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Stock assessment and estimation of current yield for tilapia stock (*Oreochromis niloticus*) Alwero reservoir, Gambella, Ethiopia

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Abstract
This study has been conducted on Alwero Reservior one of the Reservoir found in Gambella Ethiopia. Data were collected on a daily basis for 60 days (from 1-10-2019 to 1-12-2019) from the area where fish were landed. The length composition of tilapia caught by the fishery, total tilapia yield and fishing effort expanded were the basic information collected from the site The aim of the analysis was to estimate the population number of tilapia and fishing mortality coefficient by length group as well as estimate the current fish yield and biologically optimum level of fishing pressure for the tilapia stock of the reservoir. Jones length based cohort analysis Model and length-based Thompson and Bell yield Prediction Model have been employed to estimate the current yield with the corresponding biologically optimum fishing effort level. The estimated current annual yields were 251.07 tons /year of Tilapia. Based on data collected of the fishing pressure on Alwero Reservior. The analysis on data collected of the fishing effort indicated that the recommended safe level of exploitation is at an F factor of 1.8 and the effort can be maintained at its current level of 210 nets/ day.

Keywords: Fishery management, MSY, optimum fishing effort, stock assessment, virtual population analysis, yield prediction

Introduction
The basic purpose of stock assessment is to provide advice on the optimum level of exploitation of aquatic living resources such as fish. Aquatic living resources are limited but renewable and fish stock assessment may be described as the search for the exploitation level, which in the long run gives the maximum yield in weight from fishery [MacLean and Evans, 1981, cited in Yosef, 2002] [13]. Estimation of sustainable fish yield and optimum fishing effort is usually done by means of mathematical models .The global capture fisheries production in 2008 was reported by [FAO] Fisheries and Aquaculture Departmentas,90 million tones, with an estimated first-sale value of US$93.9 billion, comprising about 80 million tons from marine waters and a record 10 million tons from inland waters. However, the proportion of marine fish stocks underexploited or moderately exploited declined from 40 percent in the mid-1970s to 15 percent in 2008, whereas the proportion of overexploited, depleted or recovering stocks increased from 10 percent in 1974 to 32 percent in 2008 [FAO, 2010] [4]. The above status of fisheries was also stated by Alverson & Dunlop, [1998] [2] as "If the earth's oceans were a human being they'd be rushed to the hospital, admitted to the intensive care unit and listed in grave condition." This explanation indicates the degree of severity of ocean fish. He continued his saying as the great geographic expansion of fisheries and although some further developments of resources beyond national authority is frequently occur; more and more species are moving into the fully exploited and overexploited categories**.**
In our country, Ethiopia 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 total area of the lakes and reservoirs stands at about 7000 to 8000 km2 and the important rivers stretch over 7000 km in the country. In addition, minor water bodies such as crater lakes and reservoirs make up about 400 km2. Most of the lakes are located in the Ethiopian Rift Valley depression, which is part of the Great East African Rift Valley system [Kelil, 2002]. The capture fisheries in Ethiopia help to sustain local community directly.

The Gambella region has enormous water bodies and the most diverse fish resources in the Country. Traditionally, the fishery resource has been exploited for centuries by the native people. Despite this, the current level of development and utilization of the fishery resource to achieve food security and economic growth in the region is not as it would be. A wide range of constraints contributed to this problem, of which lack of skilled human power to explore the opportunities and challenges, and devise appropriate interventions are considered to be the most critical one. The Alwero reservoir is formed by damming the Alwero River. It is located at a distance of 6.5km to the west of the Abobo town. At its full supply level, the water surface area reaches 2,210ha and it is made for the purpose of irrigation and fishery development. The reservoir has a capacity to irrigate more than 10,000ha but it is not functioning at the moment owing to the demand of huge outlay to construct the canals among others.

The best possible supplies of fish for the future generation could be guaranteed when all those involved in fisheries work together to conserve and manage fish resources and habitats. Giving emphasis to the necessity of fisheries management, in order for countries to manage their fisheries they need to have clear and well-organized fishing policies which are developed in cooperation with all groups that have an interest in fisheries [FAO, 2000] [3]. In order to overcome the problems faced to the fisheries sector, stock assessment play an important role for the increment of knowledge and information on the status of fishery.

Methodology

Site description

Location

The Gambella People's Regional State [GPNRS] is located south west Ethiopia between geographical coordinates 6028'38" to 8034' North Latitude and 33to 35011'11" East Longitude, which covers an area of about 34,063 km2 about 3% of the nation.

Gambella is the nine region among others region, which constitute Federal Democratic Republic of Ethiopia. It is at a distance of 766 km from Addis Ababa [GPNRS, 2011].

The study area is Abobo Woreda which is found in Anywaa zone. It is one among the five districts. It is located 45 Km from south of Gambella (the capital of the region). The Alwero

Reservoir is formed by damming the Alwero River. It is located at a distance of 6.5km to the west of the Abobo town. At its full supply level, the water surface area reaches 2,210ha and it is made for the purpose of irrigation and fishery development. The reservoir has a capacity to irrigate more than 10,000ha but it is not functioning at the moment owing to the demand of huge outlay to construct the canals among others.

Alwero reservoir is productive and one of the reservoir that found in Gambella region. It has rich phytoplankton and zooplankton community that support large populations of fish species. The most important commercial fish species is *Tilapia (Oreochromis niloticus)*, nile perch (*lates niloticus*), *Tilapia zilli, Heterotis nilotics* and Catfish (*Clarias gariepinus*) that account to the fishery of the reservoir. by gill nets while Catfish is caught both by gill nets and also long lines.

Method of Data Collection

The data were collected from the cooperative fishermen landing site. The data mainly constituted information on the Tilapia fishery of the reservoir that are useful to assess the stock of Tilapia and estimate the maximum sustainable yield of Tilapia and biologically optimum level of fishing effort. Specifically the basic information collected included i) the length composition of Tilapia caught by the fishery, ii) Total Tilapia yield, iii) Fishing effort expanded, iv) Number of fishermen in operation, v) Fishing site.

Sampling regime and data collection

The daily catch and yield data were collected from the fishermen for 60 days. Accordingly, the reservoir was visited on a daily basis from *(*1-10-2019 to 1-12-2019).

During each day of sampling, the total lengths of random samples of Tilapia caught by fishermen were measured to the nearest mm. Also the length measured fish were weighed as well as the total catch of each fisherman was weighed. The latter data was then used to estimate the total number of Tilapia caught by the respective fishermen. Other data collected on a daily basis included number of nets set, place of setting as well as number of fishermen operating.

Data summarization and analysis

The catch statistics data were summarized in a manner useful for stock assessment work using Jones length based cohort analysis model and Length-based Thompson and Bell yield prediction model. The catch statistics data collected of the fishing pressure were analyzed and interpreted. The summarization and analysis were done by using Microsoft Office Excel (2007) software.

Summarizing length composition data

The length composition catch data of Tilapia were summarized to prepare a table of the average total annual catch of Tilapia distributed by length groups. This was done as follows [Pauly, 1984; Sparre and Venema, 1992] [7, 10, 11]

Preparing length frequency of the sample catch

I. Length measurements recorded daily were grouped in to two cm length intervals to prepare a table of the length frequency of Tilapia sampled each day during the sampling occasions.
II. Estimating the total number of fish landed per day by each fisherman This was estimated by multiplying the number of length measured fish by a conversion factor (W/w) where W= the total weight of the catch of the respective fisherman and w = sample weight of the length measured fish. Thus fish that were simultaneously counted and weighed were used to determine appropriate raising factor to convert records of the daily weight of the catch in to numbers.
III. Estimating the length composition of the total daily catchThis was achieved by multiplying the total numbers caught per day by the relative frequency of each length group in the daily sample obtained under item 'i' above. The total length frequency of fish landed during the sampled day was then determined by summing the frequencies of respective length groups. Also the total numbers of fish landed during the sampling days were determined.
IV. Estimating the annual total length composition of fish landed.

    This was done by multiplying the length frequency of the sampled days catch by an appropriate conversion factor which was equal to C/c, in which 'C' = the estimated

total catch of fish during the whole year and 'c' = the total catch of fish during the sampled days. 181,990 fish were length and weight measured during the 60days of sampling and the length frequency produced using such a large sample size was considered adequate to give a good picture of the length frequency of the catch of Tilapia in the reservoir .

Estimating average weight of fish per length group

The average weights of fish of each length group were approximated using previously established length-weight relationship formula expressed as follows [Yosef, 2002] [13]

$$Wt\ (gm) = 0.0184 * L^{3.0197}$$

Where Wt is the average weight of each length group, L = the average length of each length group, values of the regression coefficients are a = 0.0184 and b = 3.0197. Then the total weight of fish landed per year in each length group was estimated by multiplying the average weights with the corresponding frequencies of respective length group.

Estimating population sizes and fishing mortalities using the Jones length based cohort analysis

The Jones length based cohort analysis model was used to estimate the population of Tilapia and fishing mortality coefficient by length group. For this the total annual catch distributed by length group was used as the basic input data to get started with the analysis. This was done in three steps as follows

Estimating the population number of the largest length group in the catch

This was done as follows

$$N_{terminal} = C_{terminal} * (Z/F)_{Terminal}$$

Where

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

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

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

Estimating the population numbers of consecutively younger length groups in the catch.

This was done using equation 16 as follows

$$N(L1) = [\ N(L2) * H(L1, L2) + C(L1,L2)] * H(L1,L2) \quad \text{.....16}$$

Here the terms are as defined earlier.

Estimating the fishing mortality rate of the respective length groups

Fishing mortality values for each length group was estimated using equation 17 as follows.

$$F(L1,L2) = (1/\Delta t) * \ln[N(L1)/N(L2)] - M \quad \text{.....17}$$

Here the terms are also as defined before.

To use Equations 16 and 17, the following input data and parameters were prepared in advance.

A. First a table of the total annual catch distributed by length group was prepared as described earlier
B. Secondly estimates of the Von Bertalanffy growth parameters namely, L_∞ and k values for the Tilapia stock were as L_∞ = 35 cm and k = 0.28 yr^{-1} [Yosef, 1990, 2002; Demeke 1998] [13].

Thirdly, an estimate of the natural mortality coefficient (M) for Tilapia which is equal to 0.35 yr^{-1} was estimated using Pauly's empirical formula as follows.

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

Predicting sustainable fish yield and optimum fishing efforts

The outputs of the above cohort analysis procedures were used as input data for the Thompson and Bell yield prediction model to predict sustainable fish yield at different levels of fishing mortalities [Thompson and Bell, 1934; Pauly and Morgan, 1987; Schnute, 1987; Sparre and Venema, 1992] [12, 8-11].

For the length based Thompson and Bell model, input data and sources comprised the following

The length composition of the annual total numbers of fish landed by the fishery. This was obtained from field data collection (catch statistics data record).

Mean weight of the landings per length group. This was estimated by using the mean length of each length group and the length-weight relationship formula developed as described earlier.

Estimates of population numbers of fish and fishing mortality coefficient (F) by length group. Source: results of the Cohort analysis.

An average estimate of natural mortality coefficient (M), and the Von Bertalanffy growth parameters ($L\infty$ and k). Same values as discussed earlier have been used.

The computation procedures of the Thompson and Bell model consisted of two main stages. First the above input data were used to estimate fish yield obtained per year from the respective length group of fish. Summing the individual contribution of each length group gave estimates of the annual total sustainable yield. These estimates pertained to the fishing mortalities that corresponded to the level of fishing effort exerted on the Tilapia stock at the time of sampling.

The second step in the calculation procedure involved assessment of the effects of changes in the current level of fishing effort (and hence that of fishing mortalities) on fish yield. This was done by predicting fish yield at higher and/or lower levels of fishing mortality coefficients pertaining to the respective length groups (F-at-length-array). i.e., the current fishing mortality values of the respective length groups were used as reference and these were increased and/or decreased by a certain raising factor (F-factor) to predict new values of sustainable yield corresponding to the changed fishing mortalities [Venema *et al.*, 1988; Spare and Venema, 1992] [10].

From this analysis, the value of F-factor that gave the maximum sustainable yield was considered as biologically optimum level of fishing mortality to be exerted on the stock. Since there is a one to one correspondence between fishing mortality (F) and fishing effort (f), the value of F-factor chosen as optimum was used to recommend how much the current level of fishing effort need to be increased or decreased to get the maximum sustainable yield from the stocks.

Results and Discussion

Fishing status of the Alwero reservior

There were overall 91 registered cooperative member fishermen operating on the Alwero reservoir during the time of sampling (Table 1). These fishermen owned on average117 nets were set daily on the reservoir The nets are basically set to catch tilapia but these nets also catch catfish (*Clarias gariepinus*), nile perch (*lates niloticus*), *Tilapia zilli and Heterotis nilotics*. Each net was on average 80 m long and 2.5 m wide and it had an average mesh width of 8 cm stretched mesh. Overall an estimated number of 42,559 nets were operated during the year of sampling *(*1-10-2019 to 1-12-2019). With this level of fishing effort, an estimated total number of 1,107,106tilapia were caught during the year that weighed about 251,070 kg. The estimated catch per net per day was 26 tilapia and it weighed about 5.7 kg/net/day (Table 1).

Table 1: Statistics of tilapia fishery of Alwero Reservior during the time of sampling

Operation Measurements	Value
Total number of fishermen in operation	91
Average nets set per day	117
Total number of nets set per year	42,559
Total number of fish caught	1,107,106
Total wt of catch (kg)	251,070
Catch per net (no./net/day)	26
Weight of catch per net (kg/net/day)	5.77

Source: Stock assessment work

Length composition of the sampled catch and estimated annual catch

Tilapia measuring in length from 14 cm up to 36 cm total length (TL) composed the catch of the fishermen during the time of sampling (Table 2). Amongst these, over 99 % of the catch ranged in length between 22 to 34 cm in TL. More importantly the length groups 24 to 34 cm TL composed about 96 % of the total catch (Table 2).

Unlike this focused group discussion with fishermen of the reservoir indicated that decade ago, tilapia measurings up to 36 to 40 cm TL were very common in the fishermen catch and the average catch size of tilapia was 28 to 34 cm TL. This may be the time during when the fishing pressure was quite low.

According to Yosef [2002] [13], the length at first maturity of tilapia about 20 cm TL. In the present result fish below 20 cm composed about 0.36 % of the total catch (Table 2). It was low portion of the fishermen catch composed immature tilapia that have not yet reproduced at least once in their lifespan. The total annual catch of tilapia during the sampled year *(*1-10-2019 to 1-12-2019) was estimated 1,107,106 fish (Table 2).

Table 2: Fish caught during the 60 days of sampling *(*1-10-2019 to 1-12-2019). and estimated total annual catch by length group.

Length group	Total caught/60 days (number)	Estimated annual catch (number)	Proportion of length group composition from the total catch (%)
14-16	29	176	0.016
16-18	31	189	0.017
18-20	46	280	0.025
20-22	60	364	0.033
22-24	7006	42619	3.850
24-26	18076	109962	9.932
26-28	42151	256419	23.161
28-30	51048	310542	28.050
30-32	45108	274407	24.786
32-34	18141	110358	9.968
34 &above	295	1792	0.162
Grand Total	181990	1107106	100

Source: Stock assessment work

Estimates of population number and fishing mortality coefficient by length group of tilapia in Alwero reservoir

Table 3 below gives estimates of population number and fishing mortality coefficient by length group of tilapia that composed the fishery. The estimates are made using John's length based cohort analysis model (John, 1984). The second column is the total number of fish caught per year in each length group estimated based on catch statistics record. Estimates of population numbers (N(L1)) and Fishing mortality coeffecients (F(L1, L2)) shown by columns 3 and 4, respectively are direct out puts of the Jones length basedcohort analysis.

Over all over 37.9 million tilapia population has been estimated to exist in the fished part of the reservior as obtained by summing the population numbers of the respective length groups that composed the fishery given by column 3 (Table 3) As shown by column 4 of Table 3, the length groups 30 to 34 cm fish shouldered heavy fishing mortality rate bearing above 0.5 fishing mortality per year. Although tilapia starting from 14 to 16 cm was recruited to the fishery, most of the fishing pressure relied up on length groups starting 28 cm to 34 cm. As estimated by the model, over 7.6million tilapia of 14 to 16 cm fish are recruited to the fishery every year at the fished part of the reservoir (Table 3).

Table 3: Estimates of population numbers, fishing mortalities and other parameters by Length group. Values are calculated using Jones length based cohort analysis.

Length group	Estimated annual catch (number)	Population number N(L1)	Fishing mortality (yr^1)F(L1, L2
14-16	176	7636704	6.8802E-05
16-18	189	6738499	7.55249E-05
18-20	280	5863667	0.0001
20-22	364	5014179	0.0002
22-24	42619	4192571	0.0190
24-26	109962	3364060	0.0527
26-28	256419	2520736	0.1412
28-30	310542	1622036	0.2243
30-32	274407	813478	0.3420
32-34	110358	230164	0.7778
34 &above	1792	2756	0.6500
Total	1,107,106	37,998,852	

Source: Stock assessment work

Fish yield

Table 4 below gives estimates of total annual yield of tilapia (tons) of the fish. Values in columns 2 are the annual catch of the respective length group fish displayed in previous tables and they are shown here to illustrate the intermediary calculation steps. The mean weight of fish (kg) shown by column 3 are the average weights of each length group of tilapia estimated using the length weight relationship expressed by the following equation [Yosef, 2002] [13]

$$Wt\ (gm) = 0.0184 * L^{3.0197}$$

The coefficient of determination (R^2) value for the relationship was 0.99 indicating that the estimated total weight for the respective length groups is 99 % valid as the measured length of each length group.

The current total yield pertaining to the respective length group (column 4) was obtained by multiplying the total catch of the respective length group by the corresponding mean weight values. In due regard, the total annual yield of tilapia shown at the bottom of columns 4 (Table 4) are obtained by summing up the yield, respectively of each length group that composed the fishery. The annual total yield of tilapia during the sampled year was 251.07 tons/year

FAO [2014] also estimated a total annual yield of 394 tons of fish/year as harvested by the fishermen cooperatives at Alwero reservoir. The estimate in 2010 was about144 tons/year (Fishery Development Program). As mentioned earlier, during the time of sampling, the fishermen were fishing at reservoir. Therefore the current estimate gives a yield estimate close to 251.07tons/year, which can be an estimate for the whole reservoir area.

Table 4: Estimates of total yield of fish by length group under the current level of fishing effort for the tilapia stock of Alwero reservoir

Length group	Estimated annual catch (number)	Mean weight (kg) W(L1,L2)	Current yield (tons/year) Y(L1,L2
14-16	176	0.05	0.009001
16-18	189	0.07	0.013999
18-20	280	0.09	0.028953
20-22	364	0.13	0.053103
22-24	42619	0.17	8.270122
24-26	109962	0.22	28.77476
26-28	256419	0.27	71.75296
28-30	310542	0.34	87.2666
30-32	274407	0.41	52.65664
32-34	110358	0.50	1.075533
34 &above	1792	0.65	1.17
	Total Yield/year 251.07		

Source: Stock assessment and yield prediction

Conclusion

According to the results of the study, the reservoir's fishery has different status from biological perspectives. Its biological status could have a potential to produce more. The current harvest is estimated at about 251.07tones/yr. Harvesting on Alwero reservoir fishery to its maximum sustainable yield may help in the reduction of the scarcity of fish in relation to its demand. This study has tried to address objectives of the study as: the existing harvest activities of the reservoir.

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