MANAGEMENT OF LAKE ZIWAY FISHERIES IN ETHIOPIA

by

Felegeselam Yohannes

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Department of Economics
Norwegian College of Fishery Science
University of Tromsø
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Long live Norway,
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Abbreviations

AC(E): Average Cost as a function of Effort

AOE: Average Observed Effort

AR(E): Average Revenue as a function of Effort

CEMARE: Centre for the Economics and Management of Aquatic Resources

CPUE: Catch per Unite Effort

EARO: Ethiopian Agricultural Research Organization

EC: Ethiopian Calendar

EDF: European Development Fund

E_{MSY}: Effort at Maximum Sustainable Yield

E_{OA}: Effort at Open Access

EthBirr/br Ethiopian Birr (currency).

FAO: Food and Agricultural Organization of The United Nations

FPMC: Fish Production and Marketing Corporation

FRDD: Fisheries Resource Development Department

LEDP: Lake Fisheries Development Project

MC(E): Marginal Cost as function of Effort

MEY: Maximum Economic Yield

MOA: Ministry of Agriculture

MR(E): Marginal Revenue as a function of Effort

MSY: Maximum Sustainable Yield

NFLARR: National Fisheries and other Living Aquatic Resources Research

π(E): Resource Rent as a function of Effort

SRAC: Southern Regional Aquaculture Center

TC(E): Total Cost as a function of Effort

TMAF: Traditional Management of Artisanal Fisheries

TR(E) : Total Revenue as a function of Effort.

UNDP: United Nations Development Programme

USD: United States Dollar.(1USD is equivalent to 8.50 br)

Abstract

This study has been conducted in the northern most Rift Valley lake fishery – lake Ziway. Catch & effort and economic data have been used to analyze its fishery. The aim of the analysis was to review the present management situation of the lake and to apply bioeconomic theory to estimate the maximum and economic yields of the lake. The Schaefer's surplus production model has been employed to estimate the maximum sustainable yield, effort that takes the maximum sustainable yield and maximum economic yield together with E_{MEY}*. The values of MSY,* E_{MSY}*, MEY, and* E_{MEY} *are 3537 t/yr, 2660 boats/yr, 1011 t/yr, and 412 boats/yr respectively. Lake Ziway is the 3rd biggest rift valley lake next to lake Abaya and Chamo. It has a potential yield of about 15% of the country's major lakes potential and it contributes also about 24% of the yield of all major lakes. Its socio-economic importance is found to be the highest in the region where it is situated. The analysis shows also that lake Ziway produces double fold of the yield of the biggest lake in the country.*

All years written as EC are equivalent to GC – 7 and/or 8 years.

Key words: Lake Ziway, Management, Bioeconomics

1. Introduction

As a response to geographic expansion, increased diversity of exploited species, and rapidly developing fishing capacity in 1950 until the late 1970s when world fish catches increased rather steadily (except the period when Peruvian anchovy stock crash), fisheries were considered to be in a rapid growth phase. However, production of marine capture fisheries dropped slightly by the late 1980s and early 1990s. In recent years, concern over the state of the world's oceans, its resources, and environment has become more serious and in 1998 it start to be a focal issue of discussion. In the discussion, scientists from different disciplines have made an increasing number of statements suggesting the oceans are "suffering from excessive overfishing, pollution and the world wide spread of disruptive foreign species." One author in describing the state of the world's oceans states, "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" (Alverson and Dunlop, 1998).

Economic problems that threaten the sustainability of fish populations or overfishing, extinction of some fish species, inefficient use of variable inputs and low returns of fishing industries are caused by open access to a fishery (Hartwick & Olewiler, 1998).

Open access either refers to an absolutely unregulated fishery or solely to matters of access. In an unregulated fishery, both effort and catch taken from the water are uncontrolled. Open access that refers solely to matters of access, the output (catch & size of fish) might be controlled but not the inputs (Charles, 2001).

FAO (1999) describes increased knowledge and the dynamic development of fisheries after World War II revealed that aquatic resources are not infinite. This means that the infinity of the marine resources was undermined during the 20th century.

FAO (1999) also stated that 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, the code of conduct advocates that inorder 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, 1999).

Alverson and Dunlop (1998) stated that the statements that have been raised by scientists regarding the state of the world’s marine fishery resources have already stimulated actions on the part of national governments to respond to the current perception of the ecological damage being imposed on the world’s oceans by human activity. Hartwick & Olewiler (1998) also said, the problems of open access give rise to extensive regulation of most fishing industries

The lack of official fisheries’ management policy leaves fisheries’ management with a free licence, which results in the lack of transparency and effectiveness. This problem, which arises in both developed and developing countries leads to management authorities having poor accountability to the fisheries sector and the public (FAO, 1999).

Due to the poor state of many important fish stocks, fisheries management is widely considered to be ineffective. However management has improved in the last decades. The adoption of Precautionary Approach in 1982 recognizes risk and consideration of long-term production in decision-making and the Exclusive Economic Zones (EEZs) provide a new framework for a better management of marine resources (FAO, 1999).

Everyone involved in fisheries has a clear understanding of the rules to be followed whenever clear fisheries management and legal framework exists. Besides the usage of the best scientific information available in the development of fisheries policy, the traditional fishing practices and knowledge should also be given full account. This would contribute to have wise policies in place that could enable the renewable natural resource to be harvested year after year (FAO, 1999).

Propositions from which to develop policy

1. Fishery resources should not be perceived as a without any property right.. As

a national property, they are to be administered in the same way as the other national properties.

2 The government (on behalf of its community) is responsible for determining the usage of each resource and granting, to each fisher, a proportion of the total allowed catch. It is common for personnel of the government agency entrusted with the protection and conservation of natural resources to assume that the agency does in fact manage them.

3. The conditions of access set by administration should relate to compliance with such generalisation as may be decided upon with regard to the amount and composition of catch, collaboration in the setting up and operation of the monitoring system.

4. Fishery resources that are exploited are natural population members of ecosystems. The target of many fisheries is at a group of units of stock and aim of fishing is to make a catch, and therefore the state of the stock is the matter of immediate concern to fishers and others of the industry. The exploitative programme must also take account of the characteristics of the host ecosystem in which the productivity of each ecosystem and verification of changes in productivity could be made, i.e. the maintenance of the competence of the system might also be looked.

5. Fish populations fluctuate in biomass, number, and composition as a result of growth, reproductive and mortality rate fluctuations (Kesteven, 1999).

Fishery resources fluctuations in supply and demand due to their changing state, change in economic, climatic and environmental conditions don’t hinder fisheries and aquaculture to play an important role in generating food, employment and income in the world. Therefore management of fishery resources would require attention as other resources.

2. Research Problem

Some development works revealed that, the lake under study showed a sign of overexploitation. This is to say, despite the usage of the regulatory tools in lake Ziway, average size of the catch and CPUE showed a declining trend (LFDP, 1998). This could imply that the management methods that are implemented either lack enforcement, are ineffective or inappropriate.

The main lakes considered as over-exploited are lake Ziway and lake Awassa, which may be attributed to favourable infrastructure, their vicinity to the capital of the country that opens market availability, and harbouring fish, which is highly preferred by consumers (for lake Ziway) (Wudneh, 1998).

Currently the resource in lake Ziway, due to high number of fishers & gears involved and use of small mesh size, which capture juveniles & breeding stocks is in undesirable state. Its resource is expected to decline as long as possible measures are not undertaken. The direct resource users agree with management solutions and are motivated and willing to share management responsibility (Kelil, 2002). Based on these problems this study is initiated to analyze the present situation of the lake and come-up with updated information that would help managers to further investigate and manage the lake fisheries.

2.1 Objectives of the Study

1. To review the existing fisheries management system of lake Ziway
2. To estimate the MSY, E_{MSY}, MEY and E_{MEY} of lake Ziway fishery.
3. To come up with possible indicative management options.

2.2 Expected Output

- Documentation of updated information on the existing status of lake Ziway fishery
- Quantitative comparison of the existing catch and effort level with the computed MSY, $E_{MSY,}$ and MEY level
- The importance of lake Ziway fishery in the domestic market
- Indicative management measures for the lake

3.Back ground of Ethiopian Fishery

3.1 Ethiopian Fishery

Ethiopia, a land locked country, is situated at 3 - 18^{0}N and 33-48^{0}E, has a total area of 1.127mill.sq.km, 65mill inhabitants and 39.2 billion USD GDP. It stands in the third most populated country in Africa after Nigeria and Egypt, 20th in the world's rank, and has a growth rate of 2.9 percent per year (Mammo, 1991 & Wudneh, 1998). Agriculture being the main backbone of the country's economy, fishery has also considerable potential that could contribute to the economy of the country. It is becoming a valuable asset in the economy. Even though it is a land locked country, Ethiopia is endowed with a number of lakes and rivers, which are believed to be promising potentials of different fish stock.

The high potential of fish resource can contribute a significant amount to the economy, but it is not developed in human personnel and administrative structure. This would contribute to underexploitation of the resource in certain areas and management problems of the sector. For instance, resources in all the rivers are not interfered by resource users but some are used mainly for fishing (Wudneh, 1998). Most Rift valley lakes harbour, African catfish (*Clarias gariepinus*), Tilapia nilotica (*Oreochromis niloticus*) and a few cyprinids mostly Barbus species (LFDP, 1998).

Annual fisheries potential of the major lakes, reservoirs, small water bodies and major rivers since 1993 is estimated to be 51 thousand tones and catch in the year 1993 was estimated 8 thousand tones (16% of the potential). In the year 1999 the total catch was estimated to be 17,000t from the estimated potential of more than 75,000t/yr. Nile Tilapia (*Oreochromis niloticus*) is the dominant fish species of the landings (FAO, 1995, LFDP, 1998, EARO 2002). Catches are still falling far below the estimated potential yields, although some lakes are heavily exploited (Ziway and Awassa) (LFDP, 1998). Hence the contribution of fisheries to the GDP is very low.

According to LFDP (1996), due to absence of enforcing the existing regulations, some of the Ethiopian lakes are already considered as overexploited. The open access characteristics of the fishery increases the number of fishermen, which in turn leads to stock depletion, economic waste and breeds conflicts. Exclusive fishing rights are considered as a solution to these problems.

The Rift valley lakes practice commercial fishing since 50s, while subsistence fishing is conducted in rivers. Riverine fishing activities exist mostly on rivers Baro and Omo (FAO, 1995). Fish production in Ethiopia was not pronounced whatever food scarcity existed. But since the end of the eighties, the government placed emphasis towards the development of the sector with ultimate goal of self food sufficiency.

The increasing trend of fishers due to unemployment in other sectors and liberalization of the economy, there is a substantial development of fishing activities. Currently fish export activities does not exist. Hence, all production is consumed within Ethiopia (FAO, 1995).

Gillnets are the most commonly used fishing gears but handlines and beach seines are also used. Most fishing vessels in Ethiopia are made of papyrus and are (except some motorized boats in lake Tana) not motorized. Gillnets are mostly operated with rafts (except some exceptions in some lakes) (FAO, 1995). According to baseline survey conducted in 1993, the number of fishermen in the major lakes was 3,094 and lake Ziway has the highest number of fishers involved (4.07 /km^2) and persons that depend on fisheries (7,500) (LFDP, 1998).

LFDP II have made significant changes in the fisheries of certain lakes; large increase in overall production, increase in catches per fisher, increased purchase by the private sector, the availability of credit to fishers and traders, and improvements in the provision of infrastructure and equipment to the government services. But, these successes are by no means sustainable as conditions stand at the moment. The current economic and social situation would lead to over fishing of some fisheries (LFDP, 1998).

Since 1993 to 1999 the trend of Ethiopian fishery shows an increasing trend in production. Despite the increase in production, Ethiopians prefer meat to fish, which is mainly attributed to the high population of cattle. Inhabitants near to shore areas consume more fish, especially Tilapia which is the dominant species in the landings, (per head per year) than those living far from the resource area. The fish consumption per head per year of the country is very low (LFDP, 1998).

However the rapid growth of population and the progressive shortage of livestock products had changed the situation to a growing demand of fish (Anon, 1999, in Kelil, 2002). The fish demand for the year 2000 as forecasted by FAO (1995) was about 10,000 t/yr. This situation is encouraging the fishery sector towards development.

Rapid growth of population and high demand for fish may be the major causes of overexploitation in some lakes. Sustainable fishery would be possible by first of all allocating finance and materials for the sector staff to collect catch and effort data, updating estimates of MSY and target production, often conduct of exploratory and experimental fisheries, elaborating and enforcing fishing regulations in consultation with fishers to limit access to the lakes, and finally by empowering private marketing (LFDP, 1998).

The artisanal fishery of Ethiopian fishery is undeveloped due to low level of economy, absence of fisheries' legislation, in-effective administration set-up and lack of expertise. Based on these facts, Ethiopian fisheries might not seem to manage. But some stocks (Nile perch & Tilapia) on some lakes (Chamo & Awassa) show signs of over-fishing and Tilapia of lake Ziway are probably at full exploitation. These threats show the necessity of managing the fishery. There is no effective fisheries' legislation and regulations existing up to know, with the exception of a decree relevant to the FPMC activities. Most notable is the lack of legal provisions to monitor fishing activities through fisheries regulations and the lack of a clearly designated enforcement agency. Frequent overlapping of various institutional activities has been encountered due to the absence of clearly defined line administration and lack of institutional consultation (FAO, 1995).

Even though the fishery in Ethiopia is effective open access, there has surprisingly not been a major shift to fishing by non – fishing communities, which may be due to financial and social barriers to entry (FAO, 1995, LFDP, 1998). Although individual fishermen are allowed to operate outside the framework of cooperatives, the majority of the fishermen were organized in fishermen's associations. This is to say, general principles as well as a set of uncoordinated fishery regulatory practices do exist (FAO, 1993, FAO, 1995).

"Fisheries management systems have been under the control of local fishermen's associations, the strongest bodies that prevailed, regardless of supposed rules and authority. The FRDD has tried to maintain an influence on local practices under MOA guidelines, despite the lack of law, which would have empowered the department to make rules. When a fishermen's association insists on beach-seining capable of damaging fish stocks, or when an individual fishermen uses a mesh size probably too small, the FRDD has no explicit legal sanction to prevent them. Each fishermen's association has therefore set regulations governing its particular fishery (gear type, mesh size, seasonal constraints, nursery areas, etc.). However, judging from the reported annual decline in catches from lake Awassa, the system has not always proved adequate. The lack of a legal framework for fisheries activities is considered to be a most serious drawback, which should be urgently addressed, especially in the transitional context towards liberalized economy. In particular there is an urgent need to clarify the legal and institutional base for setting up and implementing access conditions to fishing grounds and related regulatory measures" (FAO, 1995). The elaboration and adoption of fisheries legislation is also needed for fisheries development with regard to the implementation of special decrees on investment, which requires a proper status for potential investors (FAO, 1995).

Fisheries management in Ethiopia would have great contribution to the economy. This is because fisheries provide employment, food & income and it makes possible evaluation of overexploitation of the fisheries. According to FAO (1995), the total number of fishers, including fishers engaged in reverine fisheries, is about 2250. More over about 46000 immigrants would fish daily for subsistence on River Baro. In production areas where informal marketing has developed, the sector provides a livelihood for a significant part of the population.

Regulations should be appropriate to different levels of government responsibilities, appropriate to the various lakes and be flexible over time as the conditions on the lakes are dynamic (FAO, 1995, LFDP, 1998).

In the exception of the draft proposal, Ethiopia has no official fishery rules and regulations.

3.2 Management

The incoming fisheries regulation of Ethiopia indicates that any type of fishing, which refers to access to fisheries, is not permitted in the natural or artificial water bodies of the country unless fishing is allowed, in accordance with the rules & regulation of the areas in care of fisheries management and with permission of the operator of the aquaculture facility. Regional state pursuant to water resources proclamation of the region is authorized to issue territorial use right for any water body in the region.

The Agricultural Research Organization of the country and appropriate regional research body could conduct fishing for research duties after the issuance of permit. Harmful fishing devices (substances that cause pollution, poison, explosives, etc), introduction of any exotic fish species, (except under certain circumstances), transferring live fish from one water body to another is forbidden by the proclamation. But stocking and/or transfer of indigenous fish species in a region are permitted. Fisheries management in this proclamation aims at utilization, maintenance and biological diversity of fishery resource, usage of appropriate fisheries technology and avoidance of over capacity & overfishing.

The National Fisheries Advisory Council, composed of Vice minister of Agriculture, and representatives from the Prime Minister's office, Ministry of Water Resource, Ministry of Health, Agricultural Research Organisation and other relevant authorities and Commissions, secures the co-ordination between the Federal & Regional fisheries management bodies. The Ministry of Agriculture has an authority to propose regulations to the council of ministers and research studies. The ministry is also in charge of enforcement of the proclamation and any regulations and directives stated under it.

The National Fisheries policy that is supposed to be prepared, published and periodically reviewed by the Ministry shall include:

- Precise statement of the management measures and development strategies.

- Analysis of the state of fisheries and aquaculture in current times.
- Ensuring the sustainable development of fisheries and aquaculture by identifying the short, medium and long-term objectives to be realized.

According to the proclamation, all types of regulations, input, output, and technical regulations are effected by Regional Fisheries Management body. It also provides powers of enforcement. Licensing subsistence, commercial or recreational fishing, setting quotas for the amount of fish which may be caught, restricting type of gear, fishing methods, and size/spp of fish that could be caught, and closed areas/closed seasons, are some of the input, output and technical regulation measures respectively. The regional fisheries management body is in charge of preparing & periodically reviewing a Regional Fisheries Development Policy, establishing a Regional Fisheries Council which involves representatives from fishing communities and other stakeholders and designation of procedures for licence applications.

Exclusive right over the exploitation of fisheries would be granted according to rules established by Regional State. The proclamation in its management aims also considers habitat protection that includes protecting aquatic environment grounds of spawning and pollutants (Federal Fisheries Proclamation, 1997). Both licensing and auction of property rights would have an important role in the management of Ethiopian fisheries (LFDP, 1996).

Holding the management responsibility by fishers, in Ethiopian fishery case, might be the cheapest alternative. But the necessary prerequisites, for instance the requirement of long period to put into place, homogeneous community & awareness building of local leadership among others, may hinder this attempt. The necessary time this approach requires might not be hosted since implementing appropriate management plans are relatively urgent. Fishing communities are not homogeneous with conflicting interests and awareness building of local leadership needs considerable input, trained manpower for instance, which is not there. The willingness of the direct resource users of the lake under study to share management responsibilities requires institutional arrangements, which is currently not practical. Therefore, the best opinion of managing body will be to have control largely executed by a government institution.

As LFDP (1996) also stated, Lake Fisheries are controlled by a governmental institution because local leadership demands a lot of work to build awareness and homogeneous fishing communities where there is a chance for the fishermen to know each other.

On the other hand there is a room where the direct resource users could be involved in the management scheme, since they are known to be willing to share management responsibilities – co-management.

3.3 Existing situation of Lake Ziway

3.3.1 The Lake Ziway Fishery

Lake Ziway is found in the Great East African Rift Valley and in the Northern most Rift Valley lakes of the country. It is located between 7^0 51'N to 8^0 7'N and 38^0 43'E to 38^0 57'E. It has an open water area of 434km^2, shoreline length of 137km and average depth of 4m. The lake has two tributaries and has one outflow in the south (LFDP, 1996).

The fishing ground is used by co-operative members and private fishers where the latter occasional fishers are motivated and supported by occasional fish traders. Co-operatives are not liable for any payments to the government for use of the fish stocks and the private fishers are accused of being illegal, unorganised and not being liable for any governmental obligations (EARO, 2002).

3.3.2 Fish Production

Lake Ziway fishery is the most developed fishery having a maximum contribution of all lakes in the region (Oromia Region). This is because of the high benefit it gained from the phase I (1981 – 1984) and phase II (1991 –1998) fishery development projects assisted by the EDF.

Ashine(1995) points out that, overfishing of lake Ziway fishery has been intensified in the recent past by rapid population growth, increased unemployment and open access nature of the fishery. According to Mammo (1991), in 1984 census, Ethiopia has 92 ethnic groups. The largest ethnic group, the Oromo, accounted for 29 percent of the total population

Depending on ‘good’ and ‘poor’ production seasons, earnings from the fishery range between 25 and 500$ per month and sometimes below and above the two extremes (Kelil, 2002). FAO (1995) stated that depending on availability of market outlet, costs and earnings of fisherment differ. In 1990, the annual net income per fisher was calculated as Br800.

Landing in lake Ziway increased during January – March due to the growing demand during the fasting period and spawning aggregation of Tilapia which becomes more vulnerable to fishing (Schroder 1984, Tadesse 1988).

The landings of lake Ziway are highly dominated by Tilapia nilotica (*Oreochromis niloticus*), but recently African catfish (*Clarias gariepinus*) and Crucian carp (*Caracius caracius*) are appearing in small amounts in the total landings (LFDP 1993). The potential yield of all species of lake Ziway as estimated by empirical model range between 3,000 to 6,680tons/yr. The total production of the year 1987 was estimated at 2070 tons in which 1944 tons of the landing were composed of Tilapia. In addition the maximum sustainable yield (MSY) of Tilapia was estimated around 2,100tons/yr. Hence, Lake Ziway is exploited close to MSY. Increasing fishing efforts therefore will end up in over fishing rather than a significant increase in production (LFDP, 1996).

Table 3.1 Fish species harboured in lake Ziway and its constraints

	Major fish species	Constraints
Lake Ziway	Tilapia, Catfish, Barbus and Carp	Overfishing

(EARO, 1999).

Tilapia yield constitutes about 71% of the total yield

3.3.3 Biology of the fish species with the highest yield in Lake Ziway (Tilapia nilotica)

Nile tilapia matures at about 10 to 12 months and 350 to 500 grams in several East African lakes, but environmental conditions has influence on sexual maturity of this species (Popma and Masser, 1999). Tilapia are known for their ability to sexually mature at a small size, around 8-10 cm (3-4 in.) in body length, and a young age (sometimes when 2-3 months old).

When there is slow growth, the sexual maturity of Nile tilapia is delayed a month or two but stunted fish may spawn at a weight of less than 20 grams (Chapman, 2000). The size at first breeding of Tilapia in lake Ziway as noted in LFDP (1996), is estimated to be 15.7 cm, which is said as lower than the size estimated earlier (18-19 cm). It is also noted that this reduction in size at first breeding could be due to increased fishing pressure in which reducing minimum mesh size for gill nets from 10 to 8 cm would not have adverse effect on spawning of Tilapia. The peak breeding season of Tilapia is between December and July (LFDP, 1996).

Oreochromis species spawn in a nest excavated by male about two to four eggs per gram of brood female. The male fertilizes the eggs and then she holds and incubates the eggs in her mouth. In addition to environmental influence, sexual maturity of tilapia also depends on age and size. Tilapia raised in small farm pond reaches maturity earlier and in smaller size than the tilapia in large lakes, which could be attributed to food availability and limited area to live. Tilapia, native only to Africa, are easily spawned, use a wide variety of natural foods as well as artificial feeds, tolerate poor water quality, and grow rapidly at warm temperatures. This dominant species in the landings of Ethiopian fishery grows to a max size and age of 4,324.0 g and 9 years respectively (Popma & Masser, 1999).

3.3.4 Management of the fishery

The fishery of this lake is not under any governmental regulations, it is rather under the control of fishery associations that consists of 20 fishing communities (LFDP, 1996) and 12 co-operative society (Ashine, 2001). Lake Ziway holds the same management system as the other lakes – open access. The fishing effort exerted has no limit.

Following the change of the ruling party in 1991, any one start to fish with the earlier cooperatively organized fishermen. As most of fishing associations apply, the most common traditional regulatory measures of lake Ziway are mesh size regulation, catch limits, and closed seasons or areas. Allowed mesh sizes for beach seines and gill nets are 8 and 10 cm respectively but most of fishermen use illegal fishing gears (LFDP, 1996).

For the interests of the majority of the fishermen in lake Ziway, the management of fisheries is preferably to rely on closed seasons, closed fishing areas, restriction on number of fishers, catch quotas, mesh size restriction, restriction on beach seines and banning beach seines (Keleil, 2002).

The spawning of the dominant fish species, Tilapia nilotica, in the lake understudy lasts long. This might have influence on the implementation of closed seasons that is characterised by the protection of particularly vulnerable stages in the life cycle of a stock. Protection of vulnerable stages may include the protection of juvenile fish, and spawning stocks. In most cases, fishermen use rafts made either from papyrus reeds or from local softwood. The growing shortage of the construction material, especially softwood would limit the number of these rafts. This infact is a management measure that would limit the number of boats, but this option does not sound realistic.

Catch quota is judged to be inapplicable through out the country, since it demands high cost to implement. Closed area as a management measure would be possible to implement in lakes that are not accessible from any landing point. Lake Ziway has landing points that are already scattered along the full length of the shoreline that makes the implementation of area closure difficult (LFDP, 1996).

The overall characteristics of the fishery is:

1. Open access to the lake
2. There exist traditional Management system
    - Closed seasons
    - Gear regulations
    - Closed areas

Where any one that might respect these tools is able to fish.

4. Methodology

4.1 Type of data

4.1.1 Fish catch and Fishing effort data

4.1.2 Economic data: Fish price and Fishing cost

4.2 Data Analysis (Bioeconomic Model)

4.2.1 The Schaefer harvest function

Fisheries management, which only consider biological aspects in earlier times have been largely replaced by new models that incorporate both biological and economic considerations. Economic considerations of fisheries management reflects the consideration of the inevitable agent of the natural resources- human being. This approach was prompted by what was largely perceived as the general failure of the biological concept of maximum sustainable yield to enable good and sustainable management.This is because, commercial fishers are believed to be profit maximizers. Therefore, models that only consider the natural resource would not be able to provide adequate predictions for proper planning and management (Niel, 1997).

A steady-state bioeconomic equilibrium when harvesting is introduced is attained when the net growth or change in a stock equates with removals as harvest.
Bioeconomic theory is characterized by analysing and modelling the main interactions between fishers and fishstocks that are categorized as economic agents and resources that might sustain harvest respectively. It also considers how their interaction is affected by managers (Flaaten, 2002).

Productivity of a stock could be assessed by studying the impact of different levels of fishing intensity. The simplest analytical method available that provides a full fish stock assessment is the surplus-production model. In 1950s Schaefer described it as relatively simple to apply partly because of its ability to pool recruitment, growth and mortality into a single production function (Haddon, 2001).

Flaaten (2002) also stated that a model or theory is better not because of its complexity or detailed presentation but its incorporation of those economic variables of most importance for the issues at stake and its contribution to the knowledge of the functioning of the economy.

The basis of assumption of surplus production models is that the net growth rate of a stock is related to its biomass (B). At the carrying capacity of the environment biomass growth is zero hence it is maximized at some lower value of biomass. The assumption of Schaefer model is that the increase in stock biomass conforms to a symmetrical S-shaped or logistic curve, in which r is the rate of increase and B_∞ is the maximum biomass at the carrying capacity of the environment (King, 1995).

The logistic equation, describing the rate of change in stock biomass, is:

$$dB/dt = r\,\mathrm{B}\,[1 - B/B_\infty]$$

When the stock is exploited yield (Y) per year is deducted:

$$dB/dt = r\,\mathrm{B}\,[1 - B/B_\infty] - \mathrm{Y}$$

In equilibrium, where the rate of fishing has been maintained long enough for the system to 're-equilibrate', removals in the form of yield will be equal to biomass growth,

$dB/dt = 0$, and this implies:

$$\mathrm{Y} = r\,\mathrm{B}\,[1 - B/B_\infty] \qquad (4.1)$$

This equation, which has the form of parabola, suggests that maximum yield occurs at half of the unexploited biomass level.

Catch or yield from a stock can be written as $\mathrm{Y} = qf\mathrm{B}$, where q is the availability parameter that expresses the effectiveness of the effort with respect to the stock level. From the above expression of yield catch per unit effort can be presented as Y/f, CPUE $= q\mathrm{B}$, and:

$$B = \mathrm{CPUE}/q \qquad (4.2)$$

Substituting Equation (4.2) in (4.1) will give:

$$\mathrm{Y} = f(\mathrm{CPUE}) = r\,(\mathrm{CPUE}/q)\,[1 - (\mathrm{CPUE}/q)/(\mathrm{CPUE}_\infty/\mathrm{q})]$$

CPUE_∞ indicates the catch per unit effort at the maximum biomass (B_∞) of the stock. Dividing by CPUE gives:

$$f = r/q\,[1 - \mathrm{CPUE}/\,\mathrm{CPUE}_\infty]$$

$CPUE = CPUE_\infty - [CPUE_\infty q/r]f$

This equation is a straight line with a slope, $b = [- CPUE_\infty q/r]$, and an intercept, $a = CPUE_\infty$; with a line of the form:

$$CPUE = a + bf \quad (4.3)$$

Where a and b are parameters. Multiplying by the fishing effort, f will give:

$$Y = af + bf^2 \quad (4.4)$$

This equation comes from the relation of Y= f(CPUE) and it is the equation for Schaefer's model, which suggests that yield is related to fishing effort by a symmetrical parabola. Schafer's model uses a long series annual catch and effort data and assumes equilibrium conditions.

Using the parabolic equation $Y = af + bf^2$, MSY and effort required to take it (f_{msy}) can be calculated. The derivative of this equation ($a + 2bf_{msy}$) can be equated to zero to obtain the effort (f_{msy}) at which yield is maximized:

$$f_{msy} = -a/(2b) \quad (4.5)$$

Equating the derivative of the parabolic equation to zero is from the fact that yield is maximized at a point where change in yield with the change in fishing effort is equal to zero. Hence fishing effort that takes this maximum yield is f_{msy}.

Substituting Equation (4.5) in Equation (4.4) gives maximum sustainable yield:

$$MSY = -a(a/2b) + b(a/2b)^2 = -a^2/(4b) \quad (4.6)$$

4.2.2 Revenue

Fish production in the lake under study is mainly supplied for domestic markets and it is less likely to influence the domestic market. Therefore price is assumed to be constant across time and quantity. The total revenue from the fishery is equal to price of fish multiplied by quantity harvested:

$$TR(E) = p * Y(E) \quad (4.7)$$

From this equation, average and marginal revenues can be derived as:

$$AR(E) = TR(E)/E \quad (4.8)$$

This is the revenue per unit of effort

$$MR(E) = dTR(E)/dE \quad (4.9)$$

Marginal revenue shows the change in total revenue due to a small change in effort.

4.2.3 Cost

Each addition unit cost of effort is assumed to be constant and the fishing crafts are assumed to be homogenous. As we did to the total revenue of the fishery, total cost will be expressed in a simple function of effort as:

$$TC(E) = cE \quad (4.10)$$

Where c stands for unit cost. Average and marginal costs could also be derived as:

$$AC(E) = TC(E)/E \quad (4.11)$$

Average cost refers to cost per unit effort.

$$MC(E) = dTC(E)/dE \quad (4.12)$$

This equation shows the change in total cost as a result of a small change in effort.

4.2.4 Resource rent

$$\pi(E) = TR(E) - TC(E) \quad (4.13)$$

and profit can be maximized as:

$$d\pi(E)/dE = dTR(E)/dE - dTC(E)/dE \quad (4.14)$$

5 Results

Data available from lake ziway fishery includes potential yield, total catch and effort data, catch by species, gross revenue by year, price, and costs among others. The data is of 22 years, (1972 to 1993 EC), catch and 6 years (1985 to 1990 EC) composite effort.

The prices data are taken from the proportion of the gross revenue and total yield of the fishery and the price at the end of 1993 EC. The cost data includes boat and gear operating costs and opportunity cost of labour. Based on the dominant gears deployed in the lake, this study is limited to consider specific types of effort. Accordingly, total number of fishers and boats has been used.

Analysing the data is believed to have an insight towards lake Ziway fishery. Yield with respect to effort may give an indication of the trend of the resource. Economic analysis might also give information what the economic benefit of resource users in this lake is. Therefore the available data are analyzed and resulted as:

Table 5.1 Lake Ziway estimated total nominal fish production and effort

Yr. EC	Yield (t)	Effort (total number of fishers)	Effort (total number of boats)
1972	503		
1973	1 198		
1974	923		
1975	1 085		
1976	880		
1977	447		
1978	78		
1979	107		
1980	638		
1981	585		
1982	1 032		
1983	1 123		
1984	801		
1985	844	1137	632
1986	2 183	1448	645
1987	2 105	1758	1068
1988	2 234	1483	1488
1989	3 180	1816	1490
1990	3 011	1816	1490
1991	2 450		
1992	2 151		
1993	2 360		

The available effort data covers only six years, 1985 to 1990 EC. This forces the catch data to only consider the same period of time.

Table 5.2 Lake Ziway fisheries potential and yield by species

Species/ Yr (ec)	Potential (t/yr)	1986	1987	1988	1989	1990	1991	1992	1993
Tilapia	1960	1950	1881	1956	2821	2006	1245	1094	1298
Catfish	893	176	170	234	293	914	1046	919	826
Carp & Barbus	88	57	54	44	81	238	159	139	236
Total	2941	2183	2105	2234	3195	3158	2450	2151	2360

The highest potential and catch of the lake is from Tilapia species.

Table 5.3 Production potential and yield of the three biggest Rift Valley lakes and lake Tana (the biggest lake in the country).

Lake	Alt (m)	Area (km2)	Length (km)	Mean Depth (m)	Perimeter (km)	Potential annual yield based on area (t)	Average estimated landing 1986-1993EC (tons)
Tana	1,830	3,500	75	8	385	10,000	1,239 (12%)
Abaya	1,285	1,070	30	7.1	225	600	532 (89)
Chamo	1,280	551	35	13	120	4,500	4,036 (90)
Ziway	1,850	434	30	2.5	100	2,941	2 479 (84%)

(Source EARO, 1999)

* Percent expression refers to landings as a percentage of the potential yield.

Lakes Chamo, Abaya and Ziway seem to be exploited at about greater than 80% of their potential. But lake Tana, the biggest lake in the country seems to be exploited only at about 12% of its potential. Lake Ziway the smallest lake (434km^2 surface area) of these lakes produces more than the two biggest lakes (Lake Tana and Abaya). This could be attributed to its favourable condition to producers and consumers. Availability of market outlet and vicinity of production area to the capital and other towns could be mentioned as some of the favourable conditions among others. These all could relatively put the lake as economically very important.

Table 5.4 Yield/km^2 and proportion of yield of the four largest lakes (1986 to1993 EC)

	Lake Ziway		Lake Tana		Lake Abaya		Lake Chamo	
TYML (t)	PY (%)	Yield/km^2	PY (%)	Yield/km^2	PY (%)	Yield/km^2	PY (%)	Yield/km^2
90235	24	5.71	12	0.35	5	0.50	39	7.32

(LFDP, 1996 & EARO, 1999)

TYML ⇒ Total Yield of Major Lakes

PY ⇒ Proportion of Yield = Total yield of the Lake 1986 -1993 EC/TYML(1986-1993 EC) *100

The smallest lake of these four lakes, lake Ziway, seems to have higher proportion of yield. Its proportion of yield is double fold of the biggest lake in the country. This could show its high socio-economic importance, which might include consumption, employment and others.

Yield per unit of area of lake Ziway is second to lake Chamo and by far greater than lake Tana and lake Abaya, which are the first and second biggest lakes in the country respectively. Higher yield per unit of area might also give biological information. Relatively lake Ziway could probably be better habitat to harbour fish, which might include better photosynthetic activity due to its shallow depth. This could trigger growth and recruitment. Higher growth rate and recruitment imply higher biomass and ultimately higher yield.

Table 5.5 Average level of effort involved in lake Ziway -in number

	Year 1985 – 1987 EC					Year 1988 – 1990 EC									
	fishers (A)	Gill nets (B)	Beach seiens (C)	Hooks (D)	Boats (E)	fishers (F)	%Δ (F-A)	Gill nets (G)	% Δ (G-B)	Beach seines (H)	% Δ (H-C)	Hooks (I)	% Δ (I-D)	Boats(J)	% Δ (J-E)
Ziway	1448	1810	116	1056	782	1705	(+) 18	2362	(+) 31	182	(+) 57	1413	(+) 34	1489	(+) 90

% Δ ⇒ percent change

percent change = Average effort (1988 – 1990) – Average effort (1985 – 1987)/ Average effort (1985 – 1987) *100

Beach seines contribute about two thirds of the total production and gill net seems to be the highest number of gear deployed. From the table above all types of efforts deployed in Lake Ziway during 1985 to 1990 EC is increasing. During these years, the average number of fishers, gill nets, beach seines, hooks, and total boats were increased by about 18%, 31%, 57%, 34% and 90% respectively.

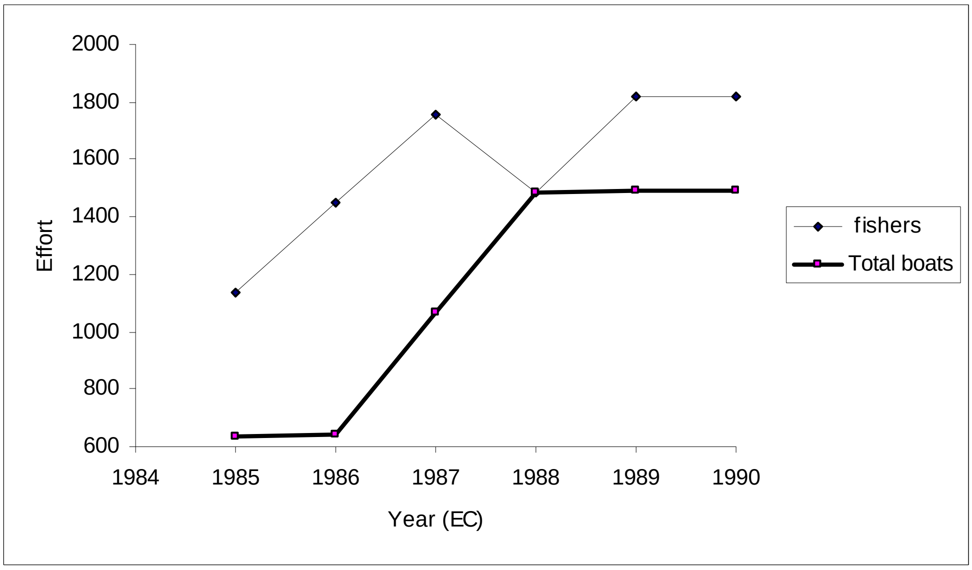


Figure 5.1 Trend of effort (total boats and fishers) by year

Total number of boats increased in 1985 to 1990 EC. The total number of fishers decreased in 1988 but showed an increasing trend in the rest of the years between 1985 and 1990 EC.

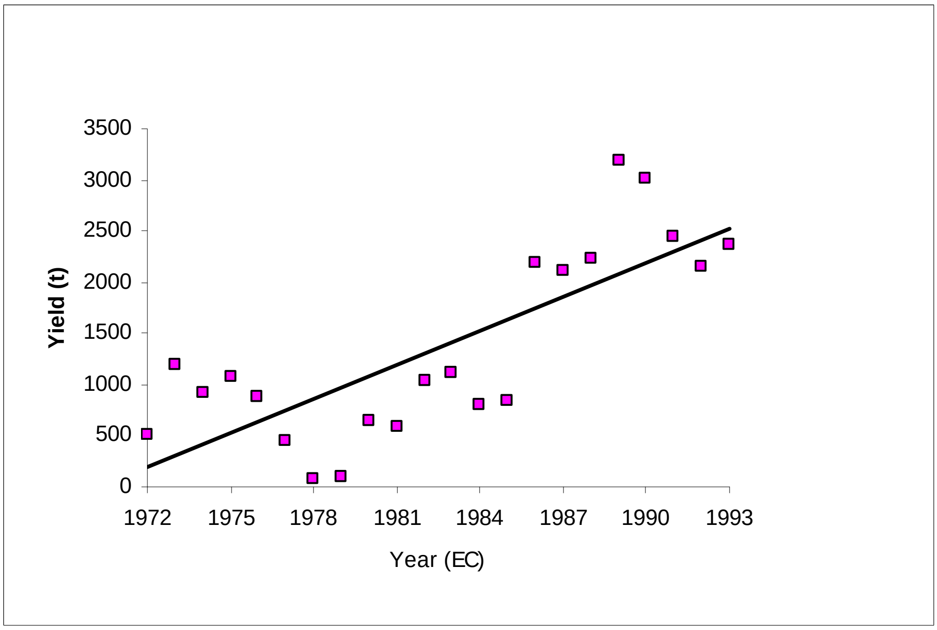


Figure 5.2 Catch trend of lake Ziway fishery

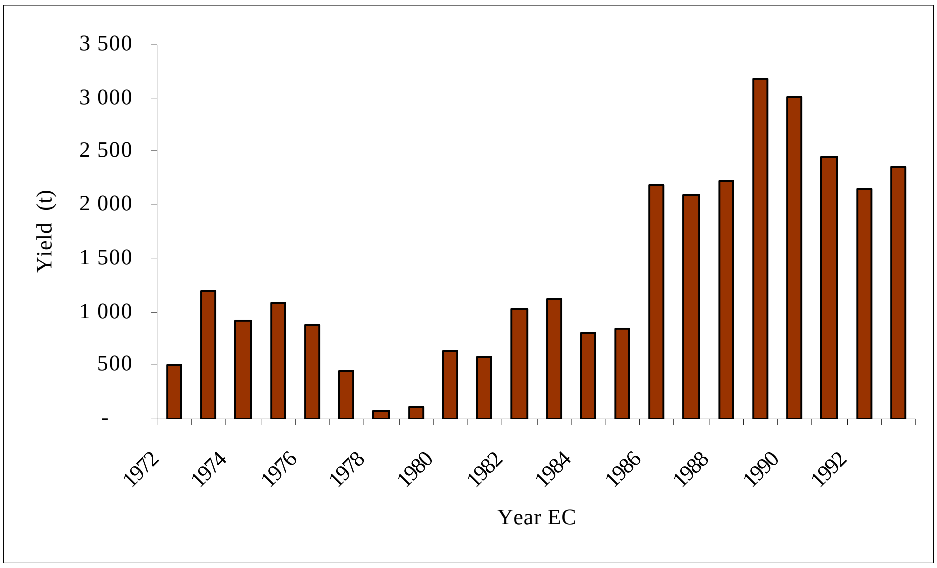


Figure 5.3 Catch pattern by year

Even though the general trend of the catch seems to be increasing, it is hardly possible to predict the pattern. The recurrent drought, which happens to occur in a cyclic way in Ethiopia, would have impact in the yield of this lake. The dramatic drop in catch in years 1978 to 1981 and 1985 EC would probably be due to this environmental effect.

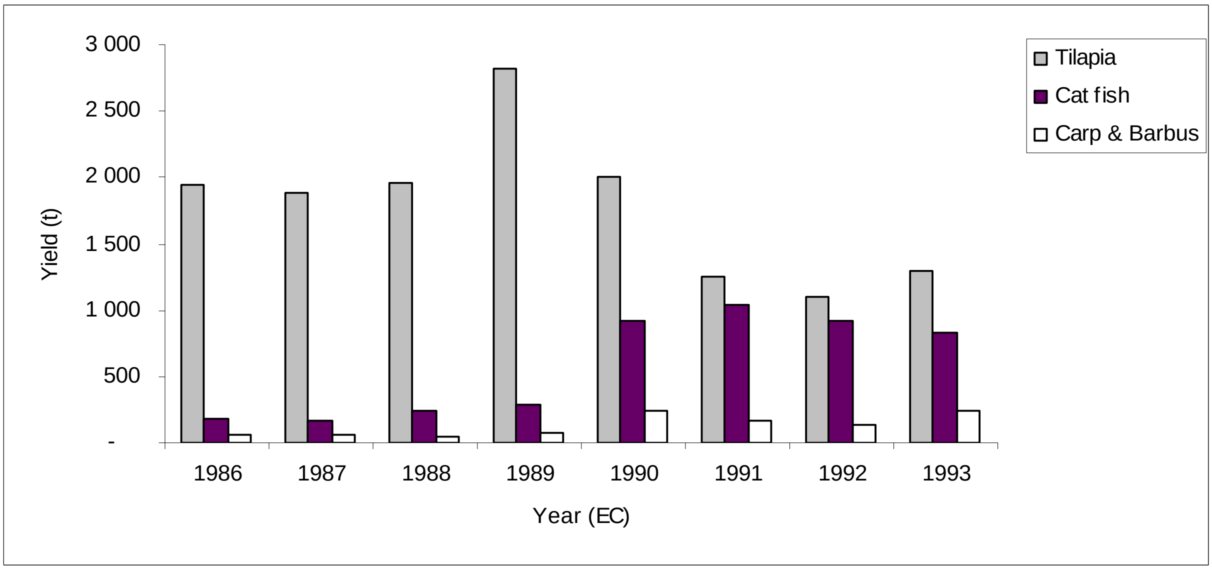


Figure 5.4 Yield by species

The dominant species in the yield of the lake seems to be Tilapia. But its catch has clearly declined from the year 1990 to 1993. On the other hand the catch of Catfish and

Carp & Barbus has increased with time. This might be attributed to change in gear type or as a result of high effort pressure on Tilapia.

Table 5.6 Marketing of fish in tons of whole fresh equivalent

Year EC	Total Yield	Consumption by fishers	Traded	% traded
1986	2 183	109	2 074	95
1987	2 105	105	2 000	95
1988	2 234	112	2 122	95
1989	3 180	159	3 021	95
1990	3 011	151	2 860	95
1991	2 450	123	2 328	95
1992	2 151	108	2 044	95
1993	2 360	118	2 242	95
Average	2 459	123	2 336	95

Lake Ziway fish production seems to have high market outlet. Since 1986 to 1993 about 95% of the production is traded.

5.1 Maximum sustainable yield & Maximum sustainable yield effort

The estimation of maximum sustainable yield and the effort level that could take it might be important to make sustainable use of the resource. The growth rate of fish stock differs depending on the size of the stock. The lower the stock biomass the higher the growth rate. This is because of the availability of ample food and space that would trigger recruitment and growth of the existing stock. Virgin stock could have zero net increase in biomass and it is maximized at half of this virgin stock or at half of the carrying capacity of the habitat. This maximum growth would result a maximum potential yield. The estimation of MSY and E_{MSY} are calculated according to Schaefer’s model shown in Equations 4.3 to 4.6.

Table 5.7 Computed CPUE

Year EC	Yield (t)	Effort (No. of fishers)	CPUE (t/f)	Effort (No. of boats)	CPUE (t/b)
1985	844	1137	0.74	632	1.34
1986	2183	1448	1.51	645	3.38
1987	2105	1758	1.20	1068	1.97
1988	2234	1483	1.51	1488	1.50
1989	3180	1816	1.75	1490	2.13
1990	3011	1816	1.66	1490	2.02

t/f - ton/fisher

t/b – ton/boat

CPUE = Yield/Effort

* number of boats include the total number of reed and wooden boats

Catch per unit effort computed from fishers as a measure of effort increased within the given years but CPUE of boats as a measure of effort is declining.

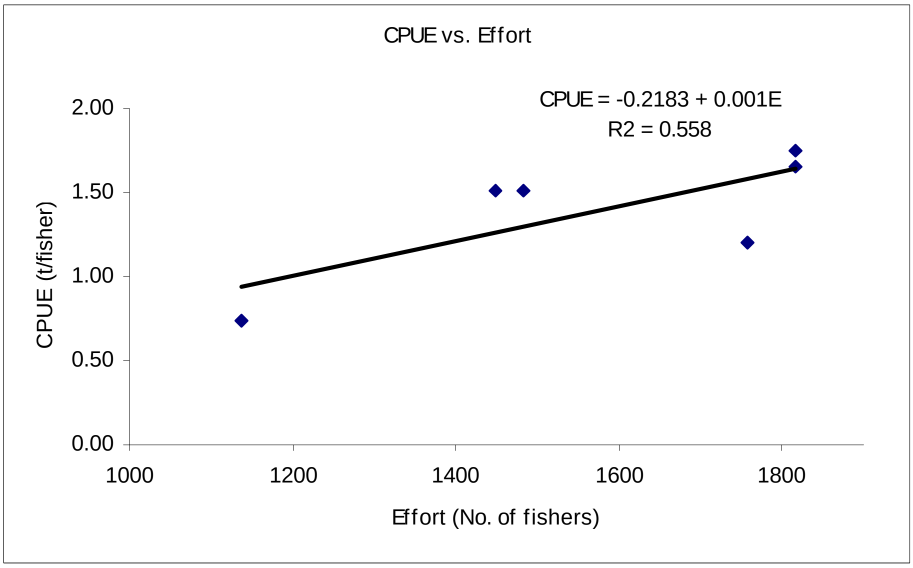
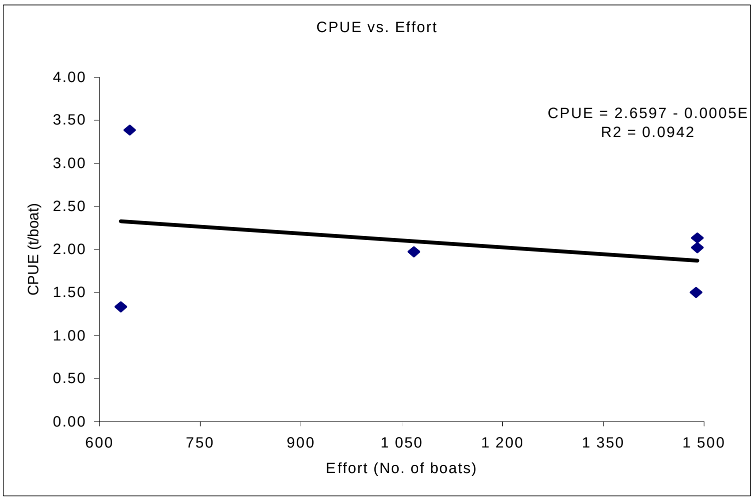


Figure 5.5 A fitted regression line of CPUE vs Effort (number of fishers)

An increasing trend of catch with effort might not indicate or show the sign of stock depletion. The stock might be depleted as catch keeps on increasing linearly with effort as a result of increased efficiency of effort. Fishers might be well adapted to the trend of fishery decline and increase their efficiency to maximise their output, but catch per unit of effort would decline.

Regression of CPUE against number of fishers showed an increased trend with effort, which could tell that each additional unit of effort brings higher catch. For every additional fisher CPUE increases by about 0.001 points.



CPUE = 2.6597 - 0.0005E (a - b E)
Y = 2.6597E - 0.0005E^2 (a E - b E^2)
Effort at which yield is maximized
E_{MSY} = (2.6597E - 0.0005E^2)' = 0
= a /2b
2659.7 = 2660 boats
MSY = -b (a /2b)^2 + a (a /2b) = a ^{2}/4b
3537 tons
Y = 2.6597E - 0.0005E^2
2.6597E -0.0005E^2 = 0
E(2.6597-0.0005E) = 0
E = 0 or 2.6597 - 0.0005E = 0
E 5319.4
Yield is zero either at effort level of zero (no boats) or 5319.4 boats.

Figure 5.6 A fitted regression line of CPUE vs Effort (number of boats)

Figure 5.6 shows that for every additional boat CPUE declines by about 0.0005 points. Unlike the fitted regression line in Figure 5.5, CPUE is declining as effort increases. This could be due to the interaction of variable factor (effort in this case) and fixed factors (the stock of fish). Fixed stock of fish may refer to a fish population that could be sustained indefinitely. As effort increases on this fixed stock, the return of the marginal effort diminishes. Therefore the trend of catch per unit effort would slope down. Based on the theoretical relationship of variable and fixed factors the regression of CPUE vs number of boats will be used to analyze lake Ziway fishery but not the regression of CPUE vs number of fishers.

If the straight lines in Figure 5.5 and 5.6 are the correct models, observed CPUE above the line (positive residual) represents CPUE more than it should be and vice versa.

5.2 Least-squares estimates

Least squares estimation is used as an additional methodology to the regression line that Excel fits in Figure 5.6 to estimate the values of the coefficients *a* and *b*.

Table 5.8 Least square estimation

Yr EC	Effort (No. of boats)	Observed Yield (t)	Observed CPUE (t/boat)	Estimated CPUE (t/boat)	Error of prediction (OCPUE-ECPUE)^2	SSQ (residual^2)
1985	632	844	1.34	2.34	1.02	
1986	645	2183	3.38	2.34	1.10	
1987	1068	2105	1.97	2.13	0.02	
1988	1488	2234	1.50	1.92	0.17	
1989	1490	3180	2.13	1.91	0.05	
1990	1490	3011	2.02	1.91	0.01	
Mean	1136	2260	2.1			
Sum					2.37	2.37

OCPUE: Observed CPUE, ECPUE: Estimated CPUE

SSQ: Sum of squares

The regression line fitted to the available data was in the assumption that the data follow the linear model: $y = \alpha + \beta x + \varepsilon$

Where α is the "true" intercept, β is the "true" slope, and ε is an error term. Estimates of α and β, will be labelled as "*a*" and "*b*." The predicted values of *y* using these estimates is labelled as y, so that

$$y = a + bx$$

To get estimates for α and β, *a* and *b* should have values that could result in a minimum value for the sum of squared residuals:

Sum of Squared Residuals = $\sum_{i=1}^{n}(y_i - y_i)^2$, where y and y stands for observed and predicted yield respectively. This is the sum of the squared all positive residuals (residuals above the observed CPUE) and negative residuals (residuals below the observed CPUE in the fitted regression line).

Minimizing the value of the sum of squared residuals would minimize the deviation of an observed value from the estimated value or the regression line so that the effect that would be incurred by factors other than the factor under study might be minimized (or it is to minimize error). The values of *a* and *b* that result in the smallest possible sum of the squared residuals can be calculated from:

$$b = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) \Big/ \sum_{i=1}^{n}(x_i - \bar{x})^2$$

$a = \bar{y} - b\bar{x}$, where x is the independent variable (effort in this case), y is the dependent variable (yield), $\bar{x}$ and $\bar{y}$ are means (Berk & Carey, 2000).

According to the above formulas the coefficients *a* and *b* are calculated from the available data as:

$\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) = -463$

$\sum_{i=1}^{n}(x_i - \bar{x})^2 = 874, 256$

$b = -463 / 874,256$

$= -0.0005$

$a = 2.1 + 0.0005 * 1136$

$= 2.6597$

Minimized *a* and *b* values are 2.6597 and –0.0005 respectively. Therefore the least-squares estimate of the regression equation is: ***y* = 2.6597 - 0.0005 *x***

The values of these coefficients obtained from the regression line that Excel fits in Figure 5.6 and as calculated by the least square method that would result in the smallest possible sum of the squared residuals and regression statistics in Table 5.9 were exactly the same. The use of different methods to obtain values for the same parameters was made in order to increase the accuracy of the study.

5.3 Regression statistics

The regression equation in Figure 5.6 gives useful information but it doesn't tell whether the regression is statistically significant or not. Therefore to calculate the significance of this regression, a regression statistics was implemented with two hypotheses:

H0: There is no linear relationship between CPUE and effort

Ha: There is a linear relationship

Table 5.9 Regression statistics

Effort (No. of boats)	Observed CPUE (t/boat)	Estimated CPUE (t/boat)
632	1.34	2.34
645	3.38	2.34
1068	1.97	2.13
1488	1.50	1.92
1490	2.13	1.91
1490	2.02	1.91

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.306955325
R Square	0.094221572
Adjusted R square	-0.132223036
Standard Error	0.768235477
Observations	6

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.245571	0.245571	0.41609104	0.554027919
Residual	4	2.360742992	0.590185748		
Total	5	2.606313993			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	2.659687735	0.984264088	2.702209466	0.05397067	-0.073073134	5.392448603	-0.073073134	5.392448603
X variable 1	-0.000529992	0.000821628	-0.64505119	0.55402792	-0.002811202	0.001751217	-0.002811202	0.001751217

RESIDUAL OUTPUT

Observation	Predicted Y	Residuals	Standard Residuals
1	2.324732761	-0.989289723	-1.439740246
2	2.317842864	1.06665326	1.552329507
3	2.093656228	-0.122682445	-0.1785431
4	1.871059568	-0.369715482	-0.538056999
5	1.869999584	0.264228604	0.384539076
6	1.869999584	0.150805785	0.219471762

Some of the regression statistics shown in Table 5.9 have the same value as it is calculated by Excel to fit the regression line of CPUE against effort in Figure 5.6. The R^2-value of 0.0942 indicated in the fitted regression line for example holds the same value as it is shown in the regression statistics. R^2 measures how successfully the straight line Y = *a*x + *b* has been fitted to the empirical data. R^2 value of 0.0942 means that 9.42% of the variation in the CPUE can be explained by the change in effort level. The remaining 90.58% of the variation is presumed to be due to random variability (Berk & Carey, 2000). This means the line CPUE = 2.6597 – 0.0005E fits the data less (Nolan, 1994).

The multiple R is equal to the absolute value of the correlation between the dependent variable (CPUE) and the predictor variable (Effort). The standard error measures the size of a typical deviation of an observed value from the regression line and it is also a way of averaging the size of the deviations (Berk & Carey, 2000). The deviation of an observed point from the regression line in Figure 5.6 according to the regression statistics is about 0.768.

The regression statistics made in this study gives an indication to reject the alternative hypothesis and accept the null hypothesis or it tells that the regression of CPUE against effort is insignificant.

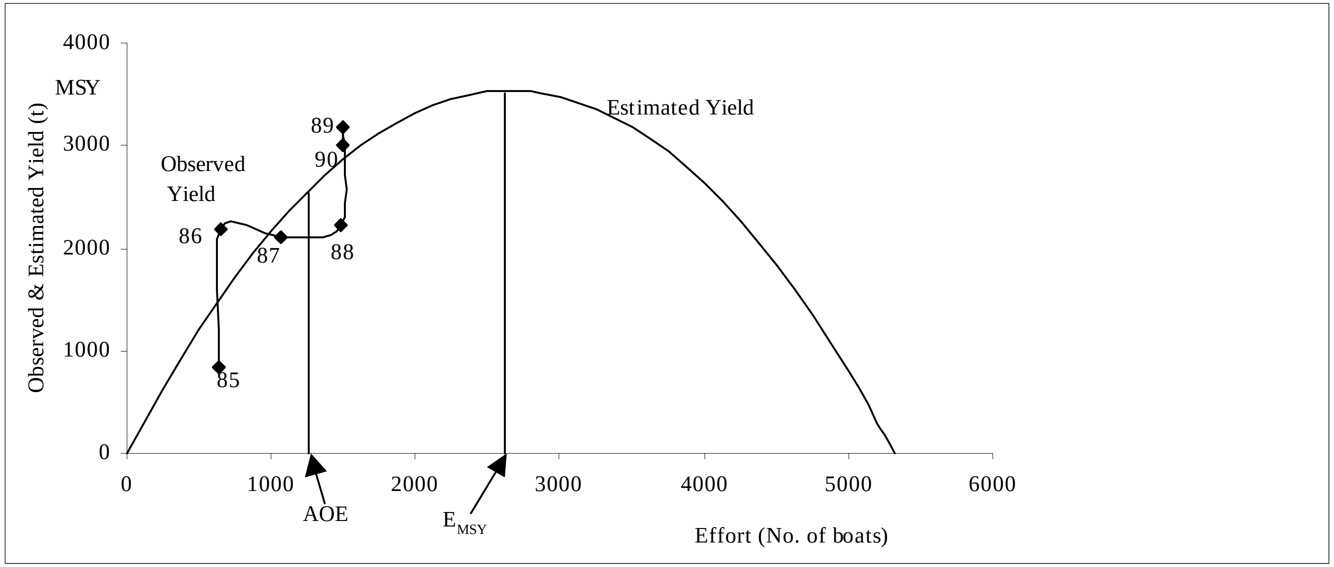


Figure 5.7 A Schaefer yield curve fitted to catch and effort data for 1985 to 1990 EC

Equation for Schaefer's model = 2.6597E - 0.0005E^{2}

The above Figure shows a Schaefer surplus yield curve fitted to lake Ziway catch and effort data for 1985 to 1990 EC only, that is, for the period that combines both catch and effort data. As it can be seen from the Figure, all the observed catch and effort data lay to one direction of the yield curve and it also shows that the observed effort and yield increased for this time series. The estimated MSY is situated at about 3,537t/yr and effort required to take it is situated at about 2,660/yr boats. This yield curve will be used to analyze the economic and biological effects of fishing under open access fishery, even though analyzing a fishery and ultimately meeting a management objective using few years and only catch and effort data is less dependable. The positions of the data points may suggest that the available data, which is used to analyze the fishery, might be data from a specific season of the fishery. The catch could probably be taken during good season in which the stock is at its high growth and recruitment period, since all the observed yield data will lie to the right of MSY stock level. The positioning of the observed yield data to one direction of the Schaefer model may also suggest that the reliability of the data is low.

Table 5.10 Estimated prices per kilogram of fish

Yr EC	Total Yield (Observed) - t	Total Revenue (Observed)- br 000	Average price TR/TY (br/kg)	Average price (br/kg)
1986 - 1993	19, 674	29, 539	1.51	
1993				2.00

TR – Total Revenue TY – Total Yield

Two price estimations have been made for this study. The aim of these two prices is to see the economic return of the fishery at different prices of fish.

Table 5.11 Estimated cost per unit of effort (boat)

Description	br.	Yr. EC	Effort (rb)	Effort (wb)	Total effort/ annum	Proportion of effort	
						rb	wb
Wooden boat operating cost	217	1985	538	94	632	0.85	0.15
Timber 450br		1986	538	107	645	0.83	0.17
Labour 150br		1987	948	120	1068	0.89	0.11
Others 100br		1988	1357	131	1488	0.91	0.09
Fixed cost (FC) 700br		1989	1297	193	1490	0.87	0.13
Capital cost = FC/6yrs ⇒ 117		1990	1297	193	1490	0.87	0.13
Boat repair ⇒ 100					Mean	0.87	0.13
Gear operating cost for wooden boat (Beach seine)	3548						
Opportunity cost of labour 230*12mths*3persons	8280						
Unit cost of fishing of Wb	12045						
Reed boat operating cost	300						
Gear operating cost for reed boat (gillnet)	307						
Opportunity cost of labour 230*12mnths*1person	2760						
Unit cost of fishing of Rb	3367						
Cost of fishing per unit of boat	4495						

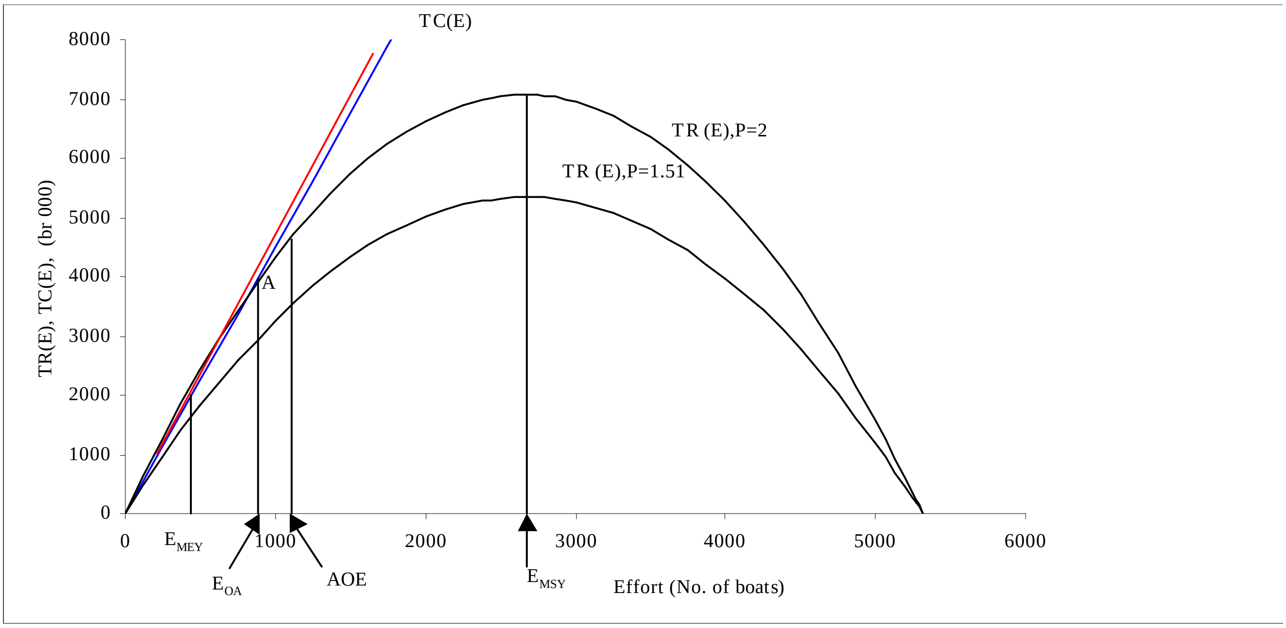
rb – Reed boat wb – Wooden boat

Economic data for this fishery comprises price per kilogram of fish and cost per unit of effort. The price per kilogram of fish of the fishery differs in periods. This study considers two prices of fish. One was calculated from the total revenue and yield of the fishery and the other price is price per kilogram of fish in the year 1993 EC, which is the latest available fish price. The price obtained from the proportion of total revenue and total yield of 1986 to 1993 EC has a value of about 1.5 br/kg and the price of fish in 1993 EC has a value of about 2.00 br/kg.

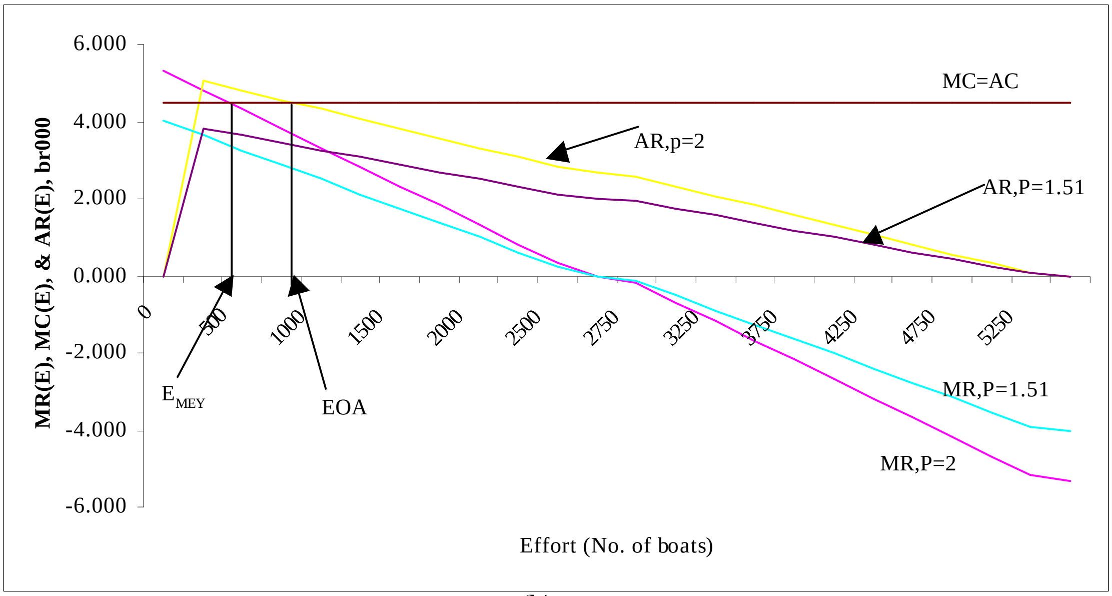
The cost per unit of effort has been calculated by taking the weighted average of reed boat and wooden boat fishing costs. Costs described in Table 5.11 are calculated as:
Fishing cost of wooden boat = Operating cost of wooden boat + Gear operating cost + Opportunity cost of labour
Operating cost of wooden boat = Capital cost of the boat + Operating cost
Capital cost = Fixed cost or investment cost / life span of the wooden boat
Fixed cost of wooden boat = Timber + labour costs
Operating cost includes cost to repair the boat

Gear operating cost = Capital cost + Operating cost
Capital cost = Fixed cost or investment cost of the gear (Beach seine / life span of the gear
Fixed cost of beach seine = Twine + Rope + Lead + Beam + Labour costs
Operating cost includes cost for net repair, rope replacement and labour.
Opportunity cost of labour = Estimated annual salary of a labourer * labour force operating the boat
Cost of fishing per unit of boat = weighted average cost of reed and wooden boats

$\Rightarrow$ 0.87 * reed boat cost of fishing + 0.13 * wooden boat cost of fishing



(a)



(b)

Figure 5.8 An open access equilibrium for the fishery occurs where TR = TC. The above curves are all functions of effort. Part (a) illustrates the TC(E) and TR(E) that the fishery could incur and earn respectively. The total cost curve, TC(E), is straight line sloping upward that shows the cost function is linear in effort at a constant cost per unit of effort. The open access equilibrium is at point A in(a). Part (b) illustrates that the open access equilibrium is attained when the average revenues (as a function of effort) balances the marginal costs (as a function of effort) and also it illustrates that in open access equilibrium marginal cost of effort exceeds marginal revenue.

Table 5.12 Summary of observed and estimated yield & effort

MSY (t)	E_{MSY} (boats)	TR(E) =TC(E) Br 000	E_{OA} (boats)	E_{MEY} (t)	AOE (1985 -1990EC) (boats)	Average observed yield (1985 – 1990EC) t/yr
3537	2660	3704	824	412	1136	2260

* Average observed yield is limited to 6 years due to available effort data.

5.4 Open access

An open access equilibrium is known to be economically inefficient since economic rent that the fishery would have earn wastes here. In open for all resource use, each resource user may not recognize or each user may ignore the effect of the stock. Therefore an open access equilibrium would require more effort than is socially optimal.

Open access equilibrium would lead to imposing additional costs made by individual user to all users, which would raise the harvesting costs. But it might not be biologically inefficient, if the open access equilibrium is to the left of MSY stock.

Figure 5.8 shows when the price of fish is 2.00 br/kg, the fishery could have resource rent at effort range of 1 to 823 boats/yr and it could also be maximized, when MR(E) = MC(E), at about 412 boats/yr (Table 5.12). As long as total revenues exceed total costs and profit is there, effort will rise. When TR equals TC (at open access equilibrium) profit becomes zero and there will no more be rise in effort. This equilibrium is attained at point A Figure 5.8(a) at about 824 boats/yr.

5.5 Maximum economic yield and Maximum economic yield effort

Maximum economic yield could be attained when marginal revenues equate marginal costs. Each additional unit cost of effort would result in proportional revenue. Hence this equilibrium is economically efficient. It is also biologically efficient, since the equilibrium occurs to the right of MSY stock. This is because, maximization of resource rent could be realized in managed fishery where stock effect is considered.

MEY might be attained in this study at about 412 boats/yr and the corresponding yield is estimated at about 1011 t/yr (Figure 5.8(b) & Table 5.12).

6 Discussion

This study has started to analyze lake Ziway fishery with the available data. This includes; 22 years catch data, 6 years composite effort, and economic data among others. The catch data doesn't include single species only. It rather includes different species as tropical fisheries, but considered as a single stock. As King (1995) also pointed out, the only practical option of managing a diversified catch is to treat the component of species as a single stock.

According to the available data lake Ziway fishery is under an increased level of fishing gears involved by year (Table 5.5). The availability of high market outlet, which might be attributed to relatively good infrastructure and vicinity of the production area to the capital, would have high probability of inviting more users to the fishery. During years 1986 to 1993, 95% of the total landing has been traded by state and private enterprises (Table 5.6).

Output from the lake fisheries varies from year to year. But the general catch trend, with slight drop in late 1970s EC, seems to increase (Figure 5.2 & 5.3).

Even though the general catch trend is increasing, in Figure 5.4, around years 1989 to 1993 EC there is a switch in catch composition from the highly commercially important fish species (Tilapia) to Catfish, Carp and Barbus. Change of a fishery from highly preferred species to less preferred might indicate overfishing, as it is also noted by LFDP (1996) that the lake is overfished or due to change in gears.

LFDP (1996) also mentioned about catfish landings increase. Catfish is thought to be introduced to this lake from the nearby lake during transportation or it could always be in lake Ziway when these two lakes were one. The higher proportion of catfish could then be due to changes in the gears.

Due to the limitation of effort data, it was only 6 years (1985 to 1990 EC) catch and effort data used. From the available composite effort, the highest number of gear deployed in this lake seems to be gill net. Each fisher would probably be has one gill net (Table5.5). Therefore this study considers total number of fishers as a measure of effort. As King (1995) also pointed out, gross measure of effort in a gill net fishery is the number of fishers using gillnets, in which case CPUE would be recorded as kg per fisher. Total number of boats (reed boats + wooden boats) was also taken as a measure of effort, since fishers might use these fishing crafts to deploy their gears.

Even though the ultimate management options need curiosity due to the few time series information, this study depends on surplus yield model to analyze lake Ziway fishery. This is because surplus yield model requires only catch and effort data in managing fisheries. Hartwick and Olewiler (1998) also stated that the basic economic model employed here is applicable to both small-scale fisheries and larger fisheries. Haddon (2001) also noted that productivity of a stock could be assessed by studying the impact of different levels of fishing intensity. Surplus-production model, which pools the overall effects of recruitment, growth and mortality into a single production function, is simple to apply.

The study analyses the regression of CPUE against number of fishers and boats. Regression of CPUE and effort is a useful tool to predict what the yield will be after certain period of time. A linear regression is also useful to predict a yield due to the fact that the pattern of data follows a linear pattern (Nolan, 1994).

The regression of CPUE against number of fishers shows a monotonous increase of CPUE with effort:

$$\text{CPUE} = -a + b\text{E}$$

$$= -0.2183 + 0.001\text{E}$$ (Figure 5.5), where the values of *a* and *b* are –0.2183 and 0.001 respectively. This means that for every additional fisher CPUE increases by about 0.001 points. The value of *a*, which is the *y*-intercept, in this study tells that if effort is 0, the value of CPUE would be –0.2183. This may contradict with the common sense towards yield. Catch or yield cannot fall below zero. But this does not mean that the linear equation is useless. But according to Berk & Carey (2000),

some one should be cautious in making predictions for effort level that lies outside the range of the observed data.

The R^2-value, a measure of the percentage of variability explained by the regression, in Figure 5.5 for this equation is 0.558. This value is also known as the coefficient of determination that measures the percentage of variation in the values of the dependent variable (CPUE) that can be explained by the change in the independent variable (Effort). R^2- values vary from 0 to 1. A value of 0.558 means that 55.8% of the variation in the CPUE can be explained by the change in effort level. The remaining 44.2% of the variation is presumed to be due to random variability (Berk & Carey, 2000).

A continuous increase of catch per unit of effort as effort exerted on fish stock increases might not be realized in production. Fish stock may sustain effort at some point of population levels. If the harvest exceeds their natural growth, the stock might decline.

Even though they are a renewable natural resource, they could not sustain all removals that exceed their ability to reproduce and grow. Their potential to sustain will dwindle as long as they are under higher pressure of harvest than their ability to replenish. Their biological dynamics limits them to sustain harvest indefinitely. As noted in Hartwick and Olewiler (1998), harvests that are relatively high to the ability of the fish stock to sustain overtime have been a threat to overfishing in recent years.

When effort on a particular stock keeps on increasing harvest might exceed their growth. This implies that the stock will ultimately decline since it looses its sustainability to high effort level and fish stocks are not infinite. A continuous increase of effort might result in an increasing catch but at a decreasing rate or more effort may result in proportionately smaller harvests, i.e; the additional effort will have less return. The well-known principle in economics of the diminishing marginal product of a variable factor as noted in (Hartwick & Olewiler 1998), also says that the marginal product of effort slopes downward given a particular fish stock. This was not realized from the regression of CPUE vs fishers. The line shows a continuous increase as effort increases.

Therefore as King (1995), also pointed out that initial stock size estimation is said to be reasonable as long as CPUE is proportional to stock size, and has been reduced over a short period of time, during which recruitment, migration and natural mortality can be ignored, the regression of CPUE against number of fishers was rejected from the analysis.

The regression of CPUE against the number of boats,

CPUE = a- bE

= 2.6597 – 0.0005E (Figure 5.6)

where the values of a and b were 2.6597 and -0.0005 respectively, and the later (b = -0.0005) tells that, as the predictor (effort) increases the dependent variable (CPUE) declines by about 0.0005 points. The value of the constant term in the above equation (2.6597) is the y-intercept, and it tells that if the effort level is 0, the value of CPUE would be 2.6597.

realizes the theory of Hartwick & Olewiler (1988) and King (1995) above. Therefore all the analysis of this study is made on the regression of CPUE against number of boats.

Basically the regression line in Figure 5.6 has developed from the theoretical relation ship of logistic growth equation and yield equation from the definition of catchability coefficient (Equations 4.1 to 4.3), q, where according to King (1995) is Y = qfB.

The equation of the regression line includes parameters of intercept and slope and the slope contains catchability and the intrinsic growth rate together with catch per unit of effort at the maximum biomass.

As mentioned earlier the value of b (-0.0005) of the linear equation in Figure 5.6 tells that, as the predictor (effort) increases the dependent variable (CPUE) declines by about 0.0005 points. To examine the significance of regressing CPUE against number of boats or the significance of the independent variable, this study hypothesise two hypotheses and conduct a regression statistics (Table 5.9). The two hypotheses comprise null hypothesis stating there is no linear relationship between CPUE and effort and alternative hypothesis that states there is linear relationship. The statistical analysis results in rejecting the alternative hypothesis and accepts the null hypothesis. This is because the significance level was higher than the highest probability of rejecting the null hypothesis when the null hypothesis is actually true (significance F= 0.554 > 0.05).

This study has limitation to conclude that the alternative hypothesis should be rejected. This is because the catch and effort data used to analyze this fishery is of few time series. In addition the type of effort used might have influence in the statistical analysis since it only considers number of fishers and boats as the present situation of effort is different. This implies that these defined types of effort might not represent all the composite efforts deployed and be able to realize the effect of effort on the fishery. The model used to analyze this fishery does not also rely on knowledge of the processes affecting a stock: growth, recruitment, mortality etc.

Therefore this few years' catch and effort data coupled with specific type of effort and simple model might not be reliable to use as a basis and extrapolation of results to management measures. It could be due to these reasons that effort is not realized as a major influencing factor in the fishery. Table 5.7, Figure 5.5 and 5.7 might also give information about the low reliability of the data. In Table 5.7, CPUE in 1986 EC has increased by about 152%, in Figure 5.5, even though it is not considered in the analysis, the continuous increase of CPUE with effort may show the overall uncertainty of the available data, and in Figure 5.7, the entire observed yield lies to only one direction of the yield curve. According to this data the observed yield might be removed from a high stock level, since these observed yield could be found to the right direction of MSY stock. This might tell that the observed catch and effort data might only be from high production season of the lake. This explanation and the insignificance of regressing CPUE against number of boats made by regression statistics may ultimately lead to look for other influencing factors to the fishery, more specifically environmental factors.

Environmental fluctuation would have its own effect in this fishery. High rainfall would enrich the lake with fertile nutrients entering as runoff through its tributary rivers. It also enlarges the size of the lake, which implies high coverage of primary producers followed by other energy flow up to high production of fish. On the other hand drought would have a negative impact on the lake. It could shrink the size of the lake and also reduce algal blooming and fish production. The high catch drop in late 1970s EC in Table 5.1 could also be due to the recurrent drought existing in Ethiopia.

Sunlight would also have its own role in fish production. High sunlight penetration implies high photosynthetic activity, high primary production and fish production of the lake. These all environmental factors could influence the fishery.

After this brief explanation of possible environmental effects on lake Ziway fishery, this study continued the usage of the only available catch and effort data to analyze the fishery.

Multiplying the linear equation in Figure 5.6 by effort or following Equations 4.1 to 4.4 we can obtain the Schaefer harvest function:

$Y = 2.6597E – 0.0005E^2$, where 'Y' denotes yield and 'E' effort.

For convenience all effort labelled as *f* in Equations (4.3) to (4.5) will be recognized as 'E' in this study and also all yields, revenues, costs and profits are manipulated with respect to effort (E).

Based on the above model, effort at which yield is maximized (E_{MSY}) and maximum sustainable yield were calculated using equations (4.5) and (4.6) respectively. Effort at which yield could be maximized was estimated at about 2660 boats/yr and the corresponding MSY was situated at about 3537 t/yr (Table 5.12). E_{MEY} and MEY was also manipulated by equating marginal revenue and marginal cost of the fishery (Equations 4.9 and 4.12). Effort that maximizes resource rent (E_{MEY}) was estimated at about 412 boats/yr and the corresponding yield was approximately 1011 t/yr.

The present situation of the fishery in Table 5.12 shows that the average effort being deployed and yield obtained were approximately 1136 boats/yr and 2260 t/yr respectively. This tells that lake Ziway fishery has the potential to expand to attain the maximum sustainable yield estimated by the surplus production model. The present situation of effort does not also seem to be sufficient to take the maximum sustainable yield. It tells rather, lake Ziway has potentials to sustain about 1524 more boats/yr that can take a yield from the stock without adversely affecting future reproduction and recruitment.

As it can also be seen from the yield curve in Figure 5.7, the observed yields lay to the left of MSY effort. This might show that the fishery might give higher sustainable yield than is removed currently. It may also show that the fishery is biologically under-fished or biologically efficient with regard to all species combined since the steady-state stock would be to the right of MSY stock. The fishery is operating to the right of MSY stock level where less effort could be used to catch a given amount of fish.

The estimated MSY lies in the range of the potential of the lake as it is estimated by LFDP (1996) as 3000 to 6680 t/yr. But the maximum sustainable yield of lake Ziway as estimated by LFDP is 2550 t/yr.

The estimated MSY shows higher biomass than the estimated MSY of the lake made by LFDP. The difference in the value of the two estimated maximum yields of the lake might tell that the data are probably less dependable. Therefore, as it is also indicated in the regression statistics in Table 5.9, the analysis of this fishery, which is made by few years ’ data series, has limitation to extrapolate the results.

According to LFDP (1996), estimated MSY of Tilapia situated at around 2,100t/yr was used as an indication of the exploitation of Lake Ziway close to its MSY. This is because the proportion of Tilapia landing at which its maximum sustainable yield was estimated by LFDP was about 94% of the total landing (2,070t/yr). But this study shows possible expansion of the fishery. Even though the statistical analysis gave a green light to consider other influencing factors, the variation of inference made by this study and LFDP could largely be attributed to less reliability of data or to the use of short time series data. The data, during which they are collected, might not reflect the then situation of the fishery, as the high value of standard error in the regression statistics also tells.

Therefore the use of short time series data (6 years) and lack of reliability of the data could be some of the influencing factors that might bring difference in the outcome of these two studies.

The total revenue curve in Figure 5.8(a) has the same shape as the sustainable yield curve in Figure 5.7 but scaled up, since the price of fish is not normalized to 1. This is to say the two curves in Figure 5.7 and 5.8(a) differ in scale since the two prices used are greater than one.

The fishing cost in this fishery seems expensive. When cost of fishing increases, effort that could be involved might have limitation to enter the fishery. Effort that might afford the cost may get involved. In this case there could be low amount of effort and the open access equilibrium may lie to the left of MSY effort level. In lake Ziway fishery, given that the economic data are reliable, it seems this situation is happening. The cost curve is steep, which could also express high fishing cost.

Cost of fishing is higher than its revenue when price of fish is at about br1.51/kg. At this price there is no intersection point between the revenue and cost curves (Figure 5.8). Fish price estimated, as br1.51/kg and the cost of fishing would probably be not the actual figures being implemented in the fishery. Therefore all the economic anaylsis will only consider fish price br2.00/kg.

But at price br2.00/kg, the fishery could have resource rent at effort range of about 1 to 823 boats/yr and it could also be maximized, when MR(E) = MC(E), at about 412 boats/yr (Table 5.12).

Obtaining resource rent when effort level is about 1 to 823 boats/yr is because, within this range of effort level, the total revenue (as a function of effort) is greater than the total cost (as a function of effort) (Figure 5.8(a)).

The access to this fishery is open for all. Therefore as long as total revenues exceed the total costs and profit, (is there), effort will rise. When TR equals TC, resource rent becomes zero and there will be no more rise in effort as the costs become greater than the revenues. The open access equilibrium in this study is at point A (about 824 boats/yr) in Figure 5.8(a).

The break-even point of this fishery is at effort level of 824 boats/yr. The observed effort in Table 5.12 above this break-even point, according to the findings of this study, would make business at loss. This is because the total cost of effort above the open access equilibrium is greater than the total revenue. Figure 5.8(b) also shows that at fish price br1.51/kg, the cost is higher than the average and marginal revenues. If these were true or the price and cost data are data that are implemented currently, at fish price br2.00/kg the excess boats would have quit business and gain the advantage of opportunity cost and also at price br1.51/kg there might not be fishery at all.

But according to the present situation of the fishery, this is less likely to be true. The average observed effort is effort deployed currently. This might indicate that the economic data used to analyze Lake Ziway fishery may either be outdated information, or cost and price of particular season or there is information gap. All the investment costs and price of fish did not also consider factors that might influence the reliability of the data – viz duration and inflation, which this study could not be able to reach these information.

In Figure 5.8(a) open access equilibrium is situated at a point to the left of MSY effort. E_{OA} units of effort will have a corresponding steady-state stock to the right of MSY stock. This is because the open access level of effort, E_{OA}, lies to the left of the maximum sustainable total revenues (as a function of effort), it is obvious that the harvest function will lie to the right of the maximum sustainable yield in terms of biomass. i.e, according to this study the fishery is expensive and lower total effort will be used than total effort that might be engaged if it is cheaper, which implies that the lower amount of effort will take the same amount of sustained biomass as excessive effort might take it from lower biomass. Therefore the lower amount of effort is being deployed to a larger stock and this will lead to larger sustainable stock. From bioeconomic point of view this fishery would be said as efficient, since the steady-state stock is to the right of MSY stock. As Hartwick and Olewiler (1998) stated, any equilibrium that is to the left of the maximum sustainable yield in terms of biomass (or to the right of the maximum sustainable total revenues) is bioeconomically inefficient.

The open access equilibrium in Figure 5.8(b) is economically inefficient since MR(E) < MC(E) and also a given harvest is to be taken by excessive amounts of effort. There could be more entry of effort as long as average revenue is greater than marginal cost and up until it balances with marginal cost. Hartwick and Olewiler (1998) noted that an open access equilibrium is economically inefficient because marginal revenue is less than marginal cost. It can also be biologically inefficient if the equilibrium is to the left of the MSY stock. If an equilibrium occurs to the left of the MSY biomass, it indicates that the same harvest could be taken at a higher sustained biomass.

7 Management implications

Lake Ziway fishery is regulated by technical and output control measures, which seems to lack proper control or implementation, most probably due to its high cost. These regulations are under fishery associations. According to the preliminary results of this study, these management tools put the status of the fishery into biologically efficient and economically inefficient.

The lake can be said to be under open access although controlled by traditional management measures leading each fisher to receive the average product of the associations total effort. This leads to economic inefficiency. The yield per fisher could be determined by the total harvest divided by the total effort. Each fisher does not capture the marginal product of his/her effort. The fisher rather harvests the associations' average product, which will lie above marginal product. This is because of the new entry of effort to share the resource rent earned from the fishery, even though the increase in output obtained by adding 1 unit of fisher (marginal product) decreases. The total product may increase as the number of fishers increases but at a decreasing rate, since they are dealing with finite creatures. But ultimately the stock might dwindle and increase the cost of harvesting. Harvesting a given quantity with a lower stock could require more effort than with a higher stock.

In Figure 5.8(b), at open access equilibrium, where AR(E) = MC(E), the marginal revenue (as a function of effort) is less than the marginal cost (as a function of effort), which means that the revenue earned from each additional unit of effort is less than its cost. This might indicate the dissipation of the small resource rent that the fishery could have earned when the total number of boats is within the range of about 1 and 823 boats. Possible remedy to save the resource rent that might be dissipated could be developing economic policies. Regulating effort and harvest might be some of the mechanisms that would generate resource rent to a fishery and lead to a new equilibrium where resource rent could be maximized (the economically efficient equilibrium: MR = MC).

The estimated MSY and E_{MSY} in relation to the average observed yield and effort indicates that lake Ziway has the potential for fishery expansion. But according to the economic analysis, effort needs to be reduced to the open access equilibrium. This is because the average observed effort exceeds effort at open access equilibrium, which might imply that the excess effort, making loss, will quit business. But practically this is not the case. The observed effort is the same effort 'currently' operating in the lake.

Most probably the economic data are less reliable. The cost of fishing might be less than the anticipated cost, which might probably be due to overestimation of opportunity cost, and fish price could also be higher than estimated by this study, which ultimately make the total cost (as a function of effort) curve steep and make the break-even point at a lower level of effort. This absence of updated information could make limitation to propose management measures from the analysis made by this study.

Nieland (1997) also stated that the absence of accurate and regularly updated relevant information as a basis for decision making is a major constraint for the management of fisheries. African inland fisheries, which lacks this information suffers greatly. This is to say, there could be difficulties in the designing and implementation of appropriate fisheries monitoring systems, limited funding, and lack of suitable study methodologies.

Bearing this in mind, we may assume that the open access equilibrium is at about the average observed effort. Attempting to earn resource rent to the fishery or save resource rent dissipation, which could be achieved by reducing the existing effort might be difficult in this Lake. This could largely be attributed to the open to all nature of the fishery and also according to LFDP (1996) the present objective of managing this lake is probably taking out of the lake the maximum possible on a sustainable basis. Therefore anticipation of maximizing or earning resource rent might be difficult to implement.

From economic point of view it might be important to consider fisheries management with respect to its bioeconomic return. Considering yield with respect to the revenue it earns and expense it incurs.

Even though there is a concern on the reliability of the data, we may put assumptions of management from the preliminary results of this study. According to the above assumption of open access equilibrium, and based on the present objective of maximizing yield, and the estimated MSY of the lake, it might first be better to make market arrangements to make best use of the lake. If the present objective of management is based on biological criterion or maximizing catch, taking 3537 t/yr that require 2660 boats/yr may need better price or cheaper cost of fishing. If revenue from the fishery is enhanced by price subsidy or cost is reduced, more effort than existing now will get involved and shift the fishing effort towards E_{MSY} and be able to take the maximum sustainable yield. In the short run, the fishery can make profit but in the long run the stock might be affected. This is because the existing fish species are short lived and fast growing species. Their natural production might fluctuate a lot from year to year. Removing the MSY during bad years may have negative consequence.

In other words, from the interest of the existing management (taking the maximum yield in a sustainable basis) and the primary necessity of food, attaining maximum sustainable yield might not be possible by using the existing effort. As indicated in the summary of results, it does not seem sufficient to take the MSY. This might be possible, provided that the results are reliable, by subsidising (revenue enhancing and cost reducing transfers) the lake fishery. But the long-run impact of subsidy might cost higher than the earnings from its management and also in the long run it might impact the fishery (decreased fish stock levels and increased size of effort).

Works from LFDP also revealed that supplying fishing inputs in lake Ziway has caused fishers to seek any opportunity to gain advantage of profit from the fishing. It expands the level of effort as new entrants and it also cause fishers to change the fishing gears to catch maximum fish. Therefore, subsidising the fishery according to the study might lead to undesirable outcomes.

But LFDP (1996) used the estimated MSY of Tilapia, which has been covering about 94% of the total landing, as an indication of the exploitation of Lake Ziway close to its MSY. According to the preliminary results of LFDP there are no more opportunities to expand the fisheries and regulating fishing effort is becoming necessary. It is considered as over-exploited.

The difference in predicting on the status of the fishery made by LFDP and this study might be attributed to less accurate data, duration when the catch and effort data is collected, environmental variation, and model used to estimate the maximum sustainable yield among others.

In both ways the best way to manage the fishery might be to adopt the precautionary approach, which focuses on the integration of social, economic and biological objectives during management planning. It also refers the usefulness of defining safe biological limits with low fishing mortality and high spawning stock biomass. Implementation that puts in place all planned decisions needs also to involve the interested parties.

According to the present management situation of the lake, some of these precautionary approaches might exist in the lake but with low enforcing capacity, which could be a major problem in the sustainable management of the lake. Whatever attempt to enforce the existing regulations is made according to LFDP (1996), enforcing only is not sufficient. The use of illegal fishing gears and change in the size of gears is widespread. Whatever be the ultimate management tools decided upon, the question of control would be central to any success or failure. It could either by the fishermen themselves or and authority based approach to management. The easiest way, according to LFDP (1996), to implement the management tools is control by the fishermen themselves.

As Neiland (1997) also pointed, overexploitation of fisheries increased through time as a result of a limited success of centrally controlled fishery management systems and many fisheries under "common property resource" have been managed effectively in the past by local community-based fisheries management institutions that have been ignored by centrally- controlled management systems

7.1 Thesis limitations

The reliability of the available data used to analyze lake Ziway fishery is sceptical. Data found in different sources but collected within the same period of time showed discrepancy. Additional information (environmental) that could refine the thesis work was not manageable to find, largely due to time limitation. Shortage of reference material for the lake was also a handicap in this study.

8.Conclusion

According to the results of the study (if accurate), the lake fishery has different status from biological and economic perspectives. Its biological status may be able to produce more but economically it might need attention. Even though the product is able to enter market easily, the price seems to be cheap.

Maximum sustainable yield might be the most desirable equilibrium for a fishery in the absence of consideration of costs to harvest or discounting of future revenue from fishing. But fisheries management that may consider only biological factors might loose economic information, which could in turn have a valuable input and importance in management.

The maximum sustainable yield of the lake is about 3537 t/yr and the current mean removal is estimated at about 2260 t/yr. Harvesting lake Ziway fishery to its maximum sustainable yield may help in food self sufficiency programme. But the cost of harvesting the MSY would be high.

To meet the objective of the management, harvesting the MSY could be made possible by enhancing revenue or reducing the cost of production (or it might need subsidy). But from the long run impact of subsidy and from economic point of view coupled with the experience of subsidy in lake Ziway (undesirable outcomes), subsidising the fishery might not be appropriate.

With all the limitations in place, this study might give an insight to the need of further investigation for better outcome in the status of the lake by making use of accurate data, incorporating environmental effects and gears. Whatever the discrepancy between the results and inference of LFDP and this study, adopting the precautionary approach would favor the lake fishery.

Even though it is worth to note the less accuracy of the data, this study has tried to address the three initial objectives of the study as: the existing regulations of the lake are reviewed and find out that they kept the status of lake Ziway in bioeconomically efficient but economically inefficient. The maximum sustainable yield, effort that takes it, maximum economic yield, and E_{MEY} of the lake are estimated. In addition some indicative management measures are noted.

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Appendix: Map of major lakes and Ethiopia

Map showing the main water bodies of Ethiopia

0 100 200 km
0 100 200 mi
SAUDI ARABIA
no defined boundary
Red Sea
SUDAN
ERITREA
YEMEN
Gonder
Bahir Dar
T'ana Hāyk'
Desē
Gulf of Aden
DJIBOUTI
Blue Nile
Dirē Dawa
Hārer
SOMALIA
ADDIS ABABA
Nazrēt
Jīma
Werdēr
Āwasa
Ogadēn
Lake Rudolf
Dolo Odo
Moyalē
SOMALIA
UGANDA
KENYA