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Length based estimation population numbers of Nile tilapia (*Oreochromis niloticus*) stock in Lake Hayq, Ethiopia

Alemken Berihun[1,*], Minwyelet Mingist[1], Abebe Getahun[2], Degsera Aemro[1]

[1] *College of Agriculture and Environmental Sciences, Department of Fisheries and Aquatic Sciences, Bahir Dar University, Bahir Dar 79, Ethiopia*
[2] *College of Natural and Computational Sciences, Department of Zoological Sciences, Addis Ababa University, Addis Ababa 1176, Ethiopia*

Abstract

The study was conducted at Lake Hayq, one of the lakes of Wollo, Ethiopia. Data were collected at the landing sites for 365 days (June 8, 2022 to June 7, 2023). The basic information gathered in the fishing part of the Lake was Nile tilapia caught by fishermen, the total number of tilapia and the increase in fishing effort. The aim of the research was to estimate the size of the Nile tilapia population and the fishing mortality rate in length groups for Nile tilapia stocks occurring in the lake. A Jones length-based cohort analysis model was used to estimate Nile tilapia population. The estimated Nile tilapia population was over 46.8 Million tilapia per year. The model estimates that more than 13.3 million 8-10 cm Nile tilapia are caught in fisheries each year.

Keywords: Estimated population, Length group, Nile tilapia, Fishing mortality

Introduction

Recently, there has been development interest in length-based methods for assessing fish populations. Development of improved methods for analyzing length data; and the increasing availableness of computers, particularly desktop computers, provides wholly the computer science power required to use some of the new methods (Sparre et al., 1989). The main importance of the length-based method is the ease of data collection.

In Ethiopia, around half a million people depend their living straight and indirectly from fishery (Tesfaye & Matthias, 2014). The country has numerous lakes and reservoirs, small reservoirs and large floodplains spread-out the nation from lowlands to highlands, with a sum area of approximately 13,637 km^2 (Tesfaye & Matthias, 2014). The diversity of the country's fisheries is estimated to include more than 200 species (Getahun, 2017; Tesfaye & Matthias, 2014).

Lake Hayq is one of Ethiopia's lakes and is home to important fisheries. It is a direct and indirect source of livelihood for the people around the lake. About ten years ago, fish product in Lake Hayq was high, supporting approximately 2,000 fishermen and communities (Fetahi et al., 2011; Seid, 2016; Tessema & Geleta, 2013). Many another works and reports suggest that the trend of fish production, especially Nile tilapia, is reducing

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***Corresponding author:** Alemken Berihun
College of Agriculture and Environmental Sciences, Department of Fisheries and Aquatic Sciences, Bahir Dar University, Bahir Dar 79, Ethiopia
Tel: +251-918707070, **E-mail:** alemkenberihun@gmail.com

in time to time (Tessema & Geleta, 2013; Worie, 2009; Worie & Getahun, 2014). Therefore, the aim of this research was to estimate the Nile tilapia population in Lake Hayq.

Materials and Methods

Data were gathered at the fisher's landing area. The data is primarily collected about Nile tilapia catches in the lake and is useful for assessing tilapia stocks and biologically optimum fishing effort. In particular, the key selective information collected included i) length group of Nile tilapia caught, ii) total harvest of tilapia, iii) increase in fishing effort, iv) amount of fisheries, v) fishing areas.

Sampling and data collection methods

Catch and yield information were collected from fishers all day for 365 days the lake was visited daily from June 8, 2022 to June 7, 2023.

On each sampling day, the total length of Nile tilapia randomly caught by fishers was measured to the closest centimeter. Fish length was measure and weighed on with each fishers total catch. The data was then measured to estimate the total add up of Nile tilapia caught by fishers. Other data gathered daily includes the number of nets released, where they are released, and the number of of active fishermen and analyze data.

At the heart of length-based methods are varied techniques that have been estimate important parameters of growth population dynamics, increase and mortality rates as well as models natural selection and recruitment. Each of the methods is described with its advantages and disadvantages, and usually enough information is provided to the subscriber to apply the methods. However, to save space, when the methods are complex and have been described in published form, and especially when computer programs allowing the use of the method are available on request, only provide sum-up descriptions. This applies in particular to the ELEFAN rooms of programs and the growth and mortality parameters obtain using the fisat software.

Catch statistics information are summarized using the Jones length-based analysis model. The collected fishing statistics were analyzed and interpreted. The analysis was carried out Microsoft Excel (2010).

Summarize data by length group

Nile tilapia length composition data were summarized to create a table showing the average annual tilapia catch by length group. This happens as follows (Pauly, 1983; Sparre & Venema, 1998).

Prepare to length frequency

i) Daily recorded length measurements were grouped at two-centimeter intervals to produce a defer of sampling frequencies of tilapia length each day during the sample distribution period.

ii) Catch the total amount of fish for each one fishers catches each day

This value is estimated by multiplying the amount of fish measured by length by the conversion factor (W/w), where W = the total weight of the fishers catch and w = the weight of the fish sample measured by length. The fish were then counted, weighed and used to determine the corresponding rate to convert weight catch information into numbers.

iii) Estimated length component of summate daily catches

It is unregenerate by multiplying the total catches by the relation relative frequency of each length group in the daily sample determined in the early point. The relative frequency of the total duration of fish caught on the day of sampling was then determined by summing the frequencies of the corresponding length groups. The total number of fish caught on sampling years was also determined.

iv) Estimated year of total fish catches. This is done by multiplying the frequency of sampled fishing days by an appropriate C/c conversion factor, where "C" = estimated total fish for the year and "c" = sum up fish catch on sampling days. duration and fish were measured on 162,916 fish of a period of 365 sample days, and the length frequency obtained from such a large sample was well-advised sufficient to of length relative frequency in fish catches. tilapia in the lake the average fish weight per duration group.

The average weight of fish in to each one length group was estimated victimization the established weight-length formula, which is expressed as follows.

$$\text{Weight (g)} = 0.024 \times L^{3.00} \quad (1)$$

where Wt is the average out fish of each length group, L = the average length of each length group, the regression coefficient values are a = 0.024 and b = 3.00. The add together weight of fish caught each year in to each one length group was then estimated by multiplying the average weight by the corresponding relative frequency in the corresponding length group.

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Estimation of population size and fishing death rate using length-based Jones length analysis

The Jones length-based analysis model was used to estimate Nile tilapia populations and fishing mortality rates by duration group. For this purpose, total annual catches divided by length groups were used as the data to take up the analysis. This happens in the following three steps estimate the population size of the group with the longest capture fish.

This happened as follows

$$N_{terminal} = C_{terminal} \times (Z/F)_{terminal} \quad (2)$$

$N_{terminal}$ = the population of the largest length group in the catch

$C_{terminal}$ = the catch of the largest length group

$(Z/F)_{Terminal}$ = the proportion of the total mortality to the fishing mortality of the largest length group in the catch

Estimated number of consecutive juvenile groups.

This was done using Equation (3) as follows.

$$N(L1) = [N(L2) \times H(L1, L2) + C(L1, L2)] \times H(L1, L2) \quad (3)$$

The terms were antecedently defined here. Estimated fishing mortality rates for individual duration groups.

Fishing mortality values? for each one group, lengths were estimated using the following Equation (4).

$$F(L1, L2) = (1 / Dt) \times \ln [N(L1) / N(L2)] - M \quad (4)$$

Here the terms are the same as previously defined.

In order to use Equations (3) and (4), the following inputs and parameters were prepared in advance.

i) First, a table of the yearly catch catches by length group was created as delineated above.

ii) Second, the Von Bertalanffy estimates of growth parameters, specifically the L_∞ and K values for Nile tilapia stocks, are L_∞ = 31.5 cm and k = 0.94 yr^{-1} (based on length frequency data using the Fisat software). Third, an estimated natural mortality rate (M) for tilapia of 1.57 $years^{-1}$ was estimated using the following empirical Pauly formula.

$$\ln M = -0.00152 - 0.279 \times \ln L_\infty + 0.6543 \times \ln k + 0.463 \times \ln T$$

Site description

Hayq Lake (also better-known as Loggo) is a fresh water lake in the South Wollo Administration of Amhara Regional State, 433 km from Addis Ababa, the capital of Ethiopia. Lake Hayq is one of Ethiopia's lakes and lies at a maximum elevation of 2,030 m. The lake lies between 11° 15' N and a longitude of 39° 57' E longitude (Baxter & Golobitsh, 1970).

The surface area, average and maximum depth of the lake are 23 km^2, 37 m and 88.2 m, respectively, and its volume is 0.87 km^3 (Baxter & Golobitsh, 1970). Lake Hayq is home to galore species of fish, water birds and aquatic life. It also plays an economic role through tourism industry and fishing and in the first place supplies the local population with drinking water (Fetahi et al., 2011). The species of fish in Lake Hayq include 4 species: Nile tilapia (*Oreochromis niloticus*), locally titled "Kerosso", Catfish (*Clarias gariepinus*), locally named "Ambaza", common carp (*Cyprinus carpio*), locally called "dubae" and (*Garra deembecha*). is called "Yewenz Assa" by locals which means river fish. However, only the three species are economically important. Used as food by local communities (tilapia, catfish and carp). *Garra deembecha* has no economic value in the area and is not targeted by fishermen for sale. Sometimes fishermen use these small-sized fish serves as razz for catching catfish using hook and line (Elizabeth et al., 1992; Getahun & Stiassny, 1998).

Results and Discussion

State of the Fish in Lake Hayq

At the time of sampling, a total of 250 fishers were fishing at Lake Hayq (Table 1). These fishers set an average of 194 nets into the lake per day. The nets are mainly used to catch tilapia, but also to catch catfish and carp. Each net has an average length of 215 m and a width of 2.5 m with an average mesh size of 3.5 to 8 cm. In total, around 70,787 nets were in operation in the year (from June 8, 2022 to June 7, 2023). With this fishing

Table 1. Growth and mortality parameter of Nile tilapia in Lake Hayq using FISAT II from length frequency data

Parameters	Values
Growth coefficient (K)	0.94 /year
L–Asymptote (L∞)	31.5 cm
Natural mortality (M)	1.57 /year
Fishing mortality (F)	1.96 /year
Total mortality (Z)	3.53 /year

effort, the estimated number of total Nile tilapia caught the year was 5,954,953 and the total weighing close to 162,160 kg. The estimated daily catch per net was 84 Nile tilapia and weighed approximately 2.29 kg/net/day (Table 2).

The composition of sampled catches and estimated annual catches at the time of sampling, fish caught

Nile tilapia with total length from 8 cm to 32 cm (TL) was caught by fishermen at the time of sampling (Table 3). Of these, more than 92.7% of the catch was between 8 and 22 cm in TL. More importantly, groups with a length of 8–20 cm TL accounted for about 84.3% of the total catch (Table 3).

In contrast to group discussions with fishers in the lake, it was direct out that Nile tilapia with a length of 36–40 cm TL was very commons in fisher's catches twenty years ago. Population and the average size of the tilapia catch was 28 to 34 cm TL. This may be a period of fairly low fishing pressure. According to Tessema et al. (2019), the length at first maturity of tilapia was related to females (12.8 cm) and males (12.9 cm) in Lake Hayq. In the present results, fish fewer than 12.85 cm in size accounted for about 37.2% of the total catch (Table 3). The majority of fishermen's catch consists of juvenile Nile tilapia that have not spawned at least once in their lives. Total annual Nile tilapia catch during the sampling year (June 8, 2022 to June 7, 2023) an estimated 5,954,953 fish (Table 3). Table 3 Number of fish caught on 365 sample distribution days (June 8, 2022 to June 7, 2023) and estimated total yearly catches by length group.

Table 2. Nile tilapia statistics in Lake Hayq during the sampling period

Fishing activity measurements	In number
Total number of fishers in fishing activity	250
Mean nets set per day	194
Total number of nets set per yearly	70,787
Total number of tilapia caught	5,954,953
Total wt of tilapia (kg)	162,160
Tilapia per net (no./net/day)	84
Weight of tilapia per net (kg/net/day)	2.29

Estimated population numbers and fishing mortality coefficients by length group of Nile tilapia in Hayq Lake

Table 4 below shows population estimates and fishing mortality rates by length group of tilapia used in the fishery. Estimates were made using a length-based Jones analysis model (Jones, 1984). The second column shows the total number of fish caught to each one year in each length group, estimated from catch statistics. The population (N (L1)) and fishing fatality rate (F (L1, L2)) estimates conferred in columns 3 and 4, respectively, are direct results of the Jones Cohort length-based analysis system.

In total, more than 46.8 million Nile tilapia populations are estimated within the lake's fishery, obtained by aggregating population number for the respective length groups comprising the

Table 3. Fish caught during the 365 days of sampling (6-8-2022 to 6-7-2023) and estimated total annual catch by length group

Length interval	Total caught/365 days (number)	Estimated yearly tilapia (number)	Percentage of length group composition from the total catch (%)
8–10	20,684	756,049	12.696
10–12	25,675	938,480	15.760
12–14	28,275	1,033,516	17.356
14–16	24,743	904,413	15.188
16–18	22,001	804,187	13.505
18–20	15,933	582,388	9.780
20–22	13,716	501,351	8.419
22–24	10,370	379,047	6.365
24–26	1,259	46,019	0.773
26–28	245	8,955	0.150
28–30	9	329	0.006
30 & above	6	219	0.004
Grand total	162,916	5,954,953	100.000

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Table 4. Population estimates, fishing mortality, and other parameters by length interval. Numbers were calculated using Jones length-based cohort analysis

Length interval	Estimated yearly tilapia (number)	Tilapia number N (L1)	Fishing mortality (yr^{1}) F (L1, L2)
8–10	756,049	13279865	0.670521537
10–12	938,480	10744618	0.960474637
12–14	1,033,516	8262836	1.281195947
14–16	904,413	5952384	1.428288614
16–18	804,187	4043023	1.721391293
18–20	582,388	2493381	1.823903426
20–22	501,351	1398175	1.988521896
22–24	379,047	588780	1.205129519
24–26	46,019	85579	1.620036924
26–28	8,955	15461	1.479395883
28–30	329	1128	0.996644485
30 & above	219	112	1.96
Grand Total	5,954,953	46,865,341	

fishery presented in column 3 (Table 4). As shown in column 4 of the table. As shown in Table 4, groups of fish with a length of 12–28 cm had high fishing mortality rates each year. Although Nile tilapia ranging in size from 8 to 10 cm are recruited into the fishery, most of the fishing pressure was in groups starting at 8 to 14 cm in length. According to model estimates, more than 13.3 million tilapia ranging in size from 8 to 10 cm are caught each year in the lake's exploited area (Table 4).

According to Degsera (2019), it is estimated that there were more than 456 million *O. niloticus* throughout Lake Tana. Lake Tana is the largest lake in the country and large numbers of Nile tilapia are found in the lake. At Alwero Reservoir, it was estimated that more than 37.9 million tilapia populations exist in the exploited portion of the reservoir. According to model estimates, more than 7.6 million tilapia measuring 14–16 cm are recruited annually to the fishery in the exploited part of the reservoir (Mengist & Fakana, 2020) and some Lakes and reservoirs of Ethiopian tilapia populations were estimated using Jones's length-based cohort analysis model (Jones, 1984) including Lake Chamo, Hawassa, Ziway and Alewero Reservoir. Most water bodies in Ethiopia are not subject to research to assess and estimate fish stocks, especially Nile tilapia stocks, due to lack of modern laboratory facilities and equipment, especially otolith readers as the most important growth parameters are determined from age and problem data was also missing. Since little software allow analysis of longitudinal frequency data and other materials important for stock assessment work, these limitations reduce the motivation of researchers to conduct fish stock assessment studies in Ethiopia water body.

Conclusion

The estimated population numbers of Tilapia were over 46.8 million tilapia/year in Lake Hayq. As estimated by the model, over 13.3million tilapia of 8 to 10 cm fish are recruited to the fishery every year at the fished part of the Lake. The estimated current annual yield was 162.1628 tons of *O. niloticus* harvesting on Lake Hayq fishery to its maximum sustainable yield may help in the reduction of the scarcity of fish in relation to its demand.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

This study conformed to the guidance of animal ethical treatment for the care and use of experimental animals. There is no ethical approval process for fishery data in Ethiopia.

ORCID

Alemken Berihun https://orcid.org/0009-0007-9694-1241

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