of the most productive fishery resources along the West African coast. The EEZ is famous being among the full of fish zones in West Africa.

Clupeiform fishes are important because of their high biomass and their role in marine ecosystems. *Sardinella aurita* (Valenciennes, 1810) was selected for the present study. It is a small pelagic fish that lives in tropical and subtropical waters of the western and eastern Atlantic Ocean, the Pacific Ocean, the Mediterranean and, occasionally, the Black Sea (Sabate et al., 2006). According to the Department of Maritime Fisheries the round sardinella, *S. aurita* dominates the fish captures with nearly 38% of the unloading in 2011. The round sardinella is a mid-sized pelagic fish that represents one of the most important commercial fishery resources in the Senegalese coasts.

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Figure 1. Map of the study area with sampling sites.

This species is of paramount economic interest in the national economy. The exploitation of this stock generates employment, incomes, foreign currencies, and contributes to the population's food safety. The round sardinella is a marine pelagic fish that is widely distributed throughout the tropical and subtropical seas of the world, including the entire Mediterranean and the Black Sea (Froese and Pauly, 2003). It is a key species inhabiting the ecosystem of the northwest African upwelling region (Bard and Koranteg, 1995). It is intensively exploited and crucial to the economies of the West African countries. Indeed, this fish is the primary species fished in Senegal, and the second in Mauritania, with total landings exceeding 500,000 tons per year (Corten et al., 2012; FAO, 2013). According to Fréon (1998), the Senegalese-Mauritanian stock which extends from Mauritania (26°N) to Guinea (10°N) is most important in West Africa. In Senegal, very few data exist on its biology in general and its growth in particular. Indeed, data related to the growth parameters of *S. aurita* in Senegal were obtained by Boely et al. (1982), Boely (1983), Camarena-Luhrs (1986) and Fréon (1998). The methods used to determine the growth were subjective (method of Petersen) or unsuited to the tropical medium. Thus, it seemed important to bring up to date the principal growth parameters of this species with the aim of improving comprehension of their biological cycles, and of contributing to the evaluation of stocks and their management.

Moreover, scientific studies on sardinella in the North East Atlantic are considered insufficient and a lack of biological monitoring for several years has been reported (CSRP, 2012). Therefore, it appears difficult to make a good stock assessment to estimate the recruitment and identify different segments of the exploited stock. All these lacks make it necessary to conduct additional research.

The present study aims to determine age, growth and mortality parameters of *S. aurita* obtained from the Senegalese coastal waters.

MATERIALS AND METHODS

Study area

The study was carried out in Senegalese coasts. Fishes were collected from commercial landings in three sites of Senegalese coasts: Joal (14.10°N; 16.51°W); Mbour (14.24°N; 16.58°W) and Kayar (14.55°N; 17.07°W) (Figure 1). The hydrology of the Senegalese coast is characterized by seasonal upwelling. This phenomenon supports the phytoplankton development, which forms the base of the food chain.

Sampling strategy

A total of 5104specimens were collected from March 2012 to February 2013 by monthly random sampling of artisanal purse seine nets catches in three landing sites: Kayar, Mbour and Joal. The artisanal purse seine is an active net in which the fish is captured by surrounding.

For each sampled fish, the total weight (T_W) was recorded to the nearest 0.1 g and the fork length (L_F) was measured to the nearest cm. The length data were analyzed to study the age and the growth. The monthly length frequencies were grouped into classes of 1 cm interval and were laid out sequentially over one year to estimate the growth.

Age and growth parameters

To estimate the age and growth parameters from length frequency data, monthly length frequency distribution was constructed. The Data were analyzed using FiSAT II (FAO–ICLARM Stock Assessment Tools) software.

The routine incorporated in the FISAT II software (Gayanilo et al., 1994), assumes that a seasonally oscillating version of the von Bertalanffy equation is used to describe the growth in length of the fish studied; specifically, it uses Somers' (1988) modification of the seasonal growth model of Pauly and Gaschiitz (1979):

$$L_t = L_\infty\,[1-e^{-k(t-t_0)+St_s-St_0}]$$

Where, L, is the length at age t, L∞, the mean length of the fish would reach if they were to grow indefinitely, K is the von Bertalanffy curvature parameter, to the theoretical age at which

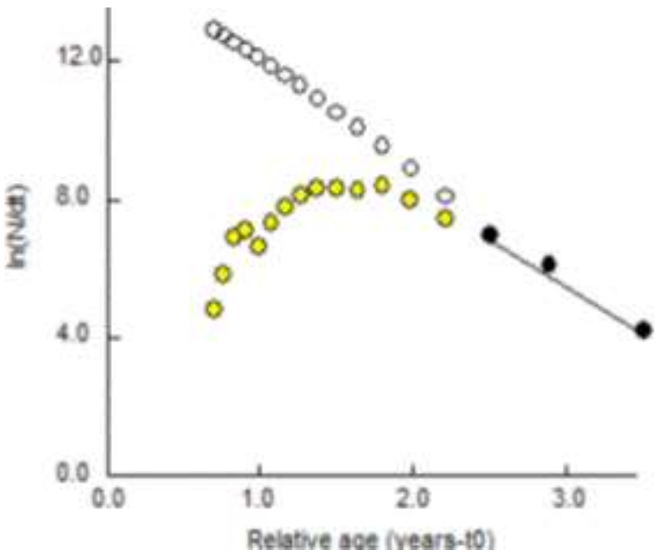

Figure 2. Length-converted catch curve for *S. aurita* based on the length frequency distribution.

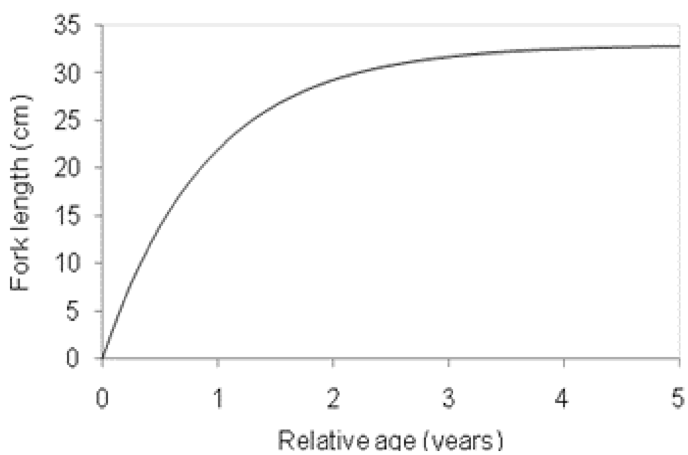

Figure 3. Linear growth curve of von Bertalanffy for *S. aurita.*

length is zero, where $St = (CK/2\pi)\sin 2\pi(t-t_s)$, $St_0 = (CK/2\pi)\sin 2\pi(t_0-t_s)$, and C and t_s describe the amplitude and timing, respectively, of the seasonal growth oscillations. This equation reduces to the standard von Bertalanffy model, $L_t = L_\infty\,[1-e^{-k(t-t_0)}]$, when C=0. C can take values generally ranging from zero (in tropical fishes) to unity (in temperate fishes) (Gaschütz et al., 1980). The seasonal parameters (C) and (WP) were used for a better adjustment of the growth curves. C indicated the amplitude of oscillations of the growth speed and (WP) the year time during which the growth is minimal.

In the present study, C was fixed at 0.1 and WP at 0.15,and t_s = WP-0.5.

The growth curves index of adjustment (R_n) identifies the growth curve which was adjusted best with the whole size frequencies data. R_n varied between 0 and 1 and its maximum value corresponds to the best combination between L∞ and K.

ELEFAN estimates only two of the three growth parameters (L_∞ and K). The theoretical age at birth (t_0) was calculated using the empirical formula:

The theoretical age at birth (t_0) was calculated using the empirical formula:

$$\text{Log}(-t0) = -0.3922 - 0.2752\times\text{Log}(L_\infty) - 1.038\times\text{Log}(K)$$

The growth index performance (ϕ') of *S. aurita* was calculated from the equation:

$$\phi' = 2\times\text{Log}(L_\infty) + \text{Log}(K)$$

Mortality rates

The annual instantaneous rate of mortality (Z) was estimated by the average of length-converted catch curve method as implemented in FiSAT II (Pauly and Munro, 1984). Natural mortality rate (M) was estimated using Pauly's empirical relationship, with a mean surface temperature (T) of 25.5°C:

$$\text{Ln}(M) = -0.0152 - 0.279\times\text{Ln}(L_\infty) + 0.6543\times\text{Ln}(K) + 0.463\times\text{Ln}(T)$$

Where, M is the instantaneous natural mortality, L∞ is the asymptotic length, T is the mean surface temperature and K refers to the growth rate coefficient of the von Bertalanffy growth function. The fishing mortality (F) was calculated as F =Z – M in order to estimate the exploitation rate (E) by the equation E =F/Z.

RESULTS

Age and growth parameters

The average values of von Bertallanfy growth function plot and length frequency estimated the asymptotic length (L_∞) value at 32.82 cm and the growth constant (K) at 1.10 year^{-1} (Figure 2). The t_0 value calculated using Pauly's formula was -0.14 year. The alignment of points on the straight line was quite satisfactory with a higher coefficient of correlation (0.99). Using the growth parameters (L_∞, K and t_0), the von Bertalanffy growth function for length at time (t) was expressed as (Figure 3):

$$Lt = 32.82\,[1-e^{-1.1(t+0.14)}]$$

Figure 4 shows the restructured length frequency with superimposed growth curves with bimodal population structure, indicating probably the existence of four cohorts within the population. On these graphs, the number of lines represents the cohorts.

The round sardinella growth was very fast at the first year, it reached 22 cm. At the second year the growth slowed down and at the end of the third year it reached its maximum size 31 cm with a longevity, which exceeded 5 years (Figure 5).

The growth performance index value (ϕ') was estimated at 3.01 for *S. aurita* in Senegalese waters.

The amplitude of oscillation (C) for the first troop was 0.1, the winter point (WP) was 0.15 and the adjustment index

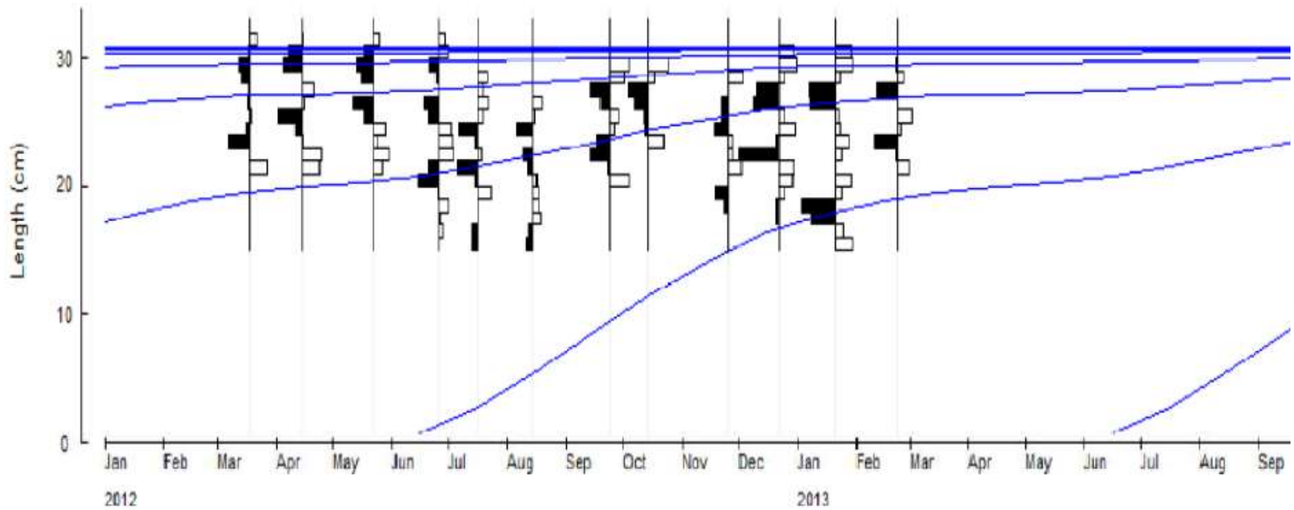

Figure 4. Seasonalized von Bertalanffy growth curve of *S. aurita* superimposed over the original length-frequency histograms and the restructured length-frequency histograms.

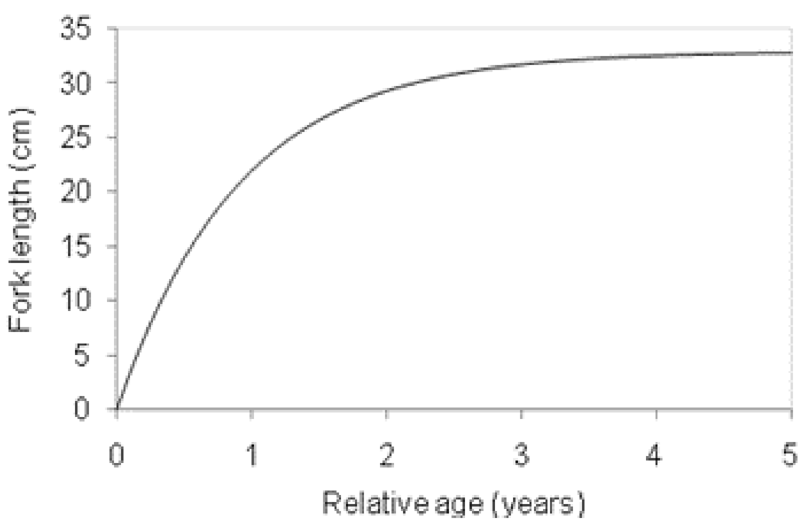

Figure 5. Growth curve of von Bertalanffy of *S. aurita* captured in Senegal.

(R_n) was 0.19 (Table 1). The largest class was 32.5 cm.

Mortality rates

The calculated mortalities from FiSAT II output of the length converted catch curve are shown Figure 2.The total mortality coefficient (Z) of round sardinella was relatively high estimated as 2.77 year^{-1} based on the average of length-converted catch curve method (Figure 2). The natural mortality (M) was calculated as 1.49 year^{-1} by using Pauly's method. Then, the fishing mortality (F) was obtained as 1.28 year^{-1}. The exploitation rate (E) was found to be 0.46.

DISCUSSION

The length frequency analysis (LFA) was used in the present study to estimate age and growth of *S. aurita*. In the present investigation, the growth constant (K) was estimated at 1.10 year^{-1}, the asymptotic length (L_∞) as 32.82 cm (F_L) and t_0 value was -0.14 year. The LFA showed that species might live for 5 years of life, whereas the age below two years dominated the catches. The data presented here confirmed that *S. aurita* is a fast-growing species (K = 1.1; ϕ' =3.07).

Growth parameters obtained in this study were compared with those found in tropical Atlantic and in Mediterranean (Table 2). Pham and Szypula (1973)

Table 1. Adjustment parameters of growth curves.

Growth parameters of *S. aurita*						
L_∞	K	C	WP	SS	SL	R_n
32.82	1.10	0.1	0.15	5	21.5	0.19

C = seasonal version parameter; WP = winter point; SS = initial sample; SL = initial length.

Table 2. Ageing methodology used and growth parameters calculated in the present study from the growth parameters originally reported and in others studies for round sardinella.

Study area	Method	Length (cm)	L_∞	K	t_o	ϕ'	Authors
Senegal	Length frequency	F_L	32.82	1.10	- 0.14	3.07	Current study
	Otolith	F_L	26.70	1.79	0.55	3.11	Samba (2011)
	Length frequency and scales	F_L	30.63	1.21	- 0.06	3.06	Boëly et al. (1982)
	Length frequency and scales	F_L	31.23	0.97	0.21	2.98	Boëly (1980)
Mauritania	Scales	F_L	34.60	0.33	- 0.63	2.60	Pham-Thuoc and Scypula (1979)
Congo	Length frequency	F_L	26.00	1.21	- 0.03	2.91	Ghénon (1975)
Mediterranean	Otolith	F_L	26.76	0.24	- 2.58	2.24	Gaamour et al. (2001)
	Length frequency		34.96	0.23	- 0.70	2.46	Bouaziz et al. (2001)
	Scales	F_L	21.37	0.51	- 0.88	2.37	Tsikliras et al. (2005)
	-----	F_L	26.00	0.53	0.34	2.55	El Maghraby et al. (1970)

found a high asymptotic length (34.6 cm) in Mauritania and a very low growth coefficient (0.33 year^{-1}). Samba (2011) found in Senegal starting from otoliths a very high growth constant (K=1.7 year^{-1}) and a very weak asymptotic length (L_∞=26.7 cm). This is explained partly by a number of much reduced sample. The growth parameters reported in Mediterranean coast of Sinai by Salem et al. (2010) (L_∞=25.83 cm, K=0.299 year^{-1} and t_0 =-0.87 year) were lower than those obtained in this study. However, results of Boely et al. (1982) (L_∞=30.63 cm; K=-1.2 year-1 and t_0=0.062 year) corroborated those found in this study. Nabil et al. (2012) obtained L_∞=28.37 cm, K=0.23 year^{-1} and t_0=-0.98 year. In Mediterranean Sea, Bouaziz et al. (1998) obtained L_∞=34.96 cm, K=0.236 year^{-1}and t_0=0.71 year in Algerian coast and Gaamour et al. (2001) obtained L_∞=31.32 cm; K=0.24 year^{-1} and t_0=0.87 year in Tunisian coast. Differences in results between authors can come from the number of examined individuals, of the interpretation of the scratches of growth or the size of the individuals considered. It is observed that the maximum size and the speed of sardinella growth in Senegal-Mauritania zone were higher than those of the other areas. That could be explained by an unfavorable environment and less food in other areas (Boely et al., 1982). *S. aurita* has a fast growth, the individuals reach 22 cm (FL) in one year, and three years a size close to the average maximum size of 31 cm. Longevity is relatively short, approximately 5 years. These results are confirmed by the studies carried out by Postel (1955), Rossignol (1955), Boely et al. (1982) and Fréon (1998), which estimate longevity beyond 5 years. The value of the parameter C (0.62) found in this study answers the biological character of the species. Indeed, according to Boely (1983), the adult individuals migrate and meet in a range of temperature of relatively narrow water (15 and 20°C).

The index of growth performance (ϕ') is considered as a useful tool for comparing the growth curves of different populations of the same species and/or of different species belonging to the same family. In this study, the value of growth performance index was ϕ'=3.01. This growth index was largest than those obtained by Gaamour et al. (2001) in the Tunisian coast (ϕ' =2.27), by Salem et al. (2010) in the Mediterranean coast (ϕ'=2.27) and by Chesheva (1998) in the Mauritanian coast (ϕ'=2.66).The mean index of growth performance Mediterranean stocks was lower than for northwest African coast (Tsikliras et al., 2005). Differences in growth parameters may be due to genetic structure, temperature, food available and diseases (Tsikliras et al., 2005).

This study provides evidence of population parameters might be used significantly to evaluate the level of exploitation of round sardinella in Senegalese coast. In the present investigation suggested by length frequency distribution, the total mortality (Z), natural mortality (M) and fishing mortality (F) were estimated at 2.77 year^{-1}, 1.49year^{-1}and 1.28year^{-1}respectively. The total mortality recorded was relatively high compared to those found in East Mediterranean Sea (North Sinai Coast) by Salem et al. (2010). He found a total mortality coefficient (Z=1.49 year^{-1}), a natural mortality (M=0.73 year^{-1}) and a fishing mortality (F=0.076 $year^{-1}$).In this study, the natural mortality (M=1.49 $year^{-1}$) was greater than the fishing mortality (F=1.28 $year^{-1}$), contrary to estimations reported by Salem et al. (2010) from East Mediterranean Sea (M=0.73 $year^{-1}$); F=0.76 $year^{-1}$). This observation could be due to the fact that *S. aurita* stock in Senegalese coastal waters is more susceptible to natural mortality conditions than to fishing gears.

S. aurita is an important resource for Senegalese inhabitants and it is well distributed all along the coastal area. The abundance of round sardinella in Senegalese waters varies seasonally. In the present investigation, the management tools were identified as spawning season and exploitation rate. The present study showed that the current exploitation of round sardinella in Senegal is not being well exploited (E = 0.46). The following management plans were advised to be applied to obtain sustainability over time. The spawning peak, eggs, larva and feeding habitat should be monitored and protected. These concerned zones should be identified and the stock managed as these species highly migrate. It was suggested to develop a selectivity gear for round sardinella targeting the marketable or legal sizes rather than the small sizes. Finally, management plans would help to improve exploitation and sustainability of round sardinella in Senegal in future.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Value chain analysis of small-scale fisheries in the High Dam Lake in Egypt

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Although, High Dam Lake small-scale fisheries is an important source of fish for residents of Aswan in Upper Egypt, there is limited information available about the performance of small-scale fisheries value chain. Structured questionnaires with fishers, traders, and processors were used to collect input and output data at each node of the chain. Focus group discussions meeting with stakeholder collected qualitative information about and critical factors influencing performance across the chain. Catch distribution composed mainly from tilapias 75%. While pebbly fish (*Alestes* spp.) and tigerfish (*Hydrocynus* spp.) accounts for 13% of catch. Fish processing is an important subsector in lake fisheries. Fishers obtained a relatively low percentage (49%) of the final consumer price. The recorded average catch per fisher 20 kg/day and the average total fishing cost in the three landing sites was EGP 5210 / t. Every 100 metric tons of fish catch and sell provides around 30 full-time equivalent jobs. This study revealed that fish stock is under pressure of overfishing. Critical factors facing the small-scale fisheries and influencing profitability are numerous. This value chain study improves our understanding of the performance of small-scale fisheries and identified limiting factors and action needed to support fisheries development in the lake.

Key words: Small-scale fisheries, value chain, tilapia, tigerfish, pebbly fish.

INTRODUCTION

High Dam Lake (known as Nasser Lake) established after the construction of the High Dam in Aswan in the 1960s. The lake in the south of Egypt and extends for more than 300 km, with a shoreline of around 7000 km (Habib and Béné, 2008). It is the most important fishery source in Upper Egypt. The Lake providing an important source of generating income and provide a livelihood for fishermen, fish traders and fish processors in Aswan and attracting large numbers of fishers from other governorates in Upper Egypt. The lake has become an important source of fish for the Egyptian markets. The fish caught from the lake represented 55% of the total catch from the inland lakes in Egypt in year 2013 (GAFRD, 2015).

Species diversity has declined in recent decades due to change of the lake ecosystem (Béné et al., 2008; van Zwieten et al., 2011; Halls et al., 2015). Four species of tilapias, *Oreochomis niloticus, Sarotherodon galilaeus, Tilapia zillii* (*Coptodon zillii*) and *Oreochromis aureus* comprise around 75% of the total catch by weight and

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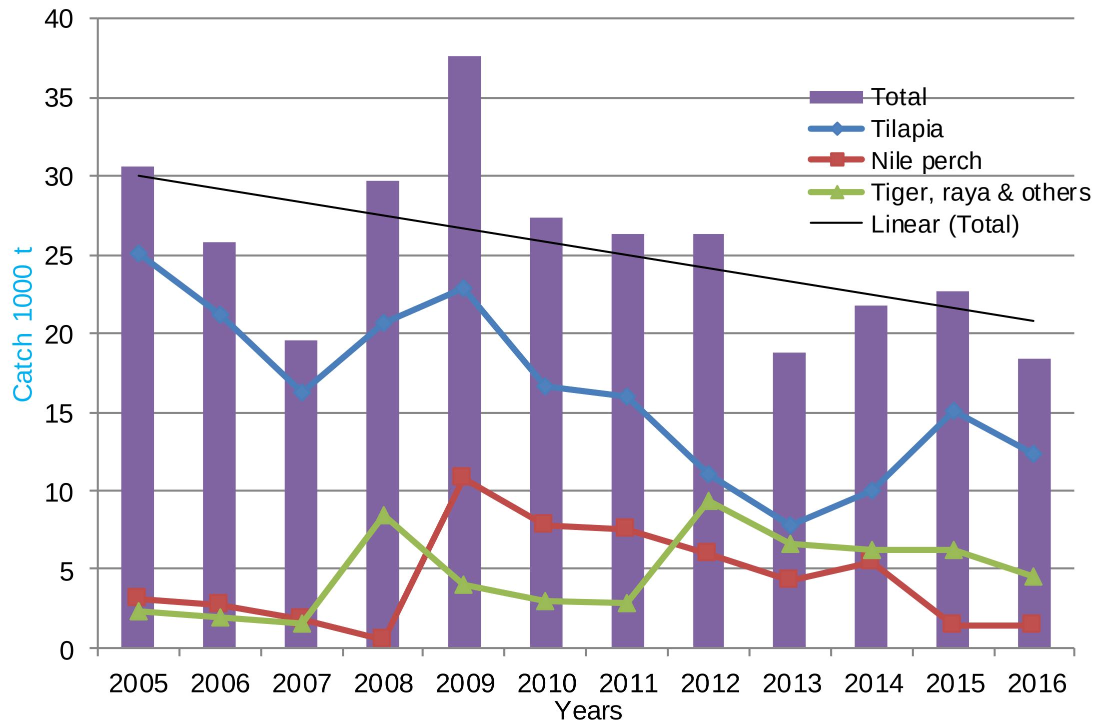

Figure 1. High Dam Lake annual catch by fish group from 2005 to 2016.
Source: GAFRD (2018).

are sold as fresh fish, while pebbly fish (*Alestes* spp.) and tigerfish (*Hydrocynus* spp.). They are important and are used as raw material to produce a traditional salted fish product (Nasr-Allah and Zakkar, 2018). Other species are recorded in the catch such as Nile perch (*Lates niloticus*), squeaker catfish (*Synodontis* spp.), sharptooth catfish (*Clarias gariepinus*), bagrus catfish (*Bagrus* spp.), and Nile carp (*Labeo* spp.). Lake yearly catch by species group from the year 2005 to 2016 are presented in Figure 1 (GAFRD, 2018). The official statistics indicate declinning catches trend gradually. Tilapia catch declined from 25 to 12.3 thousand ton during the same time. As the relative percentage of tilapia in catch declined from 82 to 67% over the time (Figure 1).

Value chain analysis is in use to understand and describe the enterprises involved in the value-chain and the financial performance across the chain (Porter, 1985; Kaplinsky and Morris, 2001; Gereffi et al., 2005; Macfadyen et al., 2012; Nasr-Alla et al., 2012; Anane-Taabeah et al., 2016). Value chain analysis (VCA) approach has become a form of analysis in the fisheries and aquaculture sectors (Veliu et al., 2009; Christensen et al., 2011; Macfadyen et al., 2011, 2012; Phiri et al., 2013; Nasr-Allah et al., 2014; Adeleke et al., 2015; Anane-Taabeah et al., 2016). Private sectors and government operators in the value chain can improve value chain performance (Riisgard et al., 2010). The private business can improve the chain performance through reducing costs, increasing output, and/or increasing the prices of their products (Macfadyen et al., 2011; Nasr-Allah et al., 2014; El-Sayed et al., 2015).

Adopting value chain analysis approach helps us to study the distribution of income for actors involved in the value-chain at each linkage and evaluate the relative importance of issues affecting competitiveness and the costs and earnings for actors involved in the value chain. It helps as well to identify the weakness in value chain performance and suggest development strategies to improve the performance of value chain actors (Macfadyen et al., 2012).

In spite of the existence of a small-scale fishery in High Dam Lake for more than 50 years, the economic and financial performance of the fishermen and different actors across the value chain, have not been performed in value chain approach. Limited information was available about the level of inputs and outputs for every node in High Dam Lake fishery value chain. As well as, limited information documented about the sector limiting factors and suggested strategy to improve value chain performance of the lake small-scale fisheries. The current paper aims to map the small-scale fisheries value chain and the flow of fish products through the chain. In addition, it helps to identify the various actors, their functions, and existing linkages across the chain. This study aims as well to conduct a preliminary analysis of the input-output structure and the distribution of margins,

Figure 2. Map of Egypt showing study area (High Dam Lake).

and job creation along the chain. Finally, this study aiming to identify the problems and opportunities facing different actors in the fisheries value chain.

MATERIALS AND METHODS

Study area and data collection

This study is limited to the fishers working at the High Dam Lake (Nasser Lake), in Aswan, at the southern border of Egypt (Figure 2). There are three officials landing sites surrounding the Lake (Aswan, Garf Hussein and Abu Simbel) (Halls et al., 2015). The secondary data indicated that there are three different enterprises in the chain. The three main actors groups identified cross the chain are fishers, traders (intermediaries, wholesalers and retailers) and fish processors. Three structured questionnaires prepared for use in the study, one per each actors group (fishers, processors and traders)[1]. Before starting fieldwork, the questionnaire was tested, and revised. The survey conducted in 2015.

In order to ensure representation of the different fishing location, fishers sample collected on a stratified random basis in the three fish ports (Aswan, Garf Hussein and Abu Simbel). Fishers interviewed at their fishing camps in the lake and/or at the three landing sites during landing their catch or sailing to their fishing areas. As fish processors are located in Aswan city, the sample selected focused only on fish processors working in the city. The sample selected for the interview from a list of processors operators. Fish traders sample selected to represent different trading activities (intermediaries, wholesalers, and retailers).

[1] Copy of the three survey forms are available in this link: https://cgiar-my.sharepoint.com/:f:/g/personal/a_allah_cgiar_org/EobPKWchTMhNs53vHKlUBWkBmyysqE3lHUanFfhRSuDkdA?e=3eeWX5

Interview of fish traders conducted in Aswan and Abu Simbel, where most of their activities were concentrated. The sample for each category considered in this study are as follows; fishers 162; processors 22 (fresh and salted processors); and traders 23 (intermediaries, wholesalers and retailers). Data from the questionnaires entered into an Excel sheet and validated for accuracy with the interviewers. Descriptive analyses of data means and standard errors conducted using Microsoft Excel to demonstrate the difference between groups.

Calculations

The questionnaires generated data on fish capture quantities, sales price and on operational and fixed costs, which allowed for the construction of costs and earnings models for each respondent group across the chain. Operating costs for fishers calculated the costs that are vary depending on the production/capture volume. Fishers operating costs include boat fuel, labor, transport, ice, food for fishers in the lake, and sales commission paid to intermediaries or wholesalers. For fish traders and processors, operating costs include fish purchase, transportation, ice/salt, fuel, electricity, and wages.

Fixed costs for fishers include fishing boat or equipment repair, fishing tools or gear and license fees. Depreciation costs for fixed cost items were calculated as described by Jolly and Clonts (1993). Annual depreciation = (Cost – Salvage Value) / Useful life. Where, salvage value calculated equal to zero assuming no value of scrape (Nasr-Allah et al., 2014). The questionnaires included questions on the number of employees at each node and classify job by nature into full-time, part-time or seasonal. The obtained data were converted into Full-Time Equivalent (FTE) jobs. FTEs estimated based on one FTE being the equivalent of 300 days per year in the fishing and processing, and 330 days FTE in the trading sub-sector as described by Macfadyen et al. (2012). Costs and earnings were calculated based on 2015 data collected in Egyptian Pounds (EGP) ($1=EGP 7.73). The financial indicators calculated included: gross output values; operational profits (gross return-operational cost) per ton and as a percentage of sales; and net profits (gross return - (operational + fixed cost)). Total value-added calculated as (net profit + wages) per metric ton sold (Macfadyen et al., 2012). The obtained data enabled the calculation of a percentage of total operational profits, net profits, and value-added throughout the chain.

RESULTS AND DISCUSSION

High Dam Lake fisheries value chain mapping

The available information about the small-scale fisheries value chain revealed that most of catch is sold as fresh on ice. Tilapia and Nile perch represent 76% of catch and are sold to middle traders and wholesalers. Pebbly fish and tigerfish represent 13.6% of catch are sold after salting. Mapping of flow of product of the small-scale fisheries in the lake is illustrated in Figure 3. Small-scale fisheries value chain in the High Dam Lake is longer that than the Egyptian aquaculture value chain (Macfadyen et al., 2012). Fish processing is an important subsector of the fisheries value chain in Aswan. The following sections summarise performance fish processing section of the chain. Fresh fish processors hold fish on average for 4–5 days and produce on average 98.4 t/year. The average sales prices of finale product is EGP 21/kg to generate annual gross revenue EGP 1.77 million/year.

By volume, degutted fish represent 84% of final product and fish fillet is only 16%. The products are sold frozen. Fresh fish processing generate value-added at average (EGP 3652/ t). Processing of fresh fish generated 5.7 FTE per 100 t of processed fish. Salted fish processors produce 71 t/year at an average sales price EGP 13.7/kg and average gross revenue EGP 0.975 million/year/ processors. By volume, pebbly fish and tigerfish represent 93% of product and the final product sold in salt in tins or jars. Processing of salted fish processing generated 5.5 FTE/100 t processed. Salted fish processing generates value-added at an average EGP 2507/t produced.

Operational and financial performance of small-scale fishing

Findings of operational data for small-scale fishers at the different fishing harbors are displayed in Table 1. The obtained data indicate that the highest catch per fishing boat per year was in Abu Simbel and lowest in Aswan. While, the highest fish sale price was in Garf Hussein and the lowest was in Aswan. The overall employment generation was 18.1 FTE/100 t of fish catch ranging from 20.8 FTE/100 t in Aswan to 15.4 FTE/100 t in Abu Simbel. The current study showed that fishing generates higher FTE compared to fish farming in Egypt. Macfadyen et al. (2011) reported that in the Egyptian aquaculture, fish farming generates 8.3 FTE/100 t of fish production.

In the three landing sites, tilapia represents most of the catch (76%). Catches of fish species for salting (pebbly fish and tigerfish) represented 13.5%. Nile perch and other species represented the remaining 10.6% of total catch. Size distribution of the catch indicates that a small-sized tilapia (< 250g) in Aswan represent (57.6%) of the total catch. While, a lower percentage small-size tilapia catches reported in Garf Hussein and Abu Simbel (43.2 and 42.7% respectively). This suggests that higher pressure in Aswan may be responsible for lower catches and higher employment levels. This study result supports the findings of Halls (2015). The authors reported that fish stock in the lake is under pressure of over fishing.

Revenue of fish sale per boat was higher in Garf Hussein and Abu Simbel landing sites compared to Aswan landing site (Table 2). This can be attributed to the higher catches quantity and sales prices in both Garf Hussein and Abu Simbel compared to Aswan. The result indicates that, average income above operating costs per boat was lower in Aswan compared to fishers` groups working in Garf Hussein and Abu Simbel. A similar trend was reported in sales revenue per boat.

Operational profit (return above operational cost) is higher for fishers working in Abu Simbel, 44% and the lowest is in Aswan, 26%. The result indicates that fixed costs were higher in Garf Hussein than Abu Simbel, while

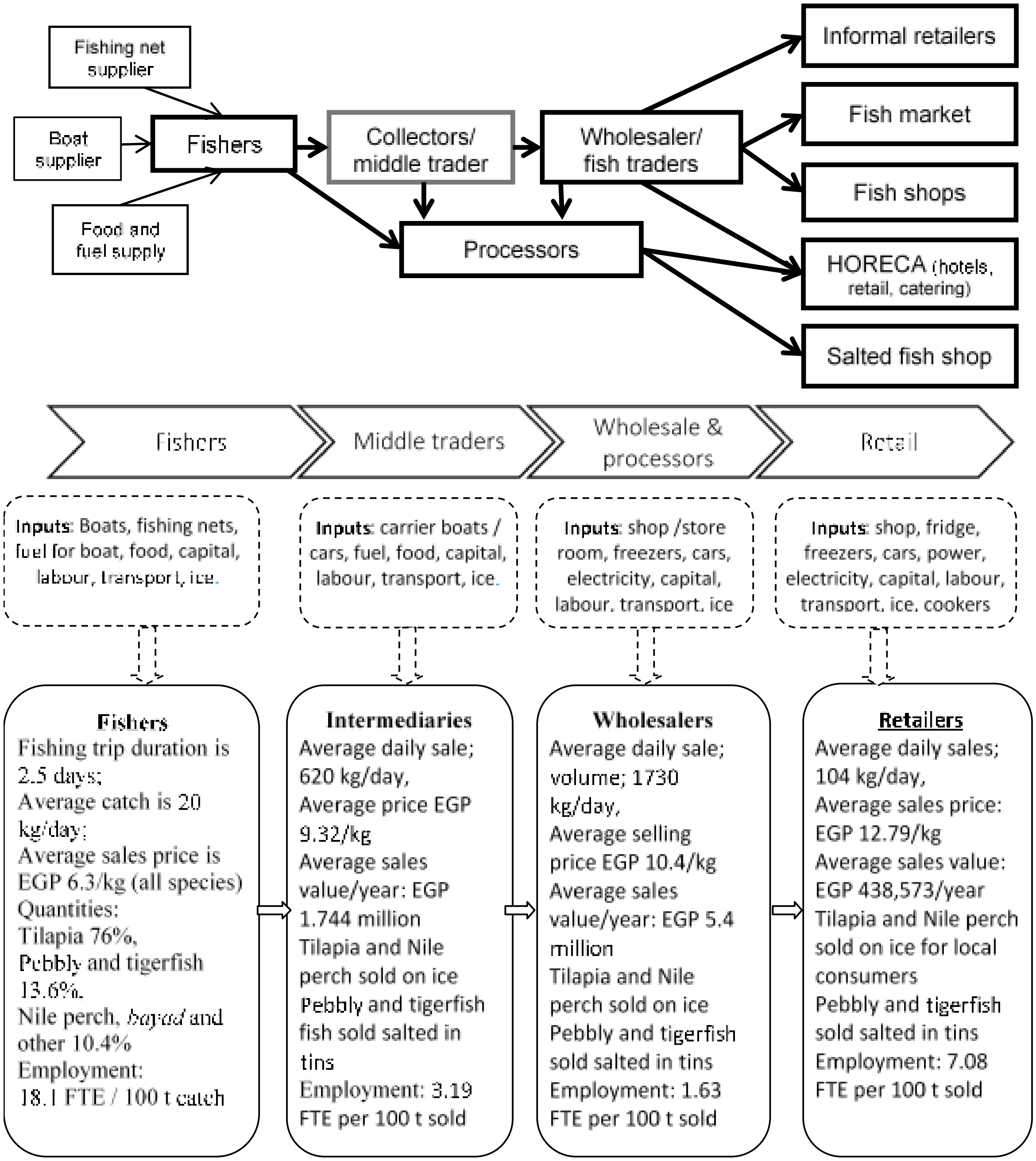

Figure 3. Value chain mapping of small-scale fisheries in the High Dam Lake.

the lowest is in Aswan. Income above total costs was similar in Garf Hussein and Abu Simbel, while Aswan recorded the lowest. Fishers in Aswan landing site generates the lowest net profit as a percentage of sales 5%, while the other two fishing locations 20-21%, giving an overall average of 15% in the lake. Value added calculated as described by Macfadyen et al. (2012) as follows = revenue – (operational and fixed costs), excluding labor costs from operational costs. Estimation of value-added per ton showed that the lowest is in Aswan and the highest is in Garf Hussein, with an average of EGP 3172/t. A lower value-added reported in Egyptian aquaculture sector by Macfadyen et al. (2012) with an average of (EGP 2989/t of fish sold).

Operational and financial performance of fish traders

Three actor groups are working in fish trade subsector. These actors' groups are intermediaries, wholesalers and

Table 1. Detail of operational data for the small-scale fishing activity in the High Dam Lake.

Operational data	Aswan	Garf Hussein	Abu Simbel	Pooled
Number	55	51	56	162
% have license	82%	98%	70%	83%
Fishing experience (yr)	19 ±1.4	29 ±1.8	24 ±1.7	24
Catch (kg/boat/yr)	10,651±342	12,995±410	13,907±345	12,506
Daily catch (kg/boat/day)	36 ±1.1	43 ±1.4	46 ±1.1	42
Average FTE/100 t	20.8 ±0.8	18.4 ±0.6	15.1 ±0.5	18.1
Sales price (EGP/kg)	5.4 ±0.2	7.2 ±0.3	6.2 ±0.2	6.3
Catch distribution (%)				
Tilapia	80.8	64	82.6	76
Nile perch	7.8	9.6	2.7	6.4
Pebbly fish	5.8	7.0	9.7	7.7
Tigerfish	2.5	11.4	3.2	5.8
Catfish *	2.8	6.4	1.5	3.5
Bayad and Others	0.3	1.9	0.2	0.7

Source: Survey data
* Catfish include (Squeaker and Sharptooth).

Table 2. Summary of financial performance of small-scale fishing in the High Dam Lake.

Financial performance data	Aswan	Garf Hussein	Abu Simbel	Pooled
Fish sales (EGP/boat/yr)	57,767±2.506	92,720±3.366	86,383±3.054	78,621
Operational cost (EGP/boat/yr)	40,293±1.512	51,517±1.699	47,895±2.025	46,447
Income above operational cost (EGP/boat/yr)	17,474±2.028	41,444±3.048	38,55±2.541	32,273
Operational cost (EGP/t catch)	3,912±154	4,059±137	3,466±131	3,807
Operational profit (EGP/t)	1,560±176	3,253±259	2,772±175	2,511
Operational profit/sales (%)	26 ±2.9	42 ±2.2	44±2	37
Labor cost (EGP/t)	2,187±87	2,206±73	1,812±59	2,065
Fixed cost per boat (EGP/yr)	12,264±970	20,977±1.581	18,831±929	17,269
Total cost per boat (EGP/yr)	52,557±2.116	72,493±2.678	66,726±2.506	63,717
Income above total cost (EGP/boat/yr)	5,209±1.872	20,468±2.859	19,724±2.766	15,004
Fixed cost per metric ton (EGP/t)	1,158±86	1,73±146	1,398±87	1,403
Total cost (EGP/t catch)	5,071±154	5,732±137	4,865±131	5,210
Net profit (EGP/t)	401±168	1,580±240	1,374±202	1,107
Net profit/sales (%)	5±3	20±2.7	21±2.7	15
Value added per ton (EGP/t)	2,588±144	3,786±242	3,186±184	3,172

Source: Computed survey data.

retailers. Intermediaries are the trader group own or manage fish carrier boats and collect fish from fishing camp to deliver to wholesalers in the landing sites. However, the liberation of fish trade in year 2001, pickup trucks replaced in some cases carrier boats and intermediate traders started to use a truck instead of carrier boats (Béné et al., 2009; Halls et al., 2015). Transportation by car is faster than using carrier boats and can collect fish from fishers all around the lakeshore rather than the three landing sites. The introduction of cell phones technology allows the intermediaries trader to arrange with fishers for lakeside meetings to collect their catch. This enables transporting fish to wholesalers in a shorter time. Landing at non-official sites where there is no catch recording system. Wholesaler trader group have land-based fish storage facilities and are able to sell fish in bulk to markets outside Aswan (to other Upper Egypt governorates and El-Obour market in Cairo). Wholesalers sell a small proportion of fish catch to retailers in Aswan markets.

Fish trader operational characteristics and financial performance are displayed in Table 3. The study result

Table 3. Fish trader operational and financial performance.

Parameter	Intermediaries	Wholesalers	Retailers	Pooled
Sample size	8	5	10	23
Operational data				
Annual sales volume (t/yr)	187 ±22	519 ±121	34 ±7	-
Daily sales volume (t/day)	0.62 ±0.07	1.73 ±0.4	0.104 ±0.02	-
Average FTE/100 t of sales	3.19 ±0.5	1.63 ±0.4	7.08 ±0.9	4.5
Sales price (EGP/kg; all species)	9.32 ±0.4	10.40 ±0.6	12.79 ±0.7	-
Daily sales value (EGP/day)	5,815 ±812	18,003 ±3,838	1,462 ±398	-
Financial performance				
Annual sales value (EGP/yr)	1,744,425±243,647	5,400,780±1,151,466	438,573±119,393	1,971,523
Operating costs (EGP/yr)	1,481,428±189,029	4,319,974±1,055,661	341,312±97,380	1,602,800
Operating profit (EGP/yr)	262,998±71,242	1,080,806±151,294	97,261±22,982	368,723
Labor costs (EGP/t)	494 ±71	299 ±64	622 ±178	507
Operating profit (EGP/t)	1,249 ±275	2,340 ±364	2,873±187	2,192
Operating profit/sales (%)	13 ±2.6	22 ±2.8	25 ±2.2	20
Fixed costs (EGP/yr)	39,256±5,966	64,450±17,292	10,059±1,951	32,038
Net profit (EGP/yr)	223,741±74,822	1,016,356±136,887	87,203±21,711	336,684
Net profit per ton (EGP/t)	1,009 ±314	2,214 ±363	2,565±191	1,948
Net profit/sales (%)	11 ±3.1	21 ±2.8	22 ±2	18
Total value added (EGP/t)	1,503 ±254	2,513 ±406	3,187 ±235	2,455

Source: Computed survey data.

indicates that the highest volume of fish sales is in wholesaler actors' group (519 t/year) compared to intermediaries (187 t/year), and only 34 t/year in retailers. A similar trend is shown in daily sales value. The daily sales value is in the following descending order wholesalers, intermediaries and retailer (18,003, 5815 and 1462 EGP, respectively). Average sales price per kg of tilapia indicated that wholesalers made around one EGP per kg, while retailers added more than 2 EGP for every kilogram sold to cover their expenses and generate income.

Analyses of input and output costs indicate that the three traders group is all making good profits from fish sales. Fish retailer generated the highest return on operating costs 25%. A lower return recorded in wholesaler trades 22%. While the lowest return on operating costs was in intermediaries 13%. The average net profits as a percentage of sales revenue were similar for wholesalers and retailers, but lower in intermediaries. Similar result reported during studying value chain of Lake Malawi by Phiri et al. (2013), who reported that fish retailer generates a slightly higher net profit. The highest employment generation rate was in fish retailers 7.08 FTE per every 100t sold, intermediaries generate 3.19 FTE per 100t sold and the lowest FTE generation was in wholesales (FTE 1.63 FTE/ 100 t sold). Labor costs per every metric ton sold were highest for retailers. While the lowest labor cost per ton sold was in wholesalers. The result indicates that fixed costs were highest for wholesalers and lowest for retailers. On the other hand, the highest value added generated per 100 t fish sold was in the retailing, followed by wholesaling, and intermediaries (Table 4).

Operational characteristics and financial performance of fish processing

Table 4 presents data of operational characteristic of fish processing establishment in High Dam Lake. The obtained result indicates that average years of experience were noticeably higher in fish salting processing (21.7) than fresh fish processing (9.9). One-third of the fish processing operators had other income sources; for instance, owning fishing boats and collect fish from their boats or fishers for processing. The average quantity of sales per processing facility was higher for fresh fish (98.4 t/yr) compared to salted fish (70.9 t/yr). The average sales prices of all fish species were also higher for fresh fish processors group (EGP 20.9 kg) compared to salted fish (EGP 13.6 kg). Fresh fish processing focused mainly on tilapia (97% of quantity processed) compared to Nile perch (1.5%). Tilapia degutted represent (82%) while sales of Nile tilapia fillets represented 15% of fresh fish processed. Salted fish processing focused mainly on different size grades of tigerfish (58%) and pebbly fish (35%). Salted fish processing steps are illustrated in Figure 4.

Table 4. Summary of operational data of fish processing in the High Dam Lake.

General information	Salted fish	Fresh fish
Number interviewed (sample size)	14	8
Experience in fish processing (yr)	21.7	9.9
Other income source (%)	35.7	25.0
Annual sales volume (t)	70.94±11	98.25±27
Average FTE/100 t	5.5±0.6	5.7±1.6
Sales price (EGP/kg; all species)	13.6±0.7	20.9±3.6
Sales volume distribution by species (%)		
Tilapia fillet (kg)	-	95,316 (97)
Other fish (kg)	-	2938 (2.9)
Tigerfish (kg)	41,197 (58.1)	-
Pebbly fish (kg)	25,071 (35.3)	-
Other species (kg)	4,671 (6.6)	-

Note: Numbers in parentheses refer to % of total fish processed.
Source: Computed survey data.

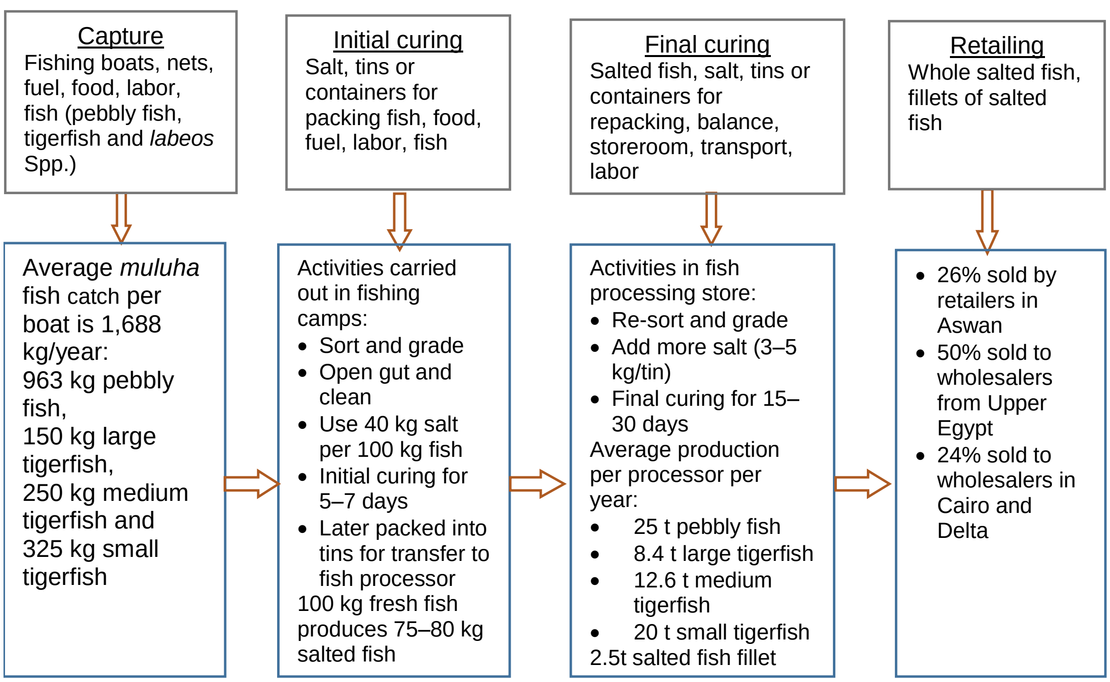

Figure 4. Salting fish processing steps in the High Dam Lake.

Salted fish *(muluha*) is a product that is unique to High Dam Lake and produced from tigerfish (*Hydrocynus* spp.), pebbly fish (*Alestes* spp.), Nile carp (*Labeo* spp.) and other species that are not marketed fresh. The process of fish salting start with gutting and salting the fish in plastic containers, during which salt absorb the liquid from the fish. After around three weeks, the moisture content has dropped, and it is a stable product for transporting from fishing camp to inland processors store. The processors repack the product into tins or jars for distribution and sale across Egypt (Nasr-Allah and Zakar, 2018). Adeleke et al. (2015) reported that fishers in Ondo State in Nigeria are practicing other form of processing such as precooking, drying and smoking. They also reported that 33% of fishers preserve fish through drying. The current study revealed that none of the fishers interviewed practice fish drying.

Obtained data of the financial performance for fish

Table 5. Fish processors financial performance in the High Dam Lake.

Financial performance	Salted fish	Fresh fish
Annual sales revenue (EGP)	975,046±164,388	1,766,025±305,132
Operating costs (EGP)	788,288±105,105	1,526,789±264,343
Operating costs (EGP/t)	11,112±634	15,539±2,686
Operating profit (EGP/t)	2,091±558	3,028±1,054
Operating profit/sales (%)	15±3	12.9±2.6
Fixed costs per metric ton	151±24	324±110
Net profit (EGP/t)	1,939±567	2,703±1,058
Net profit / sales (%)	13.8±3.1	11.3±2.9
Labor costs (EGP/t)	567±71	948±214
Total value added (EGP/t)	2,507±538	3,652±1,036

Source: Computed survey data 2016.

Table 6. Change in sales prices in the small-scale fisheries value chain.

Subsector	Average price EGP/kg	% of consumer prices
Fishers	6.29	49
Intermediaries	9.32	73
Wholesalers	10.40	81
Retailers	12.79	100

Source: Computed survey data.

processors in High Dam Lake are listed in Table 5. The result indicates that gross revenue was higher in fresh fish processing compared to salted fish processing. This can be due to higher sales volume and sales prices per kilogram product in fresh fish processing establishments. The cost of input cost in fresh fish processing contributed to higher overall operating costs compared to salt processing. Average operating profits for fresh fish processors were also higher, but when labor costs per metric ton were included, the average operating profit as a percentage of sales revenue was lower than for salted fish producers. The obtained result revealed that net profit per metric ton was higher in fresh fish processing, but average net profit as (percentage of sales) was lower for fresh fish producers. This can be justified due to the higher level of fixed cost in fresh fish processing businesses (Table 5). Akinola et al. (2006) reported that fish preservation using smoking and drying is common in the Niger Delta. The authors attributed that to the less access to electricity by fisheries communities.

Value chain performance

Changes in product price across the value chain are displayed in Table 6. The obtained result indicates that prices increase at each node across the chain. The result revealed that fishers` sales price just below 50% of the final retail price. Similar result reported by Phiri et al. (2016) in Lake Malawi. The authors reported that fishers in Lake Malawi receive only around 44.8% of consumer sales price. This is contrary to aquaculture value chain in Egypt, as fish producers receive 71% of the consumer price (Macfadyen et al., 2012).

Operational profits, net profits and value added (per ton) at each node in the chain are presented in Table 7. The study results revealed that the fish retailing generate the highest operational and net profits (EGP/ t of fish sold). While, fishers generate the highest return on operation costs, followed by fish retailers. Calculation of net profit revealed that retailers and wholesalers are achieving the highest return on investment. The highest value-added generation was in fish retailers. Both generate 62% of the value added per ton caught and sold. While, wholesalers generated only 24% (EGP 2513/t) of value added per metric ton. The obtained result shows noticeably high value-added generation across the value chain compared to value added generated in the Egyptian aquaculture value-chain reported by Macfadyen et al. (2012).

Studying High Dam Lake small-scale fisheries value chain revealed that, fish processing is an important activity. A summary of fish processing performance data is presented in Table 8. The obtained result revealed that higher FTE is generated in fresh fish processing compared with salted fish processing. Costs of labor and

Table 7. Summary of financial performance of the small-scale fishers and fish traders.

		Fishers	Intermediaries	Wholesalers	Retailers	Total
Operation profit	EGP/t	2511	1249	2340	2873	8972
	%	37.3	13.4	21.7	24.9	
	% of total	28	14	26	32	100
Net profit	EGP/t	1107	1009	2214	2565	6896
	%	15.2	10.8	20.5	22.2	
	% of total	16	15	32	37	100
Total value added	EGP/t	3172	1503	2513	3187	10375
	%	31	14	24	31	
	% of total	30.6	14.5	24.2	30.7	100

Source: Computed survey data.

Table 8. Summary of fish processors performance.

Parameter	Salted fish	Fresh fish	Overall
FTE/100 t	5.5	5.7	5.6
Output value or basket price (EGP/t)	13,597	20,898	16,252
Labor cost (EGP/t)	567	948	706
Operational profit (EGP/t)	2,091	3,027	2,431
Net profit (EGP/t)	1,939	2,703	2,217
Value added (EGP/t)	2,507	3,652	2,923

Source: Computed survey data.

sales value per ton were higher in fresh fish processing compared to salted fish processing. Similar trend exists in operational and net profits. The obtained result revealed that fresh fish processing generates noticeably higher value added per ton (EGP 3652) compared to fish salting processing (EGP 2507). This can be attributed to the high cost of labor in fresh fish processing compared to salted processors. Similar conclusion reported by, Anihouvi et al. (2012) and Nasr-Allah and Zakar (2018), who stated that salted fish is low cost methods of fish preservation.

Job creation in High Dam Lake fishery value chain

The current study revealed that fishing subsector generates in total 30 employment opportunity (FTE) per every 100 t of fish caught and sold in the High Dam. The highest employment level was in fishing (18.1 FTE/ 100 t of catch, or 60% of total FTE created) followed by retailing (24% of FTE), and intermediaries (11% of FTE) and wholesaling at (5% of FTE) (Table 9). Small-scale fisheries in High Dam Lake represent an attractive job opportunity for fishers from Upper Egypt governorates (Table 9). The current study found that most works were full time (>79%) indicating that fish businesses generate a good level of income across all subsectors. Furthermore, in fish trade (retail and wholesale), almost all employment was full time more than 95%. Youth (≤30-year age) represented 49–59% of total FTE. This can be considered indicator for accepting youth working in the fisheries value chain. Due to the remoteness of fishing grounds from harbors and residential areas and poor living conditions in fishing camps, all fishers interviewed were men. The current result revealed that around 15% of the catches are used in fish processing. Average job generation in fish processing is 5.5 FTE/100 t of fish processed. Lower contribution to FTE generation in the aquaculture value chain and fish seed value-chain in Egypt was reported by Macfadyen et al. (2012) and Nasr-Allah et al. (2014).

Analysis of critical factors limiting fisheries development

The output of focus group discussions (FGD), which held with board members of fishers' associations and resulted in the identification of a series of challenges and potential solutions as follows:

(i) Livelihood challenges (affording fuel and bread required during a fishing trip, poor living condition in the lake, no compensation scheme for boat loss, lack of

Table 9. Employment creation in the High Dam Lake small-scale fisheries value chain.

Employment	Jobs (FTE)/100 t sold	Percentage across the value chain	Full-time jobs (% of FTE)	Youth (% less than 30 years old)	Source of labor	
					Aswan (%)	Other governorates (%)
Fishers	18.1	60	79	57	9	91
Intermediaries	3.19	11	78	53	47	53
Wholesalers	1.63	5	95	59	50	50
Fish retailers	7.08	24	97	49	35	65
TOTAL	29.99	100				

Source: Computed survey data.

health service and no maintenance of navigation lighting system in the Lake).
(ii) Inputs availability challenges (access to credit; lack of skilled labor, high cost and poor ice quality).
(iii) Operation challenges (lax of enforcement of security in and around the Lake and overfishing problem due to illegal fishing methods).
(iv) Post-harvest and marketing challenges (poor post handling and absences of a fish auction in Aswan).

Recommended action for improving value chain performance

Suggested recommendations for improving value chain performance in this study mainly based on the critical issues identified during the FGD and issues raised by fishers during interviewing.

(i) Establish new service organizations to provide inputs (such as nets, handling boxes and fish-salting equipment) and help with fish marketing. Also, facilitate getting operations inputs such as food, fuel and ice.
(ii) Develop community-based fisheries management plan to create an awareness among stakeholders about the current situation in the Lake. The plan should emphasis on the importance of adopting best fisheries management practice to avoid overfishing in the lake.
(iii) Improve living condition within the fishing camps in the lake. Renovate health care service boats providing basic services for fishers in the Lake.
(iv) Train fishers on deliver first aid to victims until they can reach medical centers to get the appropriate treatment and medical care.
(v) Establish social and health insurance scheme for fishers as they work in a vulnerable situation.
(vi) Train fishers on the importance of good fish handling practices in maintaining quality, reduce spoilage, extend shelf life in markets and obtain higher selling prices.
(vii) Local authority should support establishing fish auctions in both Aswan and Abu Simbel to regulate fish prices.
(viii) Provide training on processing of both fresh and salted fish and the conversion of fish processing waste into fishmeal should be promoted to increase processors income.

Conclusion

High Dam Lake small-scale fishery is an important source of income and food security in Aswan and Upper Egypt. The current study has revealed that the small-fisheries value chain in the lake is important for economic activity, profits and employment. The long-term experience in the sector indicating that working in the value chain represents a good source of income for living for a long time. Small-scale fisheries value chain in the lake contributes significantly to direct job creation, including for youth.

However, there are no identified women employed in fish processing. The study identified a number of challenges such as overfishing due to lack of security and enforcement of regulations including legal mesh size and closed fishing periods. Official catch record indicates a declining trend in the last years mainly due to reduced tilapia catches. The opportunities for improving the small-scale fisheries value chain performance, provides a strong argument for intervention required by private-sector to maintain employment benefits generated in the sector, and to increase such benefits in the future.

This study revealed that value chain analysis could be used for understanding the financial benefits that are generated in the sector. The study identified the critical factors that are affecting the financial and social performance of the value chain. Identifying sector limiting factors can be used for recommending actions for better financial and social benefits generated across the chain. The study recommends some of the necessary actions to ameliorate this sector will be the responsibility of the sector itself, government, donors and local organizations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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