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Assessment of fishery activities for enhanced management and improved fish production in Tekeze reservoir, Ethiopia

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Abstract
This study presents an assessment of fishing practices in Tekeze reservoir between December, 2014 and March, 2015. Data on fish production potential and catch per unit effort were estimated by using different estimate models and through daily catch respectively. Assessment of fishing practices was done by using questionnaires. A total of 1016 specimens composed of juveniles and adults in Tekeze reservoir were identified and classified. They comprised of ten species belonging to three order and four families from Tekeze reservoir. In combined catch, the relative abundance of O. niloticus was 51.38% from Cichildae family, 24.11% Labeobarbus intermidius from cypriformes family and the least dominant in the catch composition was Hetrobarnchus longifilis from siluriformes family. The catch per unit effort (CPUE) for Tekeze reservoir was 8.27 kg/boat/day. In Tekeze reservoir there were 2291 legal fishermen from four districts of Amhara region and one district from Tigray region, 608 boats and two different types of fishing gears were identified. Gillnet was the most operated gear in the Tekeze reservoir followed by long lines. The fishing effort, CPUE and yields did not show any indication on the overexploitation of the resources. The dominant fish species by catch in Tekeze reservoir was O. niloticus. To avoid overexploitation of O. niloticus species in Tekeze reservoir, there is need to diversify fish catch by creating awareness among people for the exploitation and use of other fish species like Labeobarbus spp. The remoteness of the reservoir and luck of infrastructure affects the price of the fish. In addition to this the fish price was varied in species and fasting and no fasting seasons of the year.

Keywords: CPUE, fishing practices, fish production, Tekeze reservoir

1. Introduction

Reservoirs are created by human activity and therefore host semi-natural ecosystems that can be manipulated in various ways. Reservoir fishery plays an important role in the economy of the country and the livelihoods of the people living adjacent to those reservoirs. The productivity of reservoir fisheries can be increased by using a number of approaches that combine better harvesting strategies, fertilization, carefully adapted stock enhancement and aquaculture (Petr, 1998) [25].

Tropical freshwaters contribute 15 percent of the world's reported capture fishery production from only 0.2 percent of the global aquatic surface area (FAO, 2011) [14]. The relative contribution may be even higher, as less than half of the inland capture production is officially reported (Kolding and van Zwieten, 2006). Most of the small-scale fishers in the world work in inland fisheries (BNP, 2009). Reservoirs are an essential component of most irrigation systems worldwide and, together with those built for flood control and power generation, retain large volumes of water. The 60,000 largest reservoirs in the world have with a volume of 10 million m3 (Kolding and van Zwieten, 2006). In addition to their roles in power generation and provision of water for agriculture, industry and homes, most of these reservoirs also play an important role in fish production and contribute significantly to the livelihoods of the communities along their shores. There is increasing recognition that the potential of most reservoir fisheries may greatly exceed current use.

Fish is widely accepted as a food commodity, because of its high palatability, low cholesterol and tender flesh (Eyo, 2001) [13]. It is the cheapest source of animal protein and is with rich essential nutrients required for human health (Sadiku & Oladimeji, 1991) [26]. Fish may be the sole accessible and/or affordable source of animal protein for poor households in urban or semi-urban areas (Bene & Heck, 2005) [6]. Food insecurity is one of the defining features of rural poverty affecting millions of people in the world and it is believed that fisheries and aquaculture can play a significant role to fight against food insecurity of the regions in Ethiopia where there is water resource. Besides, fish is a cheap source of high protein; hence there is a need to produce it as an alternative way of fulfilling animal protein requirement for the poor rural communities (Abebe & Stiassny, 1998) [1]. Research elsewhere carried out clearly spelt that increased fish production is possible only when it introduce appropriate technology without harming the natural ecosystem wherein the fish is reared (Williamson & Beveridge, 1994) [32]. Recently the consumption and demand for fish as a cheap source of protein is increasing in Ethiopia. The country depends on the inland waters for the supply of fish as a cheap source of animal protein. It has a number of lakes and rivers with substantial quantity of fish stocks. The fish supply in most cases comes from the major lakes such as Fincha, Hawassa, Ziway, Koka, Abaya, Hashenge, Tana and rivers in the country (FAO 2003) [16].

Artisanal freshwater fishery is one of the most important economic activities in Ethiopia, (FAO, 2012) [16]. Improvements in fishery sector would contribute to poverty alleviation and environmental sustainability in Ethiopia (Global Fish Alliance, 2010) [16]. As many other countries, population rise, urbanization, agricultural development, industrialization and other water resource development activities have caused reduction in species diversity of freshwater fish species (Dereje, 2014) [12]. Fishing contributed less than 1 percent of the GDP in 1987 (Assefa, 2014) [5]. A study reported that 15,389 tons of fish were caught in 2001 which formed only 30% of an estimated potential of 51,481 tons (Wubne, 1991) [33]. According to Wubne (1991) [33] rift Valley lakes (for example, Lakes Chamo, Abaya and Ziway and the northern part of Lake Turkana), Lake Tana, rivers, and small water bodies (reservoirs, natural ponds) are the sources of inland fisheries in the country. There is fishing on all these water bodies, but commercial production (i.e. serving markets other than the local communities) is concentrated on three Lakes namely Chamo, Ziway, Hawassa and Tana.

Tekeze reservoir has constructed mainly for hydroelectric power generation, irrigation and drinking water supply. This water body is important for fish production as they can widen the opportunity of providing protein rich food to alleviate malnutrition and generate employment opportunities for the landless people. Therefore, it is essential and timely to study on the fish production and fishing practices of the reservoir for sustainable utilization. The aim of the present study, therefore, was to assess the fishing practices and fish production potential of Tekeze Reservoir.

2. Materials and methods

Description of the study Area

Tekeze Reservoir

Tekeze reservoir is a hydropower reservoir constructed on 2009 over the Tekeze River. Tekeze River is a major river in Ethiopia and it is a Nile tributary. Tekeze reservoir is with a maximum length of 75 km and maximum width of 6 km, and covering an area of about 160.4 km^2. According to National Statistics of Agency (NSA) (2008) Tekeze River is 608 kilometers long. Mana, Tsilare, Seletsa, Avera and Ariqua rivers are the main tributaries of the Tekeze River joined in to the reservoir. The canyon which it has created is the deepest in Africa and one of the deepest in the world, at some points having a depth of over 2000 meters. Tekeze River originates in the central Ethiopian Highlands near Mount Qachen within Lasta, at 14°11N 37°31.7E and 14.18.3°N 37.52 83°E. The reservoir is located at an elevation of 1107m above sea level. It is approximately 155 km from Mekelle city. The capacity of the reservoir is about 9.293 billion m^3 (9.293 km^2) of water. Although Tekeze reservoir is constructed entirely in Tigray region, the water of the reservoir is shared by Amhara region. The reservoir is communal for five districts (Tanqua Abergelle district from Tigray region and Abergelle, Zikuala, Sahla and Tselemti districts from Amhara region). The main aim of constructing of the Reservoir was to produce electricity, but the reservoir fisheries were later recognized as a significant socio-economic importance to Tigray and Amhara people. The reservoir also facilitates the transportation of goods and passengers and the provision of services for Tigray and Amhara people found on both sides of the reservoir.

3. Methods

Collection, identification and composition of fish species

Three sampling sites were selected from each water body. Each site was sampled four times (once a month). Fish samples were collected using gillnets of various mesh sizes (1cm-20cm) and monofilament with various stretched mesh size. The gillnets, monofilament and long lines were set using plastic bottles as swimmers across the water bodies starting from 3:00 PM and left in the water for 18 hours and collected in the following morning from 9:00 AM. Immediately after capture, the total length, standard length and weight were measured to the nearest 0.1 cm and 0.1 g for length and weight respectively. Specimens were preserved in 4% formalin for further investigation in the laboratory. Specimens were soaked in tap water for 6 hours to wash the formalin from the specimens and the fish were then identified to species level using taxonomic keys (Boulenger, 1911 [7]; 1916 [8]; Golubstov *et al.*, 1995 [20] & Fish Base, 2012 [15]).

Estimation of CPUE

The frame survey involved the visits of the entire water body to identify and count every fishing locality within the reservoir, the total number of fishermen, the number of crafts and fishing gears employed for fishing. Catch assessment sampling (CAS) involved a detailed examination and recording of the fish catch that had just landed after fishing trip using properly trained enumerators. On fish landing, the enumerators examined the fish catch for species composition, weight of fish, number of boats operated, types of gears used, and fishing time to estimate the catch per unit effort (CPUE). The CPUE is expressed as kg of fish caught/boat/day. In Tekeze reservoir, the catch assessment sampling was carried out in three landing sites where fishermen from different fishing sites around the reservoir were instructed to land their catches for catch assessment. All active fishing boats were counted to provide the estimate of total fishing effort for each day sampled. The catches were pooled to give an estimate of catch per unit effort (kg/ boat/day) for the landing for each craft. Then the number of boats at this fish landing was multiplied by catch per unit effort to give an estimate of the total fish landed for that day.

Catch rate in terms of (CPUE) was estimated as follows:

Total catch (kg) per day was estimated as follows= Mean CPUE*no. of active boats/day.

CPUE data was used to estimate monthly catch as follows:

Monthly CPUE= Mean CPUE * average number of boats per day* average number of fishing days per month.

Estimation of Potential Yield

The potential yield of the water bodies were estimated by using Morpho-Edaphic Index and Area based models developed by different scientists. The data of the chemical parameters (Conductivity) of the water was measured for four months and the mean was applied for the estimation of the potential yield of the water bodies. For estimating the potential fish yield the following models were applied.

Model 1: $Y = 14.3136.\ MEI^{0.4681}$ -- (Henderson & Welcome, 1974) [22]

Where; Y is the yield in kg/ha/year and MEI is the Morpho-Edaphic Index

Calculated as follows:

$$MEI = \frac{\text{Conductivity (us/cm)}}{\text{Mean depth in m}}$$

Model 2: $\ln(Y_t) = 3.57 + 0.76 \ln(A_0)$ ------ (Marshall, 1984) [23]

Model 3: $Y_t = 8.32\ A_0^{\ 0.920}\ (R^2 = 0.93)$ -------- (Crul, 1992) [10]

Model 4: $Log(Y) = 1.4071 + 0.3697 \log(MEI) - 0.00004565 A_o$ -- Teows & Griffith (1979)

Where; Y_t is the total yield in tons per year and A_o is the lake area in square kilometers

In addition to these models, different experiences from Asian reservoirs were also taken into consideration. For instance, Vander Knapp (1994). These models were also applied for estimating the potential yield of fish from African water bodies. The physico-chemical parameters of the water bodies were measured to estimate the maximum sustainable yield of fish in the water bodies.

Assessment of fishing practices

For the assessment of fishing practices questionnaires were prepared. About 147 fishermen were selected through simple random sampling method. Fishermen were interviewed at home and/or at fishing sites. In a given day approximately 10 interviews were conducted by one enumerator, where each interview lasts for about 30 minutes. The interview schedule addressed the issue of fishing activities, fishing effort, duration of fishing, gear type, fish catch and the socio-economic condition of fishermen. Secondary data included the number of fishermen association and numbers of their members were collected from Bureau of Agriculture and Rural Development and Bureau of Cooperatives of the five districts.

Data analysis

The data collected were stored in a database created in MS Excel, a variety of subjects were analyzed by combining quantitative and qualitative social scientific methods. Descriptive statistics was used to summarize and analyze the primary data collected through questionnaires to achieve the specific objectives of the study.

4. Results and discussion

Fish species composition, their total length and weight

Table 1 shows the fish species composition in Tekeze reservoir. In the reservoir eleven fish species belonging to three orders and four families were identified during the study period. The total length of the fish species ranged from 4 cm to 98 cm and their weight between 11 g and 7109 g. Maximum length and weight were recorded in *C. gariepinus (*98 cm, 7109 g) and the minimum were for *Garra dembeensis* (4 cm and 11 g, respectively). According to Goraw *et al*., (2009) [21] in Tekeze reservoir, there were 18 species, belonging to 13 genera, 7 families and 5 orders and the families included *Cichlidae, Bagridae, Clariidae, Malapteruridae, Mormyridae, Characidae,* and *Cyprinidae.* The families *Cyprinidae, Bagridae* and *Clariidae* are the most represented ones with respect to number species and *Cichlidae* was the least in number of species in this study.

Table 1: Fish species composition, total length and weight in Tekeze reservoir

Order	Family	Scientific name	Total length (cm)	Total weight (gm)
Perciformes	Cichlidae	*Oreochromis niloticus*	7.8-37	33-926
Siluriformes	Clariidae	*Clarias gariepinus*	31-98	1329-7109
Siluriformes	Clariidae	*Heterobranchus longifilis*	28-52	423-3101
Siluriformes	Bagridae	*Bagrus bajad*	25-39	351-788
Siluriformes	Bagridae	*Bagrus docmak*	35-82	1579-5730
Cypriniformes	Cyprinidae	*Labeobarbus intermedius*	21-49	250-2101
Cypriniformes	Cyprinidae	*Labeobarbus nedgia*	16-39	165-1088
Cypriniformes	Cyprinidae	*Labeo forskalii*	15-27	149-523
Cypriniformes	Cyprinidae	*Raiaas loati*	8-23	27-98
Cypriniformes	Cyprinidae	*Varicorhinus beso*	22-31	231-475
Cypriniformes	Cyprinidae	*Garra dembeensis*	4-8	11-27

The species composition at family level is presented in Fig.2. This shows that the family *Cyprinidae* has the highest number of species (54.55%) followed by *Claridae* and *Bagridae* 18.18 % each and *Cichlidae* was the least (9.1%).

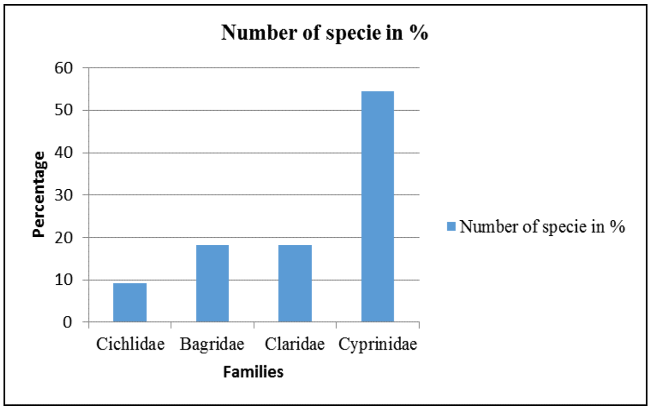

Fig 1: Fish composition of Tekeze reservoir at family level

Fish species abundance in Tekeze reservoir is presented in Table 2. A total of 1016 fish specimens were collected. It is evident from the results that, *O. niloticus* was the most dominant fish species (51.38%), *Labeobarbus intermedius* and *Labeobarbus nedgia* was the second and third in the order of abundance in Tekeze reservoir (24.11 and 10.14% respectively). *Heterobranchus longifilis* was the least in abundance in the reservoir (0.39%) caught in the month of February only. Numerically, *Cichlidae* and *Cyprinidae* were the most dominant and *Clariidae* and *Bagridae* were the least dominant ones. *L. intermidus* from *Cyprinidae* and *O. niloticus* from *Cichlidae* were the most abundant ones and *Heterobranchus longifilis* from *Clariidae* was the least dominant. The highest number of fishes was collected in February (271) and the lowest in January (237).

Table 2: Percentage of relative abundance of fish species in Tekeze reservoir

Fish species	December	January	February	March	Total	% abundance
Oreochromis niloticus	131	97	154	140	522	**51.38**
Labeobarbus intermedius	56	77	50	62	245	24.11
Labeobarbus nedgia	32	27	21	23	103	10.14
Raiamas loati	8	13	7	15	43	4.23
Clarias gariepinus	7	9	5	6	27	2.66
Bagrus docmak	5	3	7	3	18	1.77
Labeo forskalii	4	4	7	2	17	1.67
Varicorhinus beso	4	3	3	5	15	1.48
Garra dembeensis	2	2	6	2	12	1.18
Bagrus bajad	0	2	7	1	10	0.98
Heterobranchus longifilis	0	0	4	0	4	0.39
Total abundance	249	237	271	259	1016	100

CPUE in Tekeze reservoir

Table 3 shows the monthly fish catch by species in Tekeze reservoir. The highest catch was observed in December (96,535 kg) and lowest was recorded in January (65,046 kg). The lowest catch observed in this month was due to the fish mortality that occurred because of depletion of oxygen coupled with low levels of fishing operation during this month.

In average 74,388 kg were harvested in a month as shown in Table 7. *O. niloticus* was the predominantly exploited fish species from Tekeze Reservoir which accounts to 84.46% by weight followed by *C. gariepinus* (8.69%) and *B. docmak* (6.85%). The other fish species were not considered for fishing because of their bony nature and some of them are small in size.

Table 3: Monthly fish catch in Tekeze Reservoir in Kg by fish species

Month	Fish species			Total catch
	O. niloticus	***C. gariepinus***	***B. docmak***	
December	82230	8022	6283	96,535
January	55417	5400	4239	65,046
February	58828	5733	4500	69,046
March	54849	6695	5356	66,945
Total	25,1324	25,850	20,378	297,552
Catch (%)	84.46	8.69	6.85	100

The catch per Unit effort in Tekeze reservoir is given in Table 4. The range of the CPUE for the four months was between 6.77 and 11.26 kg/boat/day. The highest CPUE was recorded in the month of January (11.26 kg/boat/day) and lowest in March (6.77 kg/boat/day) and the average CPUE for the four months were 8.27 kg/boat/day. The number of active boats/days was higher in the month of December (427) and lower in January (321).

Table 4: CPUE in Tekeze reservoir

Parameters	Months				
	December	**January**	**February**	**March**	**Average**
No. of active boats/ day	427	321	404	412	391
Fishing days/ month	27	18	23	24	23
Monthly catch (Kg)	96535	65046	69046	66945	74388
Mean daily catch (Kg)	3575.37	3613.67	3002	2789.38	3234.26
CPUE (Kg/boat/day)	8.37	11.26	7.43	6.77	8.27

Monthly fish production based on gear types in Tekeze reservoir is given in Table 5. About 85.11% of the production was derived using gillnets with various mesh sizes and the rest (14.89%) were harvested using long line.

Table 5: Monthly fish production (kg) in Tekeze reservoir using different gears

Gear type	Months				Average	Percentage
	December	January	February	March		
Gillnet	82230	55416	58828	65233	65426.75	85.11%
Long line	14205	9630	10233	11712	11445.00	14.89%
Total	96535	65046	69061	76945	76871.75	100%

Estimation of potential fish yield in Tekeze reservoir

The potential fish yield in tons/year or kg/ha/year was predicted through Morpho-Edaphic- Index (MEI) as described by Henderson and Welcome (1974) [22] and Teows & Griffith (1979) and other models based on the areas of the water bodies.

Table 6: Input parameters collected and used for estimation of potential yield of fish in Tekeze reservoir

Water body	Area (km^2)	Mean depth (m)	Conductivity (uS/cm)
Tekeze Reservoir	160.4*	58*	426.00****

*From Office of Tekeze hydropower reservoir, Harza, Tekeze, (2014),

**Abraha *et al.,* (2012)

****From the present study

The models gave an estimated value of the potential yield ranging from 36.40 kg/ha/year to 104.91 kg/ha/year with an average yield of 66.16 kg/ha/year which is equivalent to 583.87 to 1682.74 tons/year and an average of 1055.48 tons/year respectively for the whole reservoir. Marshal (1984) [23] model gave the highest potential yield estimation (1682.74 tons/year) and Henderson and Welcome (1974) [22] gave the lowest estimation (583.87 tons/year). Therefore, until enough catch and effort data will be generated from the commercial catch or experimental fishing data will be collected for several years in the future, the average estimate of the above empirical models could be taken as an estimate of the potential fish yield for Tekeze reservoir. The fish potential of Tekeze reservoir was 1065.63 tons/year or 66.16 kg/ha/yr. The result was higher than to those reported by Goraw *et al.,* (2009) [21] for this reservoir (968 tons/year or 60 kg/ha/yr). The four months CPUE of the reservoir revealed that it was 27.27. This means the reservoir is under exploited. Table 10 reveals that the maximum fish production potential of Tekeze reservoir was 1055.48 tons/year. Using the maximum effort for a sustainable yield the reservoir will produce 1055.48 tons/year. If the production increase from the result shown in Table 7 the fish production will be overexploited. So that it's important to use the reservoir's resource in a sustainable manner. The average productivity of Tekeze reservoir appears to be relatively low, when compared to the productivity in other lakes and small reservoirs elsewhere in the world. In African lakes and reservoirs, the yields up to 329 kg/ha/yr and in Latin America and the Caribbean it was 125 kg/ha/yr, while in Asia, the yields reached up to 650 kg/ha/yr (FAO 2002).

Table 7: Potential fish yield estimates for Tekeze reservoir

No.	Model used	Equation	Estimated productivity in (Kg/ha/year)	Estimated potential yield in (tons/year)
1	Henderson & Welcome (1974)	$Y=14.3136MEI^{0.4681}$	36.40	606.47
2	Crul (1992)	$Yt=8.32A_0^{0.92}$	55.43	889.02
3	Marshal (1984)	$\ln(Yt)=3.57+0.76\ln(A_0)$	104.91	1682.74
4	Teows & Griffith (1979)	$Log(Y)=1.4071+0.3697log(MEI)-0.00004565A_0$	54.04	866.73
5	Vander Knapp (1994)	For medium size reservoir s mean yield estimation	80	1283.20
	Average		66.16	1,065.63

Symbols used

Yt: total yield in tons/year; Y: yield in kg/ha/year; A_0: area in km^2; MEI: Morpho-Edaphic-Index, calculated as the ratio of conductivity (uS/cm) over mean depth in meter

Assessment of Fishing Practices

Fishery cooperatives organized in Tekeze reservoir

Members of the fishery cooperative in Tekeze reservoir are legally registered and at least known to be fishermen while most, if not all, of the non-cooperated fishers are not known by the administrative body to be a fishermen. Eleven fishermen cooperatives legally organized in the reservoir in the five districts (Table 8) were found during this survey.

Gender and age distribution of the respondents from Tekeze reservoir are presented in Table 8. The interviewed data reveals that most of the respondents were males with 92.52% while females represented 7.48% only. Males predominantly participated in the fishing activities and female were less in number. This may be due to the existing culture in the region. The age ranged from the highest 58 to the lowest 14 years. The age distribution of the fisher folk revealed that, most of them were within the age group of 26-35, forming 46.26% of the total. This means that fishing activities in the reservoir can be continued for a long period of time as most of the fisher folk are still young and active.

Table 8: Gender and Age distribution of fishermen (respondents)

Demographic variables	Fishermen distribution	
Sex	**Frequency**	**Percentage**
Male	136	92.52
Female	11	7.48
Total	147	100
Age (years)		
14-25	25	17.00
26-35	68	46.26
36-45	37	25.17
46-55	11	07.48
Above 55	6	04.08
Total	147	100

The marital status and educational background of fishermen are presented in Table 9. It is seen from the table that 83.67% are married 8.16%, single and the remaining 8.17% are the members of divorced, widow/widowers and separated. The educational status revealed that 6.8% of the respondents are illiterate, 29.25% attended religious school, 43.54% attend primary school (1-8), 17.69% secondary school (9-12) and 2% are diploma holder. The study also brought to light that most of the fisher folk had their basic education. This may have contributed to the adherence to some management practices in the water bodies. Further it is also clear that, most of the fishermen involved in this sector can at least read and write except 6.80 % who are illiterate.

Table 9: Marital and Educational status of the fishermen

Demographic variables		
Marital status	**Frequency**	**Percentage**
Married	123	83.67
Single	12	8.16
Divorced	9	4.76
Widowed/widower	3	2.04
Total	147	100
Education level		
Illiterate	10	6.80
Religious school	43	29.25
Primary school (1-8)	64	43.54
Secondary school (9-12)	26	17.69
College	3	2
Higher degree	0	0
Total	147	100

The number of households and livelihood activity are given in Table 10.The number of family members in each household varies from null for those that are single with no dependents to more than 4 children on average. Households with three children are the highest with 23.13%. The highest percentages of the livelihood activity were engaged in fishing and farming (60.54%). 23.81% of the respondents were participating in fishing activity only while 10.20% were engaged in fishing and trade.

Table 10: Household number and livelihood activity

Demographic variable		
No. of children	**Frequency**	**Percentage**
No child	22	14.97
One children	23	15.65
Two children	28	19.05
Three children	34	23.13
Four children	30	20.41
>four children	10	6.80
Total	147	100
Types of livelihood activity		
Fishing	35	23.81
Fishing and farming	89	60.54
Fishing and trading	15	10.20
Fishing + other	8	5.44
Total	147	100

The duration and fish catch details are presented in Table 11. As shown in the table, the average fishing days per month in Tekeze reservoir were 23 and mean daily catch was 6.72 kg per fishermen. The average total fish catch for the month was 147.88 kg/fisherman in Tekeze reservoir. The average catch per gillnet in Tekeze reservoir was 8.89 kg and for hook and line types of gear was 0.08 kg which was very low.

Table 11: Number of fishing days and daily catch from Tekeze reservoir

Water body	Average no. of fishing day/month	Mean daily catch /fishermen	Mean of monthly catch/fishermen (kg)	Average Catch/gear type (kg)	
				GN	HL
Tekeze Reservoir	23	6.72kg	147.88	8.89	0.08

GN=Gillnet, HL= Hook and Line

The types of crafts and gears used to collect fish species from the study sites are given in Table 12. Fishermen of the reservoir were used gillnets (25.17 %), hook and line (29.25%) and 38.77% use both types of gears. About 6.80% of the interviewed fishermen do not have their own gears. They used by rent. It was observed that, the gears used in study areas were mainly gill nets and hook and line. These two types of fishing gears fell under FAO (2010) [18] checklist of 11 fishing gears. The standard size of gill net was 100m x 3m and mesh sizes (10-20cm mesh size) with a head rope and floats and footrope with sinkers. The net is made of nylon twine. Fishermen setting Long line on a floating plate in deep water (2-3m) use 20 or 30 J-shape hooks joint to monofilament line. Long line was used mainly for targeting *C. gariepinus* and *B. docmak* using *O. niloticus* by product and *Labeobarbus* species as baits. The types of fishing gear used depend mainly on the habitats exploited, fishing season, the target species and the purpose of exploitation (AMCF, 2002) [3]. The presence of underwater obstacles such as the presence of tree wood and the topography of the Tekeze reservoir restricts the use of active gears in reservoir, and the choice is often limited to passive gear such as gillnets and long line. The results showed that gillnets are widely or commonly used, and are efficient in extracting the resources of the reservoir. Gillnetting methods are widely used in artisanal fisheries in developing countries because they are efficient, relatively inexpensive and capable of catching higher amount of commercially valuable species than other peasant gears (Valdez-pizzini *et al*., 1992). Solarin and Kusemiju (2003) [27] reported gill nets as constituting the most abundant small scale fishing gear in Nigeria.

Most of the fishermen (51.02%) were not having their own fishing crafts, while 41.49 % have non-motorized metal fishing crafts. The share of wooden craft was minimal (7.48%), and they were not motorized. Thus it is clear that only about 48.97 % had their own craft constructed out of metal or wood**.** Those fishermen, who do not have fishing crafts of their own, take boats on rent.

Number of fishermen, craft and gears in the study area in each district

Detail information regarding of the number of fishermen, number of crafts and gears in the study areas are elaborated in Table 13. This data was collected from Abregelle, Tselemti, Zkuala, Sahala and T/Abergelle districts, Bureau of Agriculture and Rural Development and Cooperatives Bureau. From the table it is evident that there are five districts and 2291 fishermen are participating in fishing activities in Tekeze reservoir. The highest number of fishermen are from Abergelle (1068) and lowest were recorded in Tselemti district (152) from Amhara region. The percentage of women in the fishing practice was 2.18% and men constitute 97.82% in Tekeze reservoir. Highest numbers of boats were found in Abergelle district (333) and lowest from Tselemti (31) district. All boats operating within the study areas are classified as small scale with a capacity of less than one ton. According to Minte-Vera and Petrere (2000), some fishing strategies may consist of a combination of different equipment with appropriate mesh and type of habitat. Due to these combinations, a fisher tries to increase the chance of catching the target fish species. Therefore, in Tekeze reservoir two types of equipment are used in professional fishing: gillnets and hook and line. The number of gears in Tekeze reservoir are 5336 gillnets with various mesh size and 5497 are hook and line in number. The number of hook and line was expressed with the quantity of hooks in fishermen cooperatives. The use of gillnets and hook gear is widespread in the country's water bodies (FAO 2003) [16]. The highest number of gillnet and hook and line were recorded from Abergelle district, Amhara region (2549 and 2800 respectively). The lowest number of gears was recorded from Tselemti district fishery cooperative, 253 and 204 for gillnet and hook and line respectively. The number of gears was proportional with the numbers of members in the five districts fishery cooperatives in the reservoir. Most of the boats are not motorized (96.88%). Two types of fishing gears were used by the fishermen found in Tekeze reservoir. Long line and gill nets with different mesh size were the two kinds of gears used in the reservoir. They were found in operation during the study period. Gillnets (monofilament and multifilament) with different mesh size (10-16 cm) were the most used kinds of gear in the reservoir. In terms of catch, gill net was most productive gear followed by long line. In Africa, inland fisheries are generally synonymous with commercial artisanal fisheries that utilize gear types such as gill nets, seine nets and long-lines as harvest methods (Weyl *et al.*, 2004 [31]; Weyl, 2008 [30]). Such fisheries are recognized as important for food security, livelihoods and economic activities (Allison *et al.*, 2001) [2] and catches are monitored at formal landing sites using established methods (*Darwall et al.*, 2002 [11]; Cowx *et al.*, 2003) [9].

Fishing boats: Three types of fishing boats, steel boats, fiber boats and wooden boats are operating on fishing activities in the reservoir. In the current survey 531 steel boats, 2 fiber boats and 12 wooden types are recorded. Increase in number of fishing gear indicates the increase in pressure on fishery. Price wise the current average cost of steel boat was 40,000 birr, 27,000 birr for fiber boat and 2500 birr for wooden boat. Poor fishermen can easily afford the wooden boat. The wooden boats are mostly employed either with long line or gill net fishing activities and small in size. Steel boats are mainly used to collect/ purchase fish from fishermen on landing sites.

Gill net

During the present survey, 5336 gill net users possessing 533,600 m long (1 gill net= 100m length and 3 m width) have been enumerated. Monofilament and multifilament gill nets were isolated. The mesh size of the gill nets are ranged from 10-16 cm. the most common type of gillnet are the 14 cm mesh size. Some illegal fishermen were used 8 cm stretched mesh size. Different research findings indicated that deployment of gillnets having less than 8 cm will harm the fish resources. Recruitment could be affected if the stretched mesh sizes are allowed drop below 8 cm. The present survey revealed that 81.9% of gill net users were not used gill nets whose mesh size is less than 10 cm. 12.5% of fisherman who uses greater than 14 cm stretched mesh size targeting and the rest 6.7% were used 10 an 12 cm mesh size. The most common length of the gill nets was 100m by 3 m length and width respectively.

Long line

5497 hooks were registered in the reservoir during the study period. The main targeted fish species were *Clarias gariepinus, Bagrus docmak* and *Heterobranchus longifilis*. About 63.6% of the total fishermen have been known to be deployed the long line in the reservoir. The average number of hooks per long line user is 30. The appearance of the long line and its expansion was after the boom of *Clarias gariepinus, Bagrus docmak* and *Heterobranchus longifilis* which is shifted from the declined of *Oreochromis niloticus*. The hook users are distributed in all the fishermen cooperatives surrounding the reservoir. However, the quantity of operating hooks is higher in Abergelle district fishermen cooperative (2800) followed by Tanqua Abergelle district fishermen cooperative (1445).

Fish bait

Targeting to *Clarias gariepinus, Bagrus docmak* and *Heterobranchus longifilis*, long line users use different luring items on hooks. Most fishermen use *Oreochromis niloticus* by product on their hooks to catch the fishes and others use *Labeobarbus* species from the reservoir as bait on hooks. Generally, the current distribution of the fishermen and the fishing gears over the districts are given in Table 13 as a summary. If all these fishing gears are fully operational at a day, 0.34 hooks per 100 m^2 and 3.33 m gill net per 100 m^2 is prevalent. This implies that there is less escaping room for all fish species in the reservoir during this season.

Table 13: Number of cooperatives, fishermen, fishing crafts and gears in Tekeze reservoir

Region	Districts	NC	Number of fishermen			Number and types of boats						No. and type of gears	
			M	F	T	WB	FB	SB	T	MB	NMB	GN	HL
Tigray	T/ Abergelle	05	299	28	327	0	01	105	106	05	101	1202	1445
Amhara	Abergelle	01	1058	10	1068	12	01	320	333	07	326	2549	2800
Amhara	Tselemti	02	147	7	152	0	0	31	31	01	30	253	204
Amhara	Zkuala	02	265	0	265	0	0	60	60	03	57	378	378
Amhara	Sahala	01	472	7	479	0	0	78	78	03	75	954	670
Total		11	2241	52	2291	12	2	594	608	19	589	5336	5497
%			97.82	2.18	100	1.97	0.33	97.7	100	3.12	96.88	49.23	50.77

N.C=Number of cooperatives, M=Male, F=Female, T=Total, WB=Wooden Boat, FB=Fiber Boat; SB=Steel Boat, MB=Motorized boat, NMB=Non-motorized boat, GN=Gillnets, HL=Hook and line by quantity of Hook

Current fish price in Tekeze reservoir

Fish price varies among fish species, fish size (whole fish) and fillets (Table 14). The fish price is high during the Christian Orthodox Lent seasons (around February and March,) and reduced in the non-fasting seasons. Fish price is relatively higher at the landing sites closer to the market access and lower in the remote landing sites. The lower range of the value was for remote landing sites and the higher value of the landing sites closer access to transport. Tilapia valued higher price than other fish species because of the demands from the customers. The price for filleted Nile Tilapia ranges from 34-45 ETB (at remote landing sites during no fasting seasons) to 45 birr (at landing sites near to town during fasting seasons). This trend holds true for the remaining two fish species. The price range for whole fish varies according to the species type (Table 14).

Table 14: Average Selling Price (ETB/Kg) of Fish in Tekeze reservoir by month, fasting and non-fasting time

Fish species	Fillets price per Kg by month				Whole fish price per Kg by month			
	No fasting season		Fasting season		No fasting season		Fasting time	
	Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar
O. niiloticus	34-38	34-38	42-45	42-45	20-23	20-23	23-27	23-27
C. gariepinus	20-25	20-25	30-33	30-33	13-15	13-15	17-20	17-20
B. docmak	20-25	20-25	30-33	30-33	13-15	13-15	17-20	17-20

5. Conclusion

Fishery activities in Tekeze reservoir plays a significant role in providing income and high-protein food for an increasing number of rural families found near the water body. Although the fish production activities have already been applied in the reservoir, there is a lack of basic information on the impact of fishing practices and the natural fish productivity of the water body. Such information is essential for the formulation of a sound fisheries management program. The fish potential of Tekeze reservoir was 1065.63 tons/year and the CPUE was estimated at 8.27 kg/boat/day, indicating the fact that the reservoir seem to be in an under exploited condition since the result of the potential yield is greater than the actual yield.

The dominant fish species by catch in the reservoir was *O. niloticus* followed by *C. gariepinus* and *B. docmak*. So there is a need to exploit the resource of the water body in a wise manner. In Tekeze reservoir five districts are participating in the fishing activities. About 2291 fishermen were recorded in the reservoir. The participation of women in the fishing industries in the water bodies was very low, so it needs to increase the participation of women in the fishing activities. The price of the fish varies based of the fish species, fish size and season.

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