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Research Article

Characteristics and Status of the Highland Lake Hashenge Fishery, Tigray, Northern Ethiopia

Abstract

The study was intended to show the characteristics and the status of fishery in Lake Hashenge. Assessment of fishing practices was done by using questionnaires. Physico- chemical parameters of the lake water shows optimum for fish growth. In the lake there are three fish species of those two are economically important fish species. Common carp (*Cyprinus carpio*, Cyprinidae) introduced into the lake in the 2000s has grown to become the most important source of protein food for the four village communities. Realizing the importance of common carp, the fishermen seek the possibility of introducing a new tilapia species, Nile tilapia (*Oreochromis niloticus*, Cichlidae) to the lake. With current Nile tilapia already providing a sufficient source of protein, coupled with the surrounding people, caution must be taken in any further developments. Information on the fishery, water quality parameters and the physical environment of Lake Hashenge were collected to describe the characteristics and status of the lake fishery. A total of 265 specimens composed of juveniles and adults from lake were identified and classified. They comprised of three species belonging to two orders and two families. The catch per unit effort (CPUE) for Lake Hashenge was 23.38 kg/boat/day and estimated maximum sustainable yield of the lake were about 161.76 tones/year. The catch per unit effort of lake indicating the fact that the lake seem to be in an under exploited condition since the result of the potential yield is greater than the actual yield.

Introduction

Food production in most part of the world is not on a same level with the increasing human population. Therefore, in addition to increasing agricultural production, it is necessary to search for alternative food source. Ethiopia is fortunate to have some of the most productive freshwater fisheries in the world. Exploitation of the aquatic resource, in particular the fishery is a well-developed activity in several part of the world. In countries like Ethiopia, where there is shortage of protein, the country should utilize its fishery resource. To fill the gap aquatic ecosystem can serve as inexpensive source of fish protein and needs to be fully exploited.

Aiming at increasing the productivities of water bodies, introduction of both exotic and indigenous freshwater fishes have been made to several manmade and natural water bodies in Ethiopia since the 1970s. In most cases the Nile tilapia (*Oreochromis niloticus*) has been stocked to several small water bodies because of its adaptability to wide environmental conditions as well as high demand of the fish by the local consumers [1]. Exotic fishes which have been introduced to the country from abroad include *Cyprinus carpio* and *Tilapia zillii* [2]. In spite of some ecological problems reported by conservationists [3], there have been success stories which resulted in providing fish for the local communities and markets of major cities as evidenced in the cases of Lakes Small Abaya, Fincha, and Hashengie [4].

In Lake Hashenge after the mass fish mortality of Nile tilapia were occurred the National Fishery and Resources Research Center, Sebeta soon after the survey, *Oreochromis niloticus*, *Cyprinus carpio* and *Cyprinus carassius* fry were stocked into the lake in 1982 -1983 and 2001 with the aim of enhancing fishery and availing inexpensive fish protein to the local community [5]. In the lake long-time fishers report that the lake is becoming increasingly shallow, and deforestation and farming activities add to natural siltation. These phenomena represent the greatest threat to the lake and its fishery. Three species of fish were recorded from the lake including species introduced to the lake. The lake also supports a large number of water birds.

Common carp were introduced into Lake Hashenge in the late 1980s and 2000s and have now grown to become the most important source of protein, with minor supplementary from Nile tilapia. Most catches were for subsistence use, but occasional selling does occur when there is a surplus. With the opportunities of the lake is not so far to the towns, trade in

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fish has more potential than the actual production. In 2000 and 2014, however, there were reported incidents of tilapia dying in large numbers in the lake. There were also concerns about the abundance and size of tilapia, which were believed to be declining at this time. The aim of the present study was to assess the status of fishery and fish production potential of Lake Hashenge and to determine the characteristics of the lake resource.

Materials and Methods

Study area

Lake Hashenge is situated in Ofla Woreda Southern Tigray, about 628 km at North of Addis Ababa, Ethiopia. It is located at the coordinates of 12°34′50″N and 39°30′00″E and an elevation of 2440 masl and it is one of the crater lakes in the country and not associated with the East African rift system; instead it is the result of volcanism. This lake has no any outlet to drain its water. Hashenge Lake is five kilometers long and four kilometers wide, with a surface area of 20 km^2. Its drainage area is 129 km^2 and has a maximum depth of 25 meters. There is roughly 0.5 m difference between normal high and low water levels.

Methods

Questionnaire: questionnaire survey designed to collect general information on the fish resource of the lake and the socioeconomic of the fishermen, Nile tilapia abundance, size, its fishery (fishing methods, how often and where fished, etc.) and its physical environment was undertaken during Survey. 37 fishermen were interviewed. Additional information on the general lake appearance was collected through a tour around the lake using a 9.9 hp outboard motor steel boat.

Physico-chemical parameters of the water: Physico-chemical parameters of the water like temperature, pH, conductivity, TDS, dissolved oxygen and transparency were monitored monthly in the field using the methods as described in APHA [6]. Temperature, DO, Conductivity and TDS were measured using portable digital water quality multi meter model (CO 411), and pH was measured with portable pH meter model (CP 401).

Collection, identification and composition of fish species: Three sampling sites were selected. Each site was sampled four times (once a month). Fish samples were collected using multifilament and monofilament gill nets of various stretched mesh sizes (2cm-20cm) and monofilament with. The multifilament and monofilament gillnets were set using plastic bottles as swimmers across the lake starting from 5:00 PM and left in the water for 14 hours and collected in the following morning from 7:00 AM. Immediately after capture, the total length, standard length and weight were measured to the nearest 0.1cm and 0.1g 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 [7-10].

Estimation of CPUE: The frame survey involved the visits of the entire water body to identify and count every fishing locality within the lakes, 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 the lake, sampling was done from two landing sites. 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.

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 listed below. 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: $Y = 14.3136. MEI^{0.4681}$ -------------------- [11].

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

Calculated as follows: MEI= conductivity (uS/cm)

Mean depth in m

Model 3: $Y_t = 8.32\ A_o^{0.920}$ (R^2= 0.93) ---------------- [12].

Model 4: $Log(Y) = 1.4071 + 0.3697 log(MEI) - 0.00004565 A_o$ ----------Teows & Griffith [13].

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

The physico-chemical parameter of the water body was measured to estimate the maximum sustainable yield of fish in the water bodies.

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.

Results and Discussion

Assessment of fishing practices

Gender and age distribution of the respondents from Lake Hashenge are presented in table 1. The interviewed data reveals that most of the respondents were males with 91.9%

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while females represented 8.1% 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 25 years. The age distribution of the fisher folk revealed that, most of them were within the age group of 25-35, forming 62.16% of the total. This means that fishing activities in the lake can be continued for a long period of time as most of the fisher folk are still young and active.

The marital status and educational background of fishermen are presented in table 2. It is seen from the table that 83.78% are married 13.51%, single and the remaining 2.70% are the members of divorced. The educational status revealed that 13.51% of the respondents are illiterate, 18.92% attended religious school and 62.16% attend primary school (1-8), 5.41% secondary school (9-12). 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 lake. Further it is also clear that, most of the fishermen involved in this sector can at least read and write except 13.51 % who are illiterate.

The number of households and livelihood activity are given in table 3.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 two up to four children are the highest with 67.57%. The highest percentages of the livelihood activity were engaged in fishing and farming (45.95%). 32.43% of the respondents were participating in fishing activity only while 16.22% were engaged in fishing and trade.

The duration and fish catch details are presented in table 4. As shown in the table, the average fishing days per month in Lake Hashenge were 16 and mean daily catch was 3.22 kg per fishermen. The average total fish catch for the month was 51.52 kg/fisherman. The average catch per gillnet in the lake was 4.83 kg which was very low.

Fishing methods

Fishermen of the study site use only gillnets with different mesh sizes (10-14 cm mesh size) which this type of fishing gears fell under FAO [14], checklist of 11 fishing gears. Other fishing methods such as long-line, hook and traditional poison were either uncommon or had never been used. The standard size of gill net was 100m x 3m and mesh sizes (10-14cm mesh size) with a head rope and floats and footrope with sinkers multifilament gill net type. The types of fishing gear used depend mainly on the habitats exploited, fishing season, the target species and the purpose of exploitation [15]. The results showed that gillnets are widely or commonly used, and are efficient in extracting the resources of the lake. 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 et al. [16], reported gill nets as constituting the most abundant small scale fishing gear in Nigeria. The fishermen were not having their own fishing crafts, but have in cooperatives while 25 % have motorized steel fishing crafts and 75% are non-motorized steel crafts.

Stock and size: questionnaire survey on the abundance and size of Nile tilapia after the introduction of common carp

Table 1: Gender and Age distribution of fishermen (respondents).

	Fishermen distribution	
Demographic variables Sex	Frequency	Percentage
Male Female Total	34 3 37	91.9 8.1 100
Age (years)		
25-35	23	62.16
36-45	7	18.92
46-55	5	13.51
Above 55	2	5.41
Total	37	100

Table 2: Marital and Educational status of the fishermen.

Demographic variables		
Marital status	Frequency	Percentage
Married	31	83.78
Single	5	13.51
Divorced	1	2.7
Total	37	100
Education level		
Illiterate	5	13.51
Religious school	7	18.92
Primary school (1-8)	23	62.16
Secondary school (9-12)	2	5.41
College	0	0
Higher degree	0	0
Total	37	100

Table 3: Household number and livelihood activity.

Demographic variable No. of children	Frequency	Percentage
No child	3	8.11
One children	5	13.51
From two-four children	25	67.57
>four children	4	10.81
Total	37	100
Types of livelihood activity		
Fishing	12	32.43
Fishing and farming	17	45.95
Fishing and trading	6	16.22
Fishing + other	2	5.41
Total	37	100

Table 4: Number of fishing days and daily catch from Lake Hashenge.

Average no. of fishing day/month	Mean daily catch /fishermen	Mean of monthly catch/fishermen (kg)	Average Catch/ gillnet (kg)
16	3.22kg	51.52	4.83

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were assessed. 97 % of fishers believed that the tilapia stock abundance was declining. 3 % said there was no change in the stock abundance. 80 % claimed the average size of Nile tilapia to be decreasing, while only 20 % believed there was no size change.

Physico-chemical parameters of Lake Hashenge water: The values of physico-chemical properties of water are presented in table 5. Most of the values of water quality parameters during the study period were in the optimum condition for fish production. The mean transparency, pH, and temperature of the lake were 79.8±4.6 cm, 8.1±0.2 and 19.3±0.7°C. The conductivity of the water body showed the mean value of 619.5±26.8 uS/cm. TDS showed a mean value of 9.5±0.5g/L for Lake Hashenge. In Lake Hashenge the dissolved oxygen ranged from 5.9 in January to 7.6 mg/L in March with a mean value of 6.8±0.7 mg/L. The pH reading lake was recorded in the range of 7.8 and 8.3 the lowest of 7.8 slightly alkaline. This is normal due to the nature of the substrata of the lake and its surrounding farming area.

The mean range of values of physico-chemical factors of the lake are within limit for fish tolerance, survival and production [17], and indicated good quality of water in the study area according to APHA [6]. The desirable level of DO, temperature and pH for optimum growth of fish are >5 mg/L, 26-30°C and 6.5-8 respectively [18]. This study also shows that the water parameters were in the optimum range and the mean temperature of Lake Hashenge seems low for Nile tilapia growth. This may lead to the less abundance of Nile Tilapia in the lake.

In Lake Hashenge, three species were identified and they belong to two orders and two families table 5. The maximum length and weight recorded was in *C. carpio* (46 cm and 1240 g) and lowest in *G. ignestii* (4 cm and 28g) (Table 6).

The family wise distribution of fish species collected from Lake Hashenge is presented in figure 1 which indicates that the family *Cyprinidae* has the highest number of species (67%) followed by *Cichlidae* (33%).

Species relative abundance in Lake Hashenge: The percentage abundance of fish species in Lake Hashenge is listed in table 7. From a total of 265 fishes collected during the study period from Lake Hashenge, 61.13 % constituted *Cyprinus carpio* followed by *Garra ignestii* (21.13%) and *Oreochromis niloticus* (17.74%) thereby showing that in Lake Hashenge the most dominant species is the *Cyprinus carpio* and *Oreochromis niloticus* was the least in the percentage of abundance. The reduction of the abundance of *Oreochromis niloticus* may be due to the mass mortality of the fish species that occurred in June 2014 in the lake and the temperature of the lake (19.77°C) is not good for Nile tilapia growth and reproduction. Highest number of samples were collected in March (95) and lowest in January (40).

Estimation of CPUE in Lake Hashenge: Table 8 shows that monthly fish catch in Lake Hashenge. About 93.88% of the fish production in Lake Hashenge was constituted by *C. carpio* species. There was production of *O. niloticus* but it was lower (6.12%). The highest monthly fish production was observed in February and lowest in December, 916 kg and 539 kg respectively. The lowest fish production during the month of December may be due to the cold condition of the water in this month, because temperature affects the fish movement and fishing activities.

In Lake Hashenge the average CPUE of the four months were about 23.38 kg/boat/day. The monthly catch were lower and the effort was also lower due to this the CPUE data were higher were it compared with the CPUE of Tekeze reservoir which was 27.27 kg/boat/day (Table 9).

The results of the three models ranged from 65.47 to 98.20 kg/ha/yr and the average was 80.88 kg/ha/yr. Toews and Griffith [12], model gives the highest yield estimation (98.20 kg/ha/yr) and lowest result were obtained from Crul (65.47 kg/ha/yr). The potential yield of the lake gives about 161.76 tons/year. CPUE in Lake Hashenge during 23.38 the study period was 748 kg per month and this indicates that the lake is under

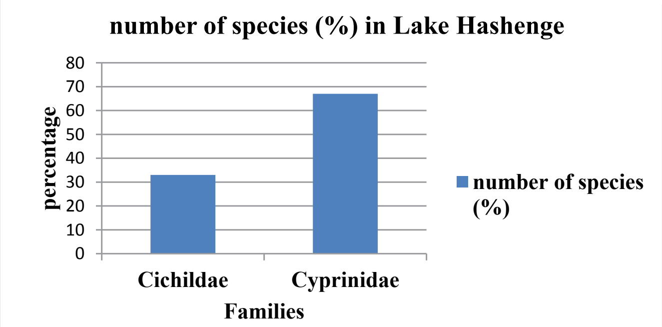

Figure 1: Fish composition of Lake Hashenge at family level.

Table 5: Monthly Physico- chemical parameters of Lake Hashenge water in 2015/16.

Month	Physico-chemical parameters of the lake					
	DO mg/L)	pH	Temperature (oC)	Conductivity (uS/cm)	TDS (g/L)	Transparency (cm)
December	6.9	8.3	18.9	644.0	10.1	74.0
January	5.9	8.1	18.8	634.0	9.3	81.0
February	7.0	7.8	19.2	617.0	9.5	79.0
March	7.6	8.2	20.3	583.0	8.9	85.0
Mean ±SD	6.8±0.7	8.1±0.2	19.3±0.7	619.5±26.8	9.5±0.5	79.8±4.6

Table 6: Species composition and total length and weight of fishes in Lake Hashenge.

Order	Family	Scientific name	Total length (cm)	Total weight (gm)
Perciformes	Cichlidae	*Oreochromis niloticus*	12-27	95-585
Cypriniformes	Cyprinidae	*Cyprinus carpio*	20-46	352-1240
Cypriniformes	Cyprinidae	*Garra ignestii*	4-10	14-28

Table 7: Percentage of relative abundance of fish species in Lake Hashenge.

Fish species	December	January	February	March	Total	% abundance
Cyprinus carpio	23	32	49	58	162	61.13
Garra ignestii	13	9	15	19	56	21.13
Oreochromis niloticus	4	8	16	18	47	17.74
Total abundance	40	49	80	95	265	100

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exploited. Assefa [19], reported that fish production potential of Lake Hashenge was estimated at 106.76 tons/year and the actual catch was 21 tons/year which was lower than estimation of the present study for the potential yield.

The maximum sustainable yield of Lake Hashenge is 161.76 tons/year table 10. But the CPUE of the lake was about 748 kg/month or 46.75 kg/day (if they harvest 16 days in a month). This result indicates that the lake is underexploited.

Above 75 % and 91% of the respondents claimed that due to the introduction of common carp to the lake the Nile tilapia production, size and abundance was decreasing. Food competition could be the most serious contributing factor to stock and size decline of Nile tilapia in the lake. Introduction of new species would undoubtedly increase fish catch, but it could also affect the native species by competing for food, disturb the breeding nest and feeding on the egg and larvae of the native species (Table 11).

The decline of Nile tilapia after the introduction to Lake Hashenge could be due to food competition among the two fish species, disturbance of breeding site of Nile tilapia by common carp and environmental effect (the temperature of the lake is less than 20°C which is not favorable to breeding of Nile tilapia (21-35°C). This temperature is suitable for common carp since carp can tolerate a temperature range of 3°C - 35°C [20]. The breeding population of common carp can negatively impact native species both directly and indirectly by competing for food [21], and habitat. Common carp *Cyprinus carpio* are distributed worldwide and considered one of the most widespread, detrimental invasive species [22], because of their ability to attain extreme densities (up to 1000 k/ha) [23], and alter freshwater ecosystems [24]. Common carp induce numerous deleterious effects on shallow lakes, at both the community and ecosystem level by increasing nutrient availability, turbidity and phytoplankton abundance, reducing benthic macro invertebrates and aquatic macrophytes, and modifying zooplankton assemblages [24,25]. By reducing or eliminating aquatic macrophytes and disrupting substrates, common carp may indirectly reduce abundance of other fishes through reductions in spawning and nursery habitats [26]. Egertson and Downing [27], and Jackson et al. [28], indicated that common carp abundance was negatively related to abundance of bluegill *Lepomis macrochirus*, black crappie *Pomoxis nigromaculatus* and largemouth bass *Micropterus salmoides*, likely driven by impaired water quality in these systems. Water birds could be also contributed to stock decline. The increased use of shore land utilization for agricultural purpose could also contribute to water pollution and siltation for the lake. There are currently no management measures in place for Lake Hashenge in regards to fishing activities. Although fishing is of open access to all lake communities, commonsense is encouraged to play an important part.

Table 8: Monthly catch of fish (in kg) in Lake Hashenge.

Month	Fish species		
	Cyprinus carpio	Oreochromis niloticus	Total
December	512	27	539
January	613	25	638
February	863	53	916
March	821	78	899
Total	2809	183	2992
Average	702.25	45.75	748
% by species	93.88	6.12	100

Table 9: CPUE in Lake Hashenge.

Parameters	Months				Average
	December	January	February	March	
No. of active boats/day	2	2	2	2	2
Fishing days/month	14	15	18	17	16
Monthly catch (Kg)	539	638	916	899	748
Mean daily catch (kg)	38.5	42.53	50.89	52.88	46.75
CPUE (Kg/boat/day)	19.25	21.26	25.45	26.44	23.38

Table 10: Estimation of Potential yield estimates in Lake Hashenge.

No.	Model used	Equation	Estimated productivity (Kg/ha/year)	Estimated potential yield in (tones/year)
1	Henderson & welcome (1974)	$Y=14.3136MEI^{0.4681}$	78.96	157.93
2	Crul (1992)	$Yt=8.32A_0^{0.92}$	65.47	130.94
3	Toews & Griffith (1979)	$Log(Y)=1.4071+0.3697log(MEI)-0.00004565A_0$	98.2	196.40
	Average		**80.88**	**161.76**

Table 11: Opinion of fishermen on Nile tilapia size and abundance after introduction of common carp to the lake.

Parameters	Increase	Decrease	No change
Abundance of Nile tilapia	2.70	91.89	5.41
Size of Nile tilapia	10.81	75.68	18.92

Conclusion

The current introduced common carp and the native Nile tilapia species in Lake Hashenge is already providing a major protein source for the communities around the lake. Despite the great potential and preferable of Nile tilapia by the society it is vital to investigate the cause of Nile tilapia decline after the introduction of common carp to the lake, much is yet to be done to fully understand the lake ecosystem. Changes in the catch composition fish species of a water body are normal; the factors affecting these changes in Hashenge deserve consideration. Siltation and fluctuations in water quality will give some species competitive advantages. Apparent increases in the abundance of common carp species cases in point. The Hashenge fishery is affected by external factors other than fishing activities. Notable among these is siltation, which threatens the existence of the lake. Human activities such as deforestation and erosion in the catchment area have caused the lake to become shallower. Because the lake is an enclosed system, the increasing use of the surrounding are for farming and adding pesticides, herbicides and fertilizers around the lake farmlands could affect the lake in the long run. Careless farming system, erosion and deforestation on the lake catchment area would also pose a threat to the lake system. Birds too are increasing in number. These birds occupy the lake and fly in flocks preying on Nile tilapia. Nile tilapia, although

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receiving a declining welcome from the people, still provides a sufficient source of protein for communities next to common carp. One of the main reasons the lake communities want an alternative species is more marketable fish, as common carp is regarded as a low-price fish in the surrounding market due to the presence of spines on the fillet of common carp compared with Nile tilapia. Fishers prefer a Nile tilapia species than common carp. In addition to this Nile tilapia is more adapted by the society than the introduced common carp. The lake seems it is underexploited. So it is better to use the resource of the lake. In Lake Hashenge fishing practices were started much longer, but fishermen involved in fishing were less in number and hence production obtained from the lake was very low as compare to its potential.

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