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Full Length Research Paper

Assessment of stomach contents of *Oreochromis niloticus* from the Lagos Lagoon, Nigeria

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Fish sustainability in an aquatic environment involves continuous and judicious management towards optimum production of resources, for rational utilization and availability for future generation. Stomach composition of *Oreochromis niloticus* collected from a tropical brackish water environment was investigated to assess food availability towards optimum fish productivity for rational public utilization. *Oreochromis niloticus*, a fish of high economic importance and a generalize omnivore endemic to fresh and brackish water of Sub-Saharan Africa, and Asia, was reviewed to know the food availability status of the Lagos Lagoon, Nigeria. The conditions of stomach contents of *O. niloticus* samples collected were visually determined and subjected to frequency of occurrence, dominance, numerical, volumetric and relative index methods. Analytical and descriptive statistics were used to show occurrence, prevalence and availability of food organisms, within Lagos Lagoon. Results of the investigation revealed the presence of phytoplankton, dinoflagellates, sand grains, insect parts, plants parts, fish parts and unidentified constituents in *O. niloticus* stomach contents. *O. niloticus* revealed herbivorous feeding habit and Bacillariophyceae food item with highest occurrence. Food items satisfy requirements for optimum sustainability.

Key words: Stomach contents, tropical, *Oreochromis niloticus*, Lagos Lagoon, Nigeria.

INTRODUCTION

Public unawareness of the benefits obtainable in aquatic environment, and uncaredful use and management has considerable adverse influence on aquatic ecosystems, especially in Sub-Saharan Africa. Lagos City is urban environment around the coast. The urbanization status has been considered to have tremendous tendencies of introducing contaminants into the aquatic ecosystem. This could result in degradation of the physico-chemical parameters of the water body; hence affecting optimum yield of the aquatic resources (Oribhabor, 2016).

Therefore, the socio-economy status of the Lagos city and indiscriminate disposal of waste / pollutant have resulted in anthropogenic input, affecting the aquatic ecosystem output and ecosystem services (Sankoh et al., 2013). Investigation of stomach contents of *O. niloticus* fish is carried out to know the status of food available for optimum production in Lagos Lagoon. *Oreochromis niloticus* also known as Nile tilapia belongs to the family Cichlidae, which is a tropical freshwater and estuarine species of high economic importance and a generalized

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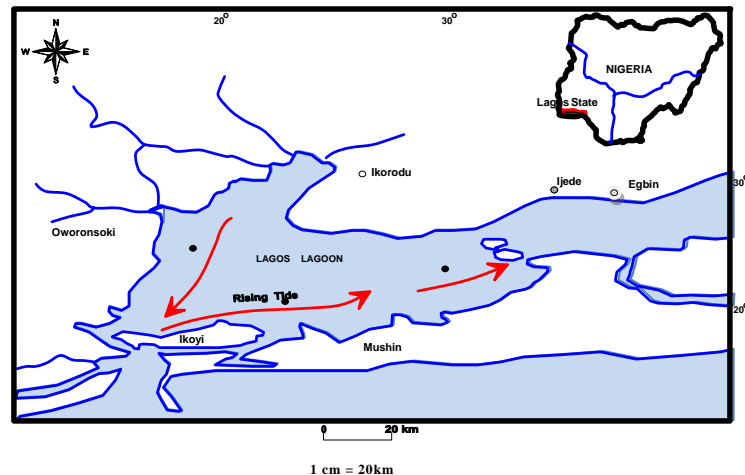


Figure 1. Map of Nigeria showing the Lagos Lagoon.

omnivore. It thrives well in shallow, still waters and in vegetated areas of lakes and rivers (Picker and Griffiths, 2011). It is a herbivore that feeds on phytoplankton, trapping plankton in a plankton rich bolus using mucus excreted from their gills (Rupinder et al., 2014). It consumes periphyton as well as aquatic plants. It eats invertebrates, benthic fauna, and at times found to have consumed fish eggs (Trewavas, 1982; FAO, 2012). *O. niloticus* exhibits suspension filtering feeding method, and also surface grazers (Lee et al., 2018). Agumassie and Mathewos (2018) mentioned that *Tilapia* fish shifts feeding behavior.

Earlier studies conducted by Moriarty and Moriarty (1973) and Pinka et al. (2014) showed that *O. niloticus* feeds on bottom deposits derived from the plankton rain and other sources, deriving its nutrient from organic particles and micro-organisms (Kumar and Gopal, 2015). Rupinder et al. (2014) reported that *O. niloticus* feeds on plankton which is structured and usually driven by nutrient dynamics of the habitat. Tesfahun (2018) stated that the feeding habit of *O. niloticus* and stomach contents are dependent on availability and abundance of plankton in the habitat, which contribute to the growth rate of the fish.

Hence, the objective of the study on stomach contents aims to reassess the status of *O. niloticus* food varieties in a lagoon that is impacted by urban activities and varying complex environmental factors for optimum production of the fish.

MATERIALS AND METHODS

Study area

The brackish water Lagos Lagoon (Figure 1) is part of the continuous system of lagoons and creeks that are found along the coast of Nigeria from the border with the Republic of Benin to

Niger-Delta. This lagoon bordering the Lagos Island is located between longitude 30° 10' and 30° 4' SE and latitude 60° 5' and 60° 36' N. Lagos lagoon lies along the coast for more than 50 km long and 3 to 13 km wide. It is bounded by tidal wetlands and swamps, and is a major lagoon among 10 other lagoons along the coastline. The Lagoon has a surface area approximately 6,354.7sq km, and it receives influx of freshwater from several rivers, the most important of which are the Ogun, Ona/Ibu, Oshun, Shasha and Oni. It is tidal in nature and it receives water from Atlantic Ocean during high tides which recede during low tides. Lagos Lagoon is fairly shallow with averages depth of 2 to 4 m and it is isolated from sea by beach barrier ridges. The lagoon empties inside the Atlantic Ocean via Lagos Harbour where it has depth increase of 10 m, with 0.5 to 1 km width and 10 km long, (Badejo et al., 2014).

Collection of samples

A total of four hundred and eighty (480) live *Oreochromis niloticus* were collected from Lagos Lagoon with the assistance of fishermen using cast net from January to December 2015. The fish were carried in a 25 L plastic container for analysis in Fish Biology Laboratory for analysis.

Measurements

The Standard Lengths (SL) of fish samples were determined to the nearest 0.01 cm using a graduated board and the corresponding weights (W) were also measured with Mettler Toledo electronic weighing balance (Model; PB8001).

Sample preparation

The fish were dissected to remove gut samples which were dissected individually to reveal the condition of the stomach. The guts and intestine contents were categorized based on degree of fullness as: {full (4/4), three quarter full (3/4), half full (2/4), one quarter full (1/4), and empty (0/4)}. The stomach contents were fixed in 4% formalin prior to examination. Stomach samples were mixed with 2.0 mL distilled water in a petri-dish for proper separation and easy identification. A drop of the prepared sample was placed on a glass slide with the aid of a dropper and covered

Table 1. Length range of *O. niloticus* and frequency of occurrence.

Length Range	Frequency of occurrence of fish	Mean weight of fish
13.70 – 14.69	113	85.73 ± 2.32
14.70 – 15.69	107	92.45 ± 2.45
15.70 – 16.69	82	103.33 ± 2.21
16.70 – 17.69	111	142.45 ± 3.17
17.70 – 18.69	67	185.44 ± 3.42

with cover slip.

Microscopy and observations

The prepared samples on the glass slides were viewed under light microscope at a magnification of x40. Stomach items were also examined using hand lens (magnifier). The observed organisms were identified using identification keys and taxonomic work (Idodo, 2002).

Analysis of stomach contents

The various items in the fish stomach were analyzed using frequency of occurrence, dominance, numerical, volumetric and relative index methods to show food item prominence and importance.

Frequency of occurrence (FOC) Method (Hyslop, 1980)

FOC = Total number of specific food item occurrence
 Percentage occurrence of a food item (% FOC):-

$$\%FOC = \frac{\text{Total number of stomachs with the particular food item}}{\text{Total number of stomachs with food}} \times 100$$

Dominant method (Hyslop, 1980)

Percentage dominance of a food item = Number of stomachs that particular food item is dominant
 Total number of stomachs with food X 100

Volumetric method (Hyslop, 1980)

$$\text{Percentage volume of a food item} = \frac{\text{Volume of the particular stomach content}}{\text{Total number of all stomach contents}} \times 100$$

Numerical Method (Hyslop, 1980)

$$N = \frac{\text{Total number of particular food item}}{\text{Total number of all stomach contents}} \times 100$$

$$N = \frac{\text{Total number of particular food item}}{\text{Total number of food item}} \times 100$$

: percentage numerical index (%N)

$$N = \frac{\text{Total number of particular food item}}{\text{Total number of all food item}} \times 100$$

Relative Index (I) (Hyslop, 1980; Costal et al. 1992)

$$I = (\% \text{occurrence} \times \% \text{volume}) \times 10^{-2}$$

The percentage numerical index of occurrences was expressed to know the food item in stomach of *O. niloticus* fish samples. The percentage occurrences of organisms were recorded according to Hyslop, (1980) and Costal et al. (1992).

RESULTS

Standard length ranged from 13.72 to 18.45 cm with a mean of 14.67 ± 1.56 cm whilst weight ranged from 83.32 to 140.68 g with a mean weight of 135.40 ± 31.46 g for the 480 samples of *O. niloticus* collected from the Lagos Lagoon. Table 1 shows fish length range and frequency of occurrence.

The stomach contents of *O. niloticus* included phytoplankton, insect parts, plant parts, sand grains and some unidentified food items. Table 2 shows percentage occurrence of stomach contents of *O. niloticus* from the lagoon. Phytoplankton ranked highest in occurrence of food items in the stomach of the fish with a percentage of 62.32%.

Table 3 shows the degree of stomach fullness of the fish samples. This indicated that 70% of *O. niloticus* stomach examined revealed half full and above degree of fullness. Hence, it is an indication of food availability in the brackish environment.

From Table 4, percent frequency of occurrence revealed that plant parts was the highest (93.13%) and also dominated the food items with a value of 58.54%. *Cyclotella meniggniana* species, which is a Bacillariophyceae ranked second desired food item (51.88 %); while Dinophyta *Ceratium sp.* ranked third (35.92 %) desired food item from the environment. This indicated all food items on rank list were plant source.

The results in Table 5 identified Bacillariophyceae as the most desired food item (R.I = 4.08) and amidst all the methods used, it is indicated that Bacillariophyceae had highest presentation, in species occurrence. This

Table 2. Percentage Occurrence of food items in Stomach of *Oreochromis niloticus* from Lagos Lagoon.

Stomach Contents	Percentage occurrences
Insect parts	3.93
Unidentified Food Items	7.10
Sand grains	10.80
Plant parts	15.86
Phytoplankton	62.32

Table 3. Degree of Stomach Fullness in *Oreochromis niloticus*

Degree of Fullness	Frequency of <i>O. niloticus</i>	Percentage of degree of fullness
Full	123.00	25.63
Three quarter full	43.00	8.96
Half full	168.00	35.00
One quarter full	117.00	24.38
Empty	29.00	6.04

Table 4. Occurrence and Dominance of organisms in the Stomach of *Oreochromis niloticus* collected from Lagos Lagoon

Stomach contents	Frequency of Occurrence (FOC) in <i>O. niloticus</i>	Percentage (%) FOC in <i>O. niloticus</i>	Dominance food Item in stomach of <i>O. niloticus</i>	Percentage Dominance food Item in stomach of <i>O. niloticus</i>
Chlorophyta				
<i>Closterium sp.</i>	172.00	38.14	112.00	24.83
<i>Pediastrum sp.</i>	74.00	16.41	36.00	7.98
<i>Volvox sp.</i>	225.00	49.89	72.00	15.96
Dinophyta				
<i>Ceratium sp.</i>	300.00	66.52	162.00	35.92
Bacillariophyceae				
<i>Cyclotella meniggniana</i>	228.00	50.55	234.00	51.88
<i>Fragillaria</i>	82.00	18.18	49.00	10.86
<i>Gyrosigma balticum</i>	48.00	10.64	46.00	10.20
<i>Navicular sp</i>	82.00	18.18	68.00	15.08
<i>Nitzschia sp</i>	197.00	43.68	126.00	27.94
<i>Tabellaria fenestrata</i>	243.00	53.88	102.00	22.62
Sand grain	286.00	63.41	180.00	39.91
Plant parts	420.00	93.13	264.00	58.54
Insect remains	104.00	23.06	98.00	21.73
Unidentified food items	188.00	41.69	136.00	30.16

revealed similar output of the varying methods used to assess stomach contents of the fish. The least desired food item is insect remain which has (R. I = 0.04).

Figure 2 shows the percentage occurrence of food item in the stomach of *Oreochromis niloticus* from Lagos

Lagoon. Bacillariophyta were the highest (38.22%) indicating that the fish highly desired this food item. Bacillariophyta species were highest in occurrence of food items identified; hence the result revealed that *O. niloticus* is a generalized grazer with higher relative index

Table 5. Percentage Occurrence, volumes and Numerical of food, of *Oreochromis niloticus* from Lagos Lagoon.

Food Items	%O	%V	%N	RI
Chlorophyta	17.78	3.65	20.07	1.30
Dinophyta	11.33	1.08	6.26	0.24
Bacillariophyceae	33.21	6.14	38.22	4.08
Sand grain	10.87	1.24	6.95	0.27
Plant parts	15.86	2.67	10.19	0.85
Insect remains	3.93	0.54	9.96	0.04
Unidentified food items	7.10	0.72	8.34	0.10

%O, Percentage Occurrences of a food item; %V, Percentage volume of a food item; %N, Percentage Number of a food item; RI, Relative Index.

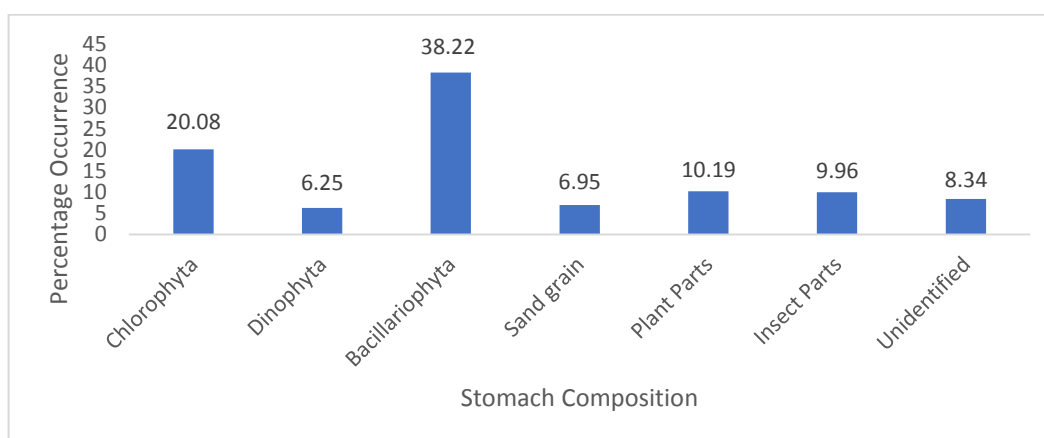


Figure 2. Percentage Occurrence of Food Item in the stomach of *Oreochromis niloticus* from Lagos Lagoon.

recorded in plant source food items (Figure 2).

DISCUSSION

Stomach contents in *Oreochromis niloticus* fish samples examined is in line with the work of Agbabiaka (2012) and Rini (2013) which reported Tilapia fish have varying food in its gut and shifting feeding behavior. These food contents seen in the stomach of the fish follow the work of Abari et al. (2015) who reported *O. niloticus* as obligate herbivore.

High desire of Bacillariophyceae by the fish is supported by Mohsen (2003) as Bacillariophyceae constituted 38.22% of the food items and the most prevailing food items, but plant parts had the highest percentage dominance food item (58.54%); while Bacillariophyceae *Gyrosigma balticum* had the least (10.20%). Hence, stomach contents obtained corroborate the reports of Fagade and Olaniyan (1972) in the Lagos Lagoon; Houehanou et al. (2016), who reported that

cichlids exploit more than one source of food item; having the ability to utilize different varieties of food makes *O. niloticus* omnivorous in nature. He et al. (2015) also reported high degree of overlap in diet of fishes from the same community.

The work of Rao (2017) supported the report that *cichlids* fed mainly on detritus, insects and plant materials; as seen in the result of this study that other unidentified food items, plants and insect materials identified from the gut of *O. niloticus* are members of its stomach contents. Ali et al. (2015) also supported the result that the species feed on plants, leaves, buds and seeds of water lilies and are thus herbivorous feeders.

The result that *O. niloticus* had higher frequency of plant material is supported by Oso et al. (2006) who also observed *O. niloticus* to be herbivores having highest percentage frequency of occurrence of higher plant remains as 49.2%. *O. niloticus* preference for diatoms than the green algae, despite the latter being more abundant is in line with the work of Kariman et al. (2009) who reported diatom preference in the nutrition of *O.*

niloticus in Abu-Zabal lakes in Egypt.

Teferi et al. (2000) who studied the food and feeding habit of Nile tilapia in Lake Chamom Ethiopia on the stomach contents of adult and juvenile fish reported that *O. niloticus* fish is phytoplanktivorous, and that the component of the phytoplankton varied seasonally, and Ali et al. (2015) also reported that Nile tilapia are filter and benthic feeder as they consumed plankton, and detritus. These supported the result that the fish is planktivorous in the food item recovered from the stomach contents examined.

Hence, stomach contents of *O. niloticus* examined in Lagos Lagoon complemented and corroborated previous management assessments on stomach analysis of *O. niloticus* from Sub-saharan Africa.

Conclusion

Lagos Lagoon environment supported food constituent of *O. niloticus* which has generalized herbivorous feeding habit with great desire for bacillariophyte species of food items among other food items. Food availability and optimum requirement for fish daily need is supported by Lagos Lagoon environment status. And this will enable production of healthy *O. niloticus* fish for public fish food of plant nutrient source.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Assessment of the fishery, challenges and opportunities of Denbi reservoir in Bench Maji Zone, South Western part of Ethiopia

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The study was conducted to assess the fishery, challenges and opportunities in Denbi reservoir, Ethiopia. Interview, focus group discussion and personal observations were used to generate data. Response was solicited from households within the catchment area of the reservoir, key informants, elders, workers of the reservoir and fishery cooperative members. The data was analyzed by combining quantitative, qualitative methods and descriptive statistics. The result showed that there was one legally registered fishery cooperative organization. Majority (81.8%) of the cooperatives members organized were men with age ranging from 18 to 35 years. It was observed that there was division of labor among men and women cooperative members where men generally did capturing and women were involved in washing mesh, processing, transporting and selling of fish. Fishing in the reservoir was carried out each other day using non-motorized single boats. The post harvest activities undertaken by the fishermen included gutting and removal of offal from fish. The demand for the fish was neither affected by season nor religious affiliation due to the low supply of fish in the study area. Lack of fishing gear and motorized boat were the top two ranked constraints. Fish production and fishery system of Denbi reservoir was characterized by low inputs and low production resulting in an underutilization of the water resource. There should be emphasis on integrated management for effective utilization of the resources.

Key words: Constraints, Denbi reservoir, fish, fishing practices, opportunities.

INTRODUCTION

Fisheries and aquaculture remain important sources of food, nutrition, income, and livelihoods for hundreds of millions of people around the world (FAO, 2016). Fish is one of the known aquatic animals which serve as food for human (Bhatnagar and Devi, 2013; Janko, 2013, 2014).

Fishing has been the main source of protein supply for many Ethiopians particularly for those who are residing in the vicinity of major water bodies like Lake Tana, Ziway, Awassa, Chamo, Baro River, etc (FAO, 2014; Tesfaye and Wolff, 2014). World per capita fish supply reached a

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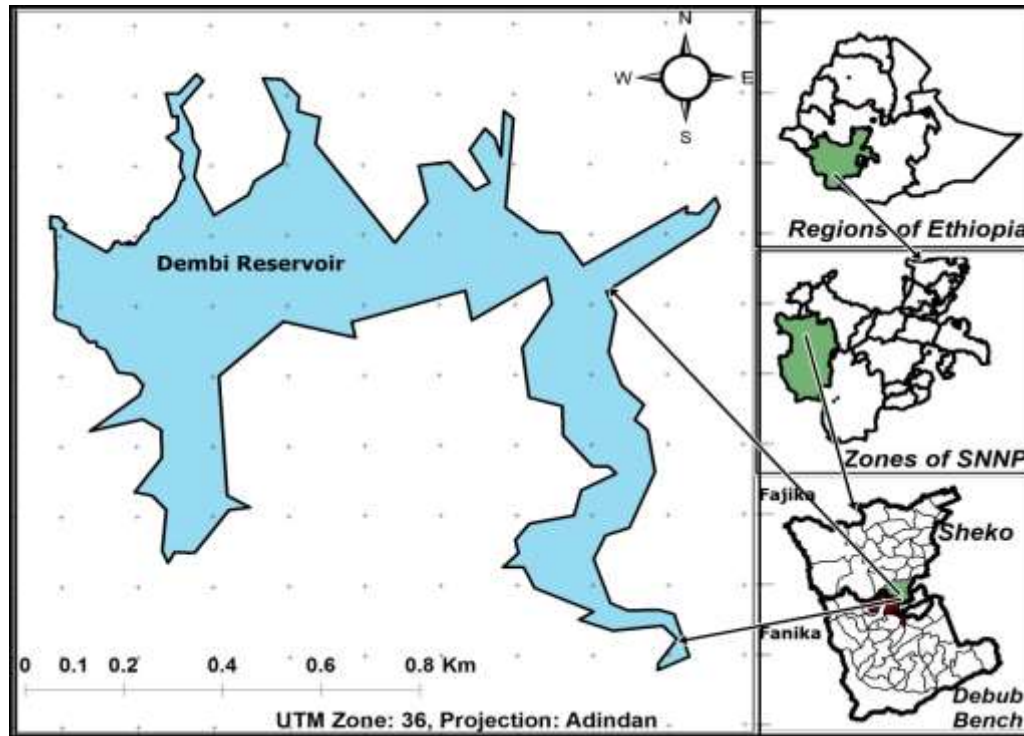


Figure 1. Location of Denbi reservoir.

record high of 20 kg in 2014 (FAO, 2016). Although annual per capita consumption of fish has grown steadily in developing regions (from 5.2 kg in 1961 to 18.8 kg in 2013) and in low income food-deficit countries (LIFDCs) (from 3.5 to 7.6 kg), it is still considerably lower than that in more developed regions (FAO, 2016).

The inland fishery of Africa contribution is estimated to be about 2.1 million tonnes of fish per year, it represents 24% of the total world fish production from inland water bodies (FAO, 2004). In Ethiopia, fish comes exclusively from inland water bodies including lakes, rivers, streams, reservoirs and substantial wetlands that are of great socio-economic, ecological and scientific importance (Janko, 2013, 2014; Tesfaye and Wolff, 2014). The overall potential yield of fish in Ethiopia water bodies are estimated as 94,500 tons per year on average (Tefaye and Wolff, 2014). Water bodies located in the Rift Valley show signs of overexploitation whereas those located in remote areas with poor infrastructure which make up the majority remain underutilized (Janko, 2014; Tesfaye and Wolff, 2014). Hence, the existing role of fishery is insignificant in the country's overall economy because the fishery sector in the country is far below its potential (Kebede et al., 2017). The current production is still far below the estimated potential yield, which suggests the possibility for further expansion of the fishery.

Ethiopia is endowed with several water bodies that contain a high diversity of aquatic fauna. Reservoir fishery plays an important role in the economy of the

country and the livelihoods of the people living adjacent to those reservoirs. Fisheries resource in Ethiopia, in spite of its significant contribution to poverty alleviation and food security, is an unexploited natural resource (Kebede et al., 2017). Ethiopia has many lakes and reservoirs of which Denbi reservoir (Denbi Mini Hydro Electric Power plants) located in Bench Maji Zone forms a part. Denbi reservoir is estimated to have an area of 72 km², and a fishery potential of 383 tonne/year (Janko, 2014). The reservoir is fitting for fishery and aquaculture development to supply fish for the community. However, there is a lack of information on fish captured method, challenges and opportunities for proper utilization of the reservoir for sustainable utilization and development of the fish sector in the area. Therefore, this study sets to assess fish captured method, challenges and opportunities of fish production of Denbi reservoir.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Denbi reservoir which is located in Bench-Maji zone in the boundary between Fanika Kebele of South Bench and Fajika Kebele of Sheko Wereda in South Western part of Ethiopia as shown in Figure 1. In addition to generating electricity, the fry fish of *Nile tilapia* (*Oreochromis niloticus* (Linnaeus, 1758)) and *Redbelly tilapia* (*Coptodon Zilli* (Gervais, 1848)) has been introduced in the dam in 1995 aimed to supply fish for the surrounding community. People found around the reservoir

Table 1. Demographic and fishing experience of fishery cooperative members

Variable		Frequency	Percentage
Sex	Men	9	81.8
	Women	2	18.2
Age(year)	18-24	6	54.5
	25-35	5	44.5
Educational level	Grade 1-4	2	18.2
	Grade 5-8	9	81.8
Marital status	Married	2	18.2
	Single	9	81.8
Experience in fisheries	4 years	3	27.3
	3 years	8	72.7

economically depends mainly on production of coffee, fruits (Banana, Avocado, Mango), maize, Enset and subsistence mixed crop livestock. Fishing in the reservoir was not an open access and only legally registered cooperative members were allowed to capture fish.

Sampling methods and size

Before implementation of the actual survey, exploratory field observations were conducted around the reservoir to decide sample size. During the field survey period it was observed that Denbi reservoir was a restricted area and fishing were permitted for legalized fishery cooperative members only. The community did not have an access to fish unless illegally. Based on this fact, in addition to fishery cooperative members, households nearby the reservoir, key informants and elders, and guard workers of the reservoir were selected to gather information for the study. Accordingly, all fishery cooperative members (11) were included in the study. Though households near the reservoir were not involved in the fishing practices, 22 key informants and elders (12 members from Fanika Kebele (Village) and 10 from Fajika Kebele (Village)) were selected for focus group discussions to have diversified information and to triangulate the collected data. In addition, 10 guard workers of the reservoirs were randomly interviewed. The overall sample size was 43 (22 from two Kebeles (Fanika and Fajika), 11 fishery cooperative member and 10 guards). Moreover, personal observation also made to gather information.

Data collection methods

The data were collected using semi structured questionnaire interview; focus group discussion and field observations. Field observation was undertaken focused on the other agricultural practices around the reservoir catchment, human and animal interaction to the reservoir, type of fishing gears and the infrastructures for fishery activities. Secondary data were also collected through review of relevant literature. Data on the socio-economic status, fish consumption, fish utilization and marketing systems, fishing methods, fish handling and processing methods, challenges and opportunities of fish production of the reservoir were assessed.

Data analysis

The data were analyzed by combining quantitative and qualitative methods. Descriptive statistics was used to summarize and analyze the quantitative data obtained by questionnaires using SPSS V.20.

RESULTS AND DISCUSSION

Socio-economic characteristics

The socio-economic characteristics of the fishery cooperative members were assessed during the study period. There was only one legally registered fishery cooperative having a total of eleven members in Denbi reservoir as indicated in Table 1. Majority (81.8%) of the fishery cooperative members were men. The age of the fishery cooperative members ranges from 18 to 35 years. The educational background of the cooperative members indicated all of them had attended primary school education. Majority (72.7%) of the fishery cooperative members had three years of experience in fishing activity though fishing were not their major income sources rather production of Maize, Coffee, Fruits, Taro and Enset. Division of labor among men and women cooperatives members were observed; women cooperative members were engaged in washing mesh, processing, transporting and selling of the captured fish while men were mainly involved in capturing. This result confirms those reported from some parts of the country like Gambella, where women are actively involved in fishing to secure their family's daily food requirements and to cover household expenditures (Tesfaye and Wolff, 2014). The labor division of women not to participate in fish capturing might be due to frustration from sinking down and lack of experience and skill to swim and barging.



Figure 2. Fish gutting during harvesting in Denbi reservoir

Fish harvesting and purpose of fishing

Fish were captured once in two days using non-motorized single boat and gillnets of 50 m length, 2 m width and mesh size of 6 to 8 cm. The peak capture yield was obtained from May to September with the maximum yield ranging from 50 to 60 fish per capture of dominant species of *O. niloticus* whereas the lowest ranged between Octobers and April in year 2016/2017 with yield ranging from 10 to 15 fishes per capture. However, the production is below the estimated potential (Janko, 2014). Similar report by Kebede et al. (2017), Nile Tilapia (*O. niloticus*) is the dominant fish species of the landings in different part of the country. According to the respondent, all fishermen used fish for income generation. However, the fishermen got additional income other than fishing in agreement with the report of Abelti et al. (2014). Fishing in the study area is mainly dependent on wild capture with no contribution from aquaculture activities. According to the response obtained from the focus group discussion, fish was captured illegally during the winter using different techniques such as chemical processed from seeds of Birbira tree (*Millettia ferruginea*). Similar reports by Tesso et al (2017) and Agumassie (2018) indicated the utilization of *M. ferruginea* by fishermen in Sale Nono district on River Ganji and different part of Ethiopia. According to the response of guards, fishing was not open access to anybody rather to legally registered cooperatives, due to the shortage of fishing gears and less emphasis and skill gap of the cooperatives to capture on the daily bases the resources was underutilized.

Fish handling, storage and preservation

The fishing activity in Denbi reservoir was not intensive only one legally registered fishery cooperative member

involved in fishing and it was restricted for other community. The processing method used by the fishermen cooperatives mainly gutting. The captured fish was processed in and around the reservoir whilst the by-products and waste materials were dumped into the reservoir as shown in Figure 2. Smoking was reported as the main means of preservation by the community. The fishermen methodically tied the fish upper lip with thread/twine then place the fish underneath the water to keep the fish fresh until it was purchased.

Transportation and marketing of fish

The gutted fish were either screwed on stick or kept in icebox and transported on foot by two persons to the nearby market and village. The cooperative fixed the price of fish based on its size. Fish processing (value addition) was not practiced as the fishermen sold the fish in the raw state. It was also reported that there was no religious and cultural restriction on the consumption of fish in the study areas. Moreover, the demand for the fish was not affected by season in the study area. It was reported that there was low captured potential and low supply of fish. Fish consumption tends to be based on locally and seasonally available products, with supply driving the fish chain (FAO, 2014).

Fish production constraints and challenges

The fishery cooperatives listed and ranked the different constraints for fish production in the study area as presented in Table 2. Shortage of fishing gears, lack of motorized boat, and retarded growth of fish as well as decrease of yield were ranked from first to third, respectively. There was also no clear border between the reservoir catchment area and the agricultural land of

Table 2. Ranked constraints of the fishery in the study area.

Constraints	No. of respondents	%	Rank
Lack of market place to sell the fish	1	1.72	10
Shortage of fishing gear	11	18.97	1
Retarded growth of fish and decrease of yield potential from time to time	9	15.52	3
Lack of infrastructure	3	5.17	8
Lack of motorized boat	10	17.24	2
Lack of supplemental feed	7	12.07	4
Lack of training and support	6	10.34	5
Illegal fishermen	2	3.45	9
Flooding and silt formation	4	6.9	7
Lack of safety cloths	5	8.62	6

**Figure 3.** Agricultural activities and deforestation near Denbi reservoir.

surrounding communities which may pose a threat for the sustainable utilization of the reservoir. This finding is in line with that of Abegaz et al. (2010) and Abelti et al. (2014) in which lack of transportation facilities, proper fishing gears was cited as the main constraints to fish production in different region of Ethiopia. Similarly, lack of modern fishing tools and illegal fishing gears are also the challenges of fisheries of South Wollo Lakes (Assefa and Kelemework, 2013). Based on observation, there were intensive agricultural activities and deforestation around the Denbi reservoir that may lead the reservoir has been filled by flood/sedimentation and which results in poor productivity of fish as shown in Figure 3. In agreement with the report of Agumassie (2018), expansion of agriculture and deforestation were the current problems of Ethiopian fishes and fishery. In general, the Ethiopian fishery is under several constraints due to different factors

(Kebede et al., 2017; Mathewos and Abebe, 2016).

Opportunity for development

There is an opportunity to maximize the fish production in the study area because there is high demand for fish in the area. Similar report showed that the demand for fishes is increasing double in Ethiopia (Mathewos and Abebe, 2016). Furthermore, there are no seasonal and religious effects on fish consumption pattern and availability of water through the year. The mentioned opportunities may increase the income of fishermen when they will give an emphasis to improve the productivity. Increasing number of fishermen to exploit the fish potential of the reservoir is important to increase the income of the society. Similarly, the current production

in Ethiopia is still far below the estimated potential yield, which suggests scope for further expansion of the fishery (Tesfaye and Wolff, 2014). Thus, fishery and aquaculture in Ethiopian is recognized as an alternative means of achieving food security in particular and poverty reduction in general, and is now considered as an integral part of rural and agricultural development strategies (Kebede et al., 2017).

Conclusion

Fish production system of the reservoir was categorized as extensive with low labor and economic inputs resulting in low productivity. Fishing in the reservoir was conducted by legally registered fishermen cooperative each other day, though illegal fishing takes place. The captured fish degutting was the major post-harvest process undertaken by the fishermen. Fish processing (value addition) was not practiced and the fishermen sold whole fish. There was no religious and cultural restriction on the consumption of fish in the study areas. Moreover, the demand for the fish was not affected by season in the study area. There were several constraints affecting fishery and fish production of the reservoir including shortage of fishing gear and lack of motorized boat were the first and second ranked, respectively. Fishing in Denbi reservoir should be commercialized, additional fisher cooperative/fishermen should be increased, fishing technologies should be improving and further study on aquaculture establishment should be undertaken for the development and utilization of the resources in the area.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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