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Impact of Fishing Activities on the Population of Nile Tilapia (*Oreochromis niloticus*) Stocks of Lake Hayq, Ethiopia

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ABSTRACT

The study was conducted between January and December, 2018. The objectives of the study were to assess fishing activities and the impact of fishing on the Nile tilapia fish species in Lake Hayq. A total of 198 fishermen selected randomly from Kebeles bordering Lake Hayq were used as respondents for structured questionnaires. In addition to this, 30 fish traders and 8 fish hotel owners specialized in fish dish were used as key informants. The average age of fishermen was around 36 which were in active force age group (< 65 years). Most (97%) of the fishermen used gillnets imported from Egypt with mesh size of 4-6 cm stretched mesh size < 8 cm which is the national standard. There are three commercially important fish species, common carp (*Cyprinus carpio*), Nile tilapia (*Oreochromis niloticus*), and Catfish (*Clarias gariepinus*). Fishery of Lake Hayq is being used as source of livelihoods for about 2000 people living around the lake. Tehulederie, the largest district bordering the lake has established three months (May- July) as breeding seasons, however, the fishermen didn't respect the regulation set by the district. As the result, the fishery production was being reduced highly since 2010. Especially, the most important fish species (Nile tilapia) has been overfished due to the illegal fishing activities. Therefore, fishery management tools such as mesh size regulation, closing season and ground and fishery regulatory systems enacted by the federal and regional governments should be implemented through application of community-based fishery management system.

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Key words
Fishery, Fishery management, Livelihoods, Monofilaments, Overfishing

INTRODUCTION

Fish is an important commodity contributing in nutrition, food security and employment in the world. According to Food and Agriculture Organization (FAO, 2018), fishery is an important sector used for food security and source of cheap protein for the poor living in developing countries. The contribution of small-scale fisheries is significant for livelihoods of millions worldwide. Fisheries have the most significant contribution in economy of developing countries where means of livelihoods are very limited. In Ethiopia, about half a million people depend on capture fishery directly and indirectly as means of livelihoods (Tesfaye and Wolff, 2014).

The country has many lakes and reservoirs, small water bodies and large floodplain areas distributed all over the country from lowland to highlands covering a total surface area of about 13,637 km^2 (Tesfaye and Wolff, 2014). The fish diversity of the country is estimated to over 200 species (Tesfaye and Wolff, 2014; Getahun, 2017).

The fish production estimation from 106 waterbodies in Ethiopia was estimated to be 94,500 tons per year (73,100 tons/year from lentic and 21,400 tons/year from lotic systems) (Tesfaye and Wolff, 2014). However, the actual fish production in Ethiopia is far below the potential and the production status is uneven across water bodies. In some lakes such as Tana, Chamo, Abaya, Hawassa, Ziway and Hayq, fishing is beyond the maximum sustainable production potential and the problem of overfishing has been already reported in these water bodies (Tesfaye and Wolff, 2016). However, in some lakes which are located in remote areas such as Lakes Maybar and Golbo the fishery is unexploited and further development is required (Tessema and Geleta, 2013; Tesfaye and Wolff, 2014; Lakew *et al*., 2016).

The most important factors limiting fish production are the use of traditional fishing methods, food habits of the people, poor facilities along the fish value chains, poor fishery regulation implementation system, pollution, weak coordination among water sectors and generally neglectence to the fishery sector (Abera, 2017; Abebe and Chalchisa, 2019).

Lake Hayq is one of the highland lakes of Ethiopia with significant fishery activities and source of livelihoods

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directly and indirectly for the people living around the lake. About a decade ago, fish production of Lake Hayq was very high and was able to support about 2000 fishermen and fish traders (Fetahi *et al*., 2011a; Tessema and Geleta, 2013; Seid, 2016). However, the fish production trend especially of Nile tilapia has been reduced from time to time (Worie, 2009; Tessema and Geleta, 2013; Worie and Getahun, 2014; Mekonen *et al*., 2019).

Though many studies were conducted on physical limnology (Kebede *et al*., 1992), phytoplankton and zooplankton community structures and energy flows and food web structures (Fetahi *et al*., 2011a, 2011b, 2014), lake morphometric and land use and land cover (Mohammed *et al*., 2013, 2015), water quality (Ruchi *et al*., 2016), there is limited information on socioeconomic importance of fisheries, status of the current fishing activities and its impact on Nile tilapia in Lake Hayq. Therefore, this study was aimed to assess the socioeconomic importance of fisheries, status of fishing activities and its implication on Nile tilapia and recommend sustainable fishery utilization methods for Lake Hayq fisheries.

MATERIALS AND METHODS

Study area

This study was conducted in two Woredas, Tehulederie, and Worebabo which are found in South Wollo Administrative Zone. The two districts are located in Awash basin some 30 and 40 km far from Dessie and 430 and 440 km from Addis Ababa, the capital city of Ethiopia respectively. The specific areas selected for the survey study were six Kebeles (2, 5, 012, 015, 017, and 027) from Tehulederie Woreda and one Kebele (02) from Worerbabo Woreda that are located bordering Lake Hayq.

Data collection

Before the actual data collection program, permit to collect data in the study area was obtained from Tehulederie Woreda Agriculture and Rural Development Office which controls the Lake. Qualitative and quantitative data were collected using structured questionnaire, focus group discussion, and personal observation during a period of January 2018 - December 2018. Items of the questionnaire were tested and refined based on information obtained during a pilot survey. Major data addressed in the questionnaires included socio-demographic characteristics of the respondents, fishing activities, types of fishing gears, commercial fish species, kind of fish harvested, amount of fish production per month, number of days at fishing, income from fishing, income from other activities, objective of fishing, market places, average price of each fish per kg and awareness of fishermen about fishery regulatory acts of the federal and regional governments, major challenges of fisheries of Lake Hayq and Institutional support.

Sampling and sampling procedure

Sample size of fishermen was determined using sample size determination formula (Bartlett *et al*., 2001). Multi-stage (four stages) sampling techniques were used for the selection of fishermen fishing from Lake Hayq. At first stage districts bordering Lake Hayq were selected purposively (Tehulederie and Worebabo). At second stage, Kebeles bordering Lake Hayq (2, 5, 012, 015, 017, 027) from Tehulederie Woreda, and 02 from Worebabo were selected purposively based on the existence of fishing activities. At third stage, fishers were selected purposively from non-fishers in collaboration with fishery expert. At fourth stage, simple random selection of fishers was done and interviewed using pre-tested structured questionnaires as indicated in Asmare *et al*. (2016).

Sample size determination

The sample size was calculated using single population proportion formula as follows, assuming 50 % probability, 95% confidence level, and 5% desired level of precision. Since there is no structured socio-economic study in the area.

$$n_o = \frac{\left(Z_{a/2}\right)^2 . p(1-p)}{d^2}$$

Where, n_o is the fishermen to be studied; $Z_a/2$ is 1.96 at 95% level of confidence and 5% level of significance; d is 5% level of precision and p is 50% (0.5).

$$n_o = \frac{(1.96)^2 . 0.5(1-0.5)}{(0.05)^2}$$

$$n_o = \frac{(3.8416)(0.5)(0}{(0.0025)}$$

$$n_o = \frac{(0.9604)}{(0.0025)}$$

$$n_o = 384.16$$

Since the total population of fishermen (N) according to Tehulederie District is 405 from Lake Hayq during the survey, and the value of n_o (385) is > 5 % of total population, finite population correction formula should be employed to come up with the desired sample size (n).

$$n = \frac{n_o}{1 + {}^{n_o}/_N}$$

The final sample size became 198.

Sampling procedure

The final sample size calculated (198) was allocated

for Lake Hayq fishermen selected randomly until the total sample size was obtained. In addition to face to face interview with fishermen, Participatory Rapid Appraisal (PRA) was conducted with 30 fish traders and 8 hotels (5 from Hayq towns and 3 from Dessie town) that specialized only in fish dish preparation. Data such as trend of fish supply and demand, price of fishes, most preferred fish species by consumers, other source of fish other than Lake Hayq and the balance between demand and supply of fish production, major challenges of the fisheries of Lake Hayq were collected.

Data analysis

Qualitative and quantitative data were summarized using both descriptive (pictures, frequencies, percentages, pie chart and bar graphs) and inferential statistics (Chi-square, ANOVA) through application of Excel version 16 and SPSS Software version 16. Data which were not normal and categorical were analyzed using Chi-square test, but those data which were continuous and normal were analyzed using one-way ANOVA.

RESULTS

Socio-demographic characteristics of fishermen

The age of the fishermen ranged from 14-75 years and the lowest mean age of the fishermen was 31.05±13.062 years observed at 02 Kebele (Worebabo district) and the highest mean age (39.75±11.21) was observed at Kebele 027 (Tehulederie district). The overall mean age of fishermen was 35.19 ± 10.79 years which was an active force age group (<65 years). The family size of fishermen ranged from 1- 8 and the lowest mean family size (1) was recorded at Kebele 012 and the highest mean family size (3.17±1.88) was observed at Kebele 027. The lowest and the highest mean fishing experience of fishermen were 5 and 21 years, respectively (Table I).

Marital status and educational levels of fishermen

Most of the fishermen of Lake Hayq (102, 51.5%) were unmarried, followed by married (94, 47.5%) and divorced (2, 1%). The chi-square test analysis showed that there was significant difference in marital status among fishermen of Lake Hayq (x^2= 207.4, df=21, P< 0.05). The educational status of fishermen of Lake Hayq were illiterate (29, 14.6%), primary school (102, 51.5%), secondary school (59, 29.8%) and diploma (8, 4%). The chi-square test analysis showed that there was significant difference in educational background among the fishermen of Lake Hayq (x^2= 257.5, df = 28, P< 0.05) (Table II).

Table I. Descriptive statistical values of some socio-demographic characteristics (Age, Family size and Fishing experience) (Mean±SD).

Kebele	Age (Range)	Family size (Range)	Fishing experience (Range)
02	31.05±13.06 (14-60)	2.74±1.85 (1-6)	10±0 (10-10)
012	33±9.01 25-45	1±0 (1-1)	8±0 (8-8)
015	32.35±4.59 (25-42)	1.59±1.12 (1-4)	9.41±2.29 (6-16)
017	31.67±15.42 (18-60)	2±1.26 (1-4)	10±0 (10-10)
2	39.75±11.21 (24-75)	2.8±1.28 (1-5)	13.61±3.29 (5-21)
027	34.38±9.65 (16-50)	3.17±1.88 (1-8)	10.23±1.18 (9-12)
5	31.28±8.61 (18-48)	2.38±1.62 (1-6)	9.19±1.33 (8-12)

Fishermen categories

From a total of 198 fishermen, 118 (60%) were full time that had no other means of income, 78 (39%) were seasonal that had other sources of income from crop and animal farming, and 2 (1%) were part-timers with other sources of income from employment as a guard in private and governmental organizations, and boating (boat owners) (Fig. 1). All fishermen have been working independently and there was no functional fishermen association for the past one decade in Lake Hayq.

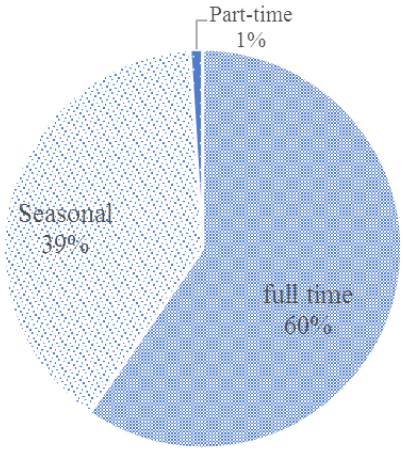

Fig. 1. Fishermen categories in Lake Hayq, January-December, 2018.

Table II. Chi-square degree of association among some socio-demographic characteristics, marital status, and educational level.

	Kebeles							Total	chi-test	df	Sig
	02	**012**	**015**	**017**	**2**	**027**	**5**		**207.4**	**21**	**P<0.05**
Marital status											
Divorced	0	0	0	0	1	1	0	2			
Married	9	3	10	4	27	24	17	94			
Unmarried	10	3	7	2	43	22	15	102			
Education level									257.5	28	P<0.05
Diploma	0	0	0	0	0	7	1	8			
Illiterate	1	0	0	0	16	6	6	29			
Secondary	6	1	3	2	11	23	13	59			
Primary	12	5	14	4	44	11	12	102			

Landing sites

There are 32 landing sites around Lake Hayq which were enclosed in 7 Kebeles under two districts, Tehulederie and Worebabo. The majority (29, 90.6%) of the landing sites are found in Tehulederie district and the remaining (3, 9.4%) are found in Worebabo district. The highest and the lowest number of landing sites were found at Kebele 015 and Kebele 017, respectively (Fig. 2). Among the seven Kebeles, the major landing sites (greater number of fishermen and fishing activities) were found in 015, 5 and 027 Kebeles in decreasing order with regard to level of importance.

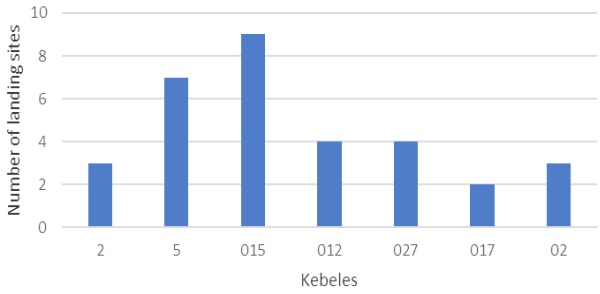

Fig. 2. Number of landing sites in Kebeles bordering Lake Hayq.

Commercially important fish species of Lake Hayq

In Lake Hayq, there are three commercially important fish species, Nile tilapia, catfish and common carp. According to the respondents, only catfish species is native fish in Lake Hayq, the other two species (common carp and Nile tilapia) are accidentally and intentionally introduced fish species, respectively into the lake (Table III).

Table III. Commercially important fish species of Lake Hayq.

Family name	Scientific name	Common name	Local name
Cichlidae	*Oreochromis niloticus*	Nile tilapia	Koroso
Cyprinidae	*Cyprinus carpio*	Common carp	Duba
Clariidae	*Clarias gariepinus*	Catfish	Ambaza

Fishing practice

Fishing gear types

In Lake Hayq, there were three kinds of fishing gears used by fishermen, gillnets (97.4%), hook and lines (1.28%) and ''Jabeto''(cages) (1.32%). The average bar mesh size of the gilnets for Nile tilapia fishing was 5 cm (< 8 cm, below the standard). Hook and lines and cages used for common carp and catfish capturing. All fishermen (100%) used traditional fishing boats made of bamboo for fishing activities. The number of fishing gears (gillnets, hooks and lines, and boats) varied based on the size of landing sites and number of active fishermen (Fig. 3). The total number of gillnets and boats were 185 and 166, respectively. The number of fishing boats and gillnets were decreasing from time to time as the result of reduction in fish production.

Fishing methods

The fishermen of Lake Hayq capture fishes both during night and day times. Fishermen set their gillnet overnight and check early morning. However, most of them (70 %) engaged in capturing Nile tilapia from the shore of the lake during day time through chase and trap method. Some experienced fishermen capture bigger sized common carp and catfish using hooks and lines. The fishermen used gills of fishes and body parts of *Garra*

species as baits for capturing catfish. They use immature maize fruit ('Chorka', in Amharic), gills, and body parts of fishes as baits for common carp fishing in Lake Hayq.

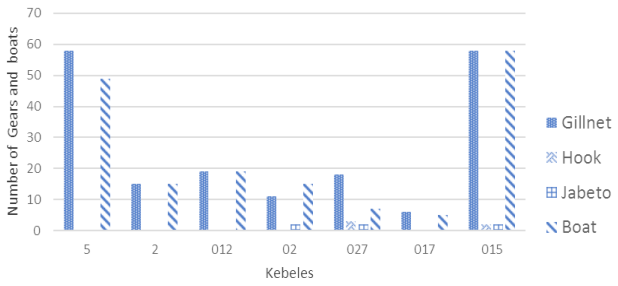

Fig. 3. Number of fishing gears and boats in seven selected kebeles bordering Lake Hayq.

Mode of transportation of fishes

Most of the fishermen (60%) used small vehicle 'Bajaj', some (20%) of them used boat and Bajaj to reach market place as means of transportation, and others (20%) travel on foot, those having no access to ''Bajaj''. Those fishermen that travel on foot were mainly using the fish for their own consumption.

Fish processing for market and consumption

The fishermen of Lake Hayq prepared or processed the fish mainly in filleted form for market to be sold either at hotels or fish market ('Asa Gebeya', inAmharic) found at Hayq Town. However, fishermen were also used to sell whole fish sometimes at landing sites for fish traders. In some instances, fishermen might consume filleted raw Nile tilapia at landing site with red pepper. Fishermen consumed about 1 kilo of fish per week. Both fishermen and other consumers prefer Nile tilapia, catfish and common carp fish species from highest to lowest order of preference, respectively. Common carp was not used for commercial purpose before 10 years around Lake Hayq. However, the scarcity of Nile tilapia forced the fishermen and the local people to consume common carp after extensive training on how to prepare carp dish was given. Currently, common carp had significant contribution to the income of fishermen and nutrition of the people living at Hayq and in Dessie towns.

Socioeconomic contribution of fisheries

The one-way ANOVA analysis showed that there was significant difference ($P< 0.05$) in mean price of fishes, mean number of fishing days, mean fish consumption, mean monthly income from agriculture and mean monthly income from fishery of fishermen. The mean price of catfish was the highest followed by Nile tilapia. Fishermen that had other sources of income have lower fishing days per month. Fishermen consume mostly Nile tilapia, followed by common carp and catfish. The income of fishermen from fishery was more than from agriculture except Kebele 02 where they had income from horticulture (banana, sugarcane, *Cata edulis*) (Table IV).

Trends in fish production

During the last six years fish production has reduced in Lake Hayq (Fig. 4). The fish production has strong association with number of active fishermen. According to Tehulederie Agricultural Office, the number of fishermen was very high (about 1500) in 2013. However, when the fish production was reduced due to overfishing, most of the fishermen changed their profession and migrated to Arabian countries (Personal communication, Woldemariam, 2018). Recently the total number of fishermen of Lake Hayq was about 405.

Fig. 4. Fish production trend for the last six years from Lake Hayq (Tehulederie District Agricultural and Rural Development Office, 2019).

Awareness of fishermen on fishery management

Most (148, 74.7%) of the fishermen of Lake Hayq have basic concepts of fishery management tools (closed breeding season and ground, mesh size regulation, gear restriction, etc.), and fishery development and utilization proclamations enacted both by the federal and regional governments such as Federal Fisheries Development and Utilization Proclamation (Proclamation No.315/2003), the Amhara National Regional State Fisheries Development, Prevention and Utilization (Proclamation No. 92/2003), and the Amhara National Regional State Fisheries Development, Prevention and Utilization Proclamation Enforcement (Proclamation No. 50/2007). However, some (50, 25.3%) of the fishermen said that they don't have information about the aforementioned proclamations and regulations.

Table IV. Mean price of filleted fishes (ETB), mean monthly fish catches (Kg), mean fishing days per month, mean monthly fish consumption (Kg), and mean monthly income of fishermen (ETB) (Mean ± SD).

	Kebeles						
	02	**12**	**15**	**17**	**2**	**27**	**5**
Price (ETB)							
C. carpio	50	64.0	63.8	50	55.6	50	51.6
O. niloticus	106.3	85	93.2	110	99.5	75.7	76.6
C. gariepinus	101.1	100	101.8	90	113.8	129.2	118.4
Fishing days	11.3	17	16.8	22	22.3	24.7	21.3
Catch (Kg)							
C. carpio	15	30	35	40	25	28	25
O. niloticus	5	10	10	15	10	12	10
C. gariepinus	0	5	5	10	10	5	5
Consumption (Kg)	6	4	10	8	4	5	2
Income (ETB)							
Agriculture	3000	400	800	766.7	1260.6	600	468.8
Fishery	1202.1	3584.2	3757.1	4840	3776.6	3734.9	3176.1
Total	4202.1	3984.2	4557.1	5606.7	5037.1	4334.9	3644.8

Note: ETB, Ethiopian birr; 1 USD, 30 ETB

Table V. Major constraints of fisheries of Lake Hayq and proposed solution mentioned by key informants and triangulated by the researcher.

Constraints	Rank	Causes	Proposed solution
Destruction of macrophytes	3	Absence of breeding ground	Protecting and replanting macrophytes
Fishing during the breeding season and at the breeding ground	2	Overfishing beyond MSY (maximum sustainable yield)	Close the season and ground properly
Lack of support from the government	9	Poor fishery management system	Implementation of the fishery proclamation, creating more jobs to minimize the fishing pressure
Narrow sized gillnet of mesh size 4-6 cm	1	Small sized fish	Gillnet of mesh Size > 8cm
Lack of other fishing ground	8	High fishing pressure	Expansion of aquaculture Looking for nearby riverine fishery (Mille)
Invasive aquatic weed	5	Hinders baby fish movement	Mechanical removal of the aquatic weeds
Point and nonpoint source of pollution	10	Degrade water quality	Integrated waste management
Sedimentation	6	Destruct fish breeding ground and kills fish eggs, larvae and baby fishes	Integrated watershed management
Open access	7	Fish stock collapse	Establish community-based fishery management and Lake Association
Common carp invasion	4	Competition for food	Introduction of more catfish and Nile tilapia to balance the ecological competition with common carp

Implementation of the proclamations

Though better awareness has been created about the fishery development and utilization proclamations through the efforts of Wollo University and Tehulederie District Agricultural and Rural Development Office, the implementation status is very poor. The district closes

the fishery for three months (May, June, and August) considering the breeding season and has employed supervisor for monitoring illegal fishing activities. But the implementation was superficial. Many factors could be mentioned for the poor implementation of the proclamation; however, all fishermen agreed that increase in the number of jobless youths around the lake is a major factor for poor implementation of the proclamations.

Focus group discussion and key informants

Fisheries experts, fish traders, senior fishermen and hotel owners at Hayq and Dessie are of the opinion that fish production from Lake Hayq reduced significantly during the past decade. The major factors mentioned by the participants were increasing number of jobless youths, destruction of buffer zone, illegal fishing gears (bar mesh size <8 cm, below the standard), fishing during breeding season and at breeding ground, and overfishing especially *O. niloticus*. Currently, the fish stocks production from Lake Hayq are overfished as the result hotels at Hayq and Dessie purchase fish (*O. niloticus*) about 20-50 kg per day from other lakes such as Lake Ardibo (Tehulederie), Tana (Bahir Dar), Hashengie (Korem), Chamo and Abaya (Arba Minch).

From the PRA (participatory rapid appraisal) and discussion with key informants, the major problems of Lake Hayq fisheries have been identified and pairwise ranking was done (Table V). Based this result, major problems were identified and their solutions were proposed. The three most significant factors for the reduction of fish production of Lake Hayq especially stunt growth of Nile tilapia were related with illegal fishing activities, narrow sized mesh size of gillnets, fishing during breeding season and at breeding ground, and destruction of macrophyte which are used for feeding, breeding, refuging for juvenile fishes and also reduce the negative effects of the pollutants entering the lake.

DISCUSSION

Fishing activities in Lake Hayq

The fishing activities was being done in Lake Hayq using traditional boats made of bamboo and gillnets of mesh size that ranged from 4-6 cm bar mesh size (gillnets which are brought from Egypt). All fishermen of Lake Hayq are using these gillnets (gillnet, 4-6 cm mesh size). The fishermen of Lake Hayq said that the reduction of the Nile tilapia fish population and stunted growth might be associated with the introduction of these monofilaments as observed in Lake Tana (Gebremedihin *et al*., 2018) and Lake Ziway (Abera, 2017). The fishing pressure was very high, especially for Nile tilapia. Fishermen capture fish both at night (setting the net overnight) and day time (chase and trap). The average age of fishermen (36) was an active force range (< 65 years) that has its own impact on resource extraction from the lake. Unlike in bigger lakes such as Tana, Ziway, Abaya, Chamo, no modern boats were used for fishing in Lake Hayq.

Composition of commercially important fish species in Lake Hayq

The number of commercially important fish species in Lake Hayq is less which is a characteristic feature of deep highland lakes in Ethiopia. Lake Hayq has three commercially important fish species which is comparable to highland Lakes, Hashengie, Ardibo, Maybar, Golbo, Dendi and Wonchi each has two fish species (Tessema and Geleta, 2013; Degefu *et al*., 2014; Vijverberg *et al*., 2012). However, Lake Hayq has lower number of fish species compared to the shallow highland lake, Lake Tana which has 10 fish species important for the fishery in L. Tana: Nile tilapia, African catfish and 8 common *Labeobarbus* fish species (Dejen *et al*., 2017). According to Golubtsov and Darkov (2008), commercially important fish species, common carp and Nile tilapia were introduced in the aforementioned highland lakes for food security purpose. Therefore, the common carp and Nile tilapia of Lake Hayq are not native unlike catfish.

Socioeconomic importance of fisheries of Lake Hayq

According to Tehulederie district Agriculture and Rural Development Office (2018), there are about 405 fishermen living in seven Kebeles (02, 2, 5, 012, 015, 017 and 027) surrounding Lake Hayq. The average family size of fishermen was 3 and total of about 1215 individuals depend directly on fisheries of Lake Hayq. Similar to fisheries of Lake Tana (Gebremedihin *et al*., 2013), fisheries are the source of livelihoods for thousands in Lake Hayq. Some of the fishermen that have additional income source such as crop and animal farming have better fish consumption habits that help them to balance their nutrition. Recently the fishery production from Lake Hayq is very low and controlled by males from production to marketing. Fisheries in Lake Tana and Rift valley lakes operated both by males involved in production and females mainly involved in processing (Abera, 2017; Lakew *et al*., 2016) which might be associated with culture of the fishermen. In Lake Hayq the demand for fish is uniform throughout the year. This is, in contrast, the situation in other lakes. For example, there is high demand during March - April, and August (fasting season) in Lake Babogaya (Abera, 2015).

Impact of fishing pressure on Nile tilapia of Lake Hayq

The intensive fishing on target fish species (*O. niloticus*) using illegal fishing activities, utilization of gillnet with 4-6 cm (monofilaments), fishing during breeding season and ground might cause stunt growth of Nile tilapia and population reduction of these fish species in Lake Hayq. In agreement with this study, illegal fishing activities especially utilization of monofilaments and excessive fishing pressure are being the cause of overfishing of Nile tilapia in Lake Tana (Gebremedihin *et al*., 2018; Amro *et al*., 2019; Worie *et al*., 2019), Lake Ziway (Abera *et al*., 2018) and Lake Hawassa in Ethiopia, Lake Victoria in Kenyan portion (Njiru *et al*., 2008; Yongo *et al*., 2018) and in Lake Naivasha in Kenya (Njiru *et al*., 2017). Similarly, Ojuok *et al*. (2007), Robert *et al*. (2009), N'sibula *et al*. (2010), Abera *et al*. (2018) and Sandun *et al*. (2018) have reported that intensive fishing selectively on target fish (*O. niloticus*), and illegal fishing such as fishing before the onset of maturation, fishing during breeding season and at breeding ground and fishing using very narrow sized gillnet might reduce size at first maturity, dominance of very small-sized fish population (95%) and early maturation.

In contrary to this study, Jackson *et al*. (2009) reported that fishing pressure may reduce intraspecific competition because fishing induces reduction in population density of target stock and lead to increased yield because of reduction in intraspecific competition that release populations from density dependence resulting in faster growth and earlier maturation. Wolff *et al*. (2015) reported that use of small-sized gillnet may promote sustainable fish production allowing a higher proportion of the spawning biomass to remain in the stock in water bodies where fishing activities are low.

Awareness of fishermen about fishery management regulatory acts

Most of the fishermen of Lake Hayq have awareness about the Fishery Development and Utilization Proclamation ratified by the Ethiopian Federal Government (Proclamation No.315/2003) and the Amhara National Regional State Fisheries Development, Prevention and Utilization Proclamation No.92/2003) and the Amahara National Regional State Fisheries Development, Prevention and Utilization Proclamation Enforcement (Proclamation NO.50/2007). However, the implementation was very poor which is a similar problem in other Ethiopian lakes as Lake Koka (Tesfaye and Wolff, 2014), Lake Tana (Dejen *et al*., 2017), and Lake Ziway (Abera, 2017).

Institutional support for sustainable utilization of fisheries of Lake Hayq

Bahir Dar Fish and Other Aquatic Life Research Center and Wollo University have organized a one-day national conference on June 1, 2013, with the objective of restoration of Lake Hayq and its fish (Nile tilapia). During the conference, about 18 stakeholders were identified which are responsible for sustainable fishery utilization of Lake Hayq. However, only some governmental organizations, Haik Agricultural Research Sub Center (Part of Amhara Agricultural Research Institute), Wollo University and Tehulederie district Agricultural and Rural Developmental Office are currently involved in research, training and fishery regulation activities which could contribute for sustainable fishery utilization of Lake Hayq in the future. Wollo University in collaboration with Ecohydrology Project (newly approved project by Ethiopian Ministry of Water, Irrigation and Eletricity and Wollo University for restoration of Lake Hayq) has approved Lake Hayq Restoration Project and working in two phases, baseline data collection (Phase I) which is completed, and phase II (restoration of Lake Hayq and its watershed) which is planned.

Challenges of fisheries of Lake Hayq

Fisheries of Lake Hayq has faced many challenges, illegal fishing activities (overfishing, narrowed sized gillnet (monofilaments), fishing during reproduction and at breeding ground), destruction of macrophytes and the buffer zone, siltation, catchment degradation, land use and land cover change, expansion of invasive weed (*Ceratophylum submersum*), less support from the government and poor implementation of the fishery regulatory acts and proclamations. The present study was in agreement to what has been studied for Lake Tana (Asmare *et al*., 2016; Gebremedihin *et al*., 2018; Worie *et al*., 2019; Amro *et al*., 2019). The present study also agrees with Abraham and Mitiku (2018) who reported about challenges of Ethiopian fisheries.

The result of the present study also was in line with Njiru *et al*. (2010) and Yongo *et al*. (2018) who reported for Lake Victoria, and Njeru *et al*. (2017) for Lake Naivasha where overexploitation, use of illegal fishing gears and poor enforcement of regulations, pollution, catchment degradation, poor waste disposal are responsible for overall decline in size at first maturity of *O. niloticus*.

CONCLUSIONS AND RECOMMENDATIONS

Despite the presence of direct fishery regulatory acts (Federal and Regional Fishery Development and Utilization Proclamations), the fishing activities in Lake Hayq is illegal. All the fishermen were using illegal fishing gears (monofilaments or gillnets of mesh size of

4-6 cm). There is no fishermen association in the lake that might help in controlling fishing during breeding season and ground. As the result of these activities, the fishery production of Lake Hayq is getting decreased from time to time and fishermen have changed profession and migrate to Arabian Countries. Therefore, re-introduction of Nile tilapia and closing of the Lake for 4-5 years should be done. For successful implementation of these efforts, responsible stakeholders, fishermen, Tehulederie District Agricultural Office, South Wollo Zonal Agricultural and Rural Development Office, Amhara Regional Livestock and Fishery Agency, Haik Agricultural Research Sub Center, Wollo University, and Ecohydrology Project should work hard in creating other source of livelihoods for the fishermen till the restocked Nile tilapia is well established.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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