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A comparative study of fish production from Lake Manzalah before and during the cleansing and development operations based on surplus production modeling approach

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ABSTRACT

Lakes fisheries play an important role in the Egyptian economy and food security. In the ’80s, they provided more than 50% of harvested fish in Egypt, but now their contribution to Egyptian fish production seriously decreased to less than 11% (2015-2020). Manzalah Lake is the largest natural lake and the most productive in Egypt, yielding annually up to 65 thousand tons. The catch is composed of a variety of marine and freshwater fish species from which the cichlid species, catfishes, and grey mullet are the most common species. Lake Manzalah faced many challenges that resulted in serious changes in its water quality and its fish production as well as the catch composition. A great development project for the Egyptian lakes was established ten years ago after the political leadership program “Rehabilitation of Egyptian Lakes”. The restoration of lake Manzalah started in 2017 and was completed by June 2022. The present study evaluated the fishery status of lake Manzalah before and after the development project. The estimated MSY using the logistic model of Schaefer was 69841.2 tons for the period 2000-2016, which is not significantly different from the average yield during 2017-2020 (72057.5 tons). The cost-benefit analysis showed that if the scientific regulatory measures were taken into consideration, millions of pounds spent in some cleaning and development steps in the lake can be saved.

INTRODUCTION

The Egyptian natural lakes are divided according to their location to the northern or coastal lakes (Bardawil, Port Fouad, Manzalah, Burullus, Edku and Mariut), and inland lakes (Qarun, El-Raiyan, Timsah and Bitter lakes). These natural lakes along with the artificial Nasser Lake provide 49% of the Egyptian fish production from natural resources (Fig. 1) and 11.8% of the total fish production from Egypt (Fig. 2) **(GAFRD, 2000-2020)**.

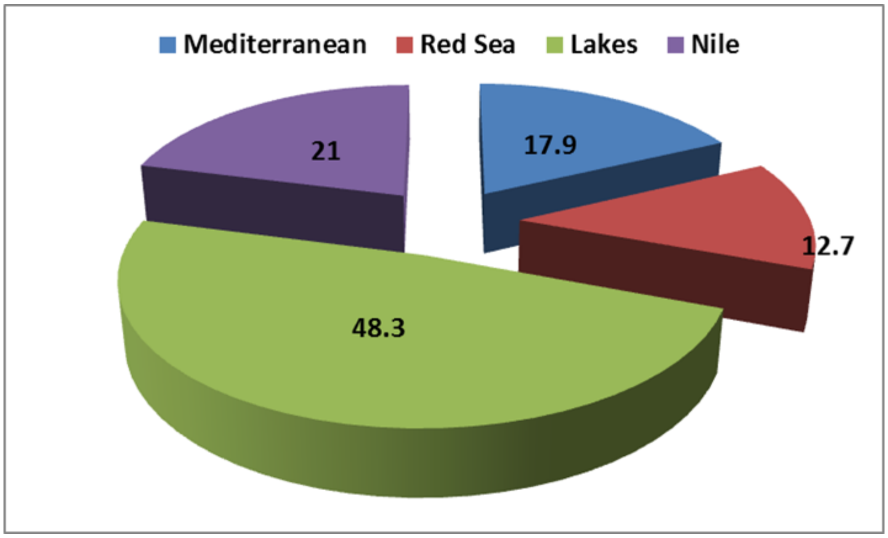

Fig. 1. Lakes contribution (%) to the natural fishery resources in Egypt

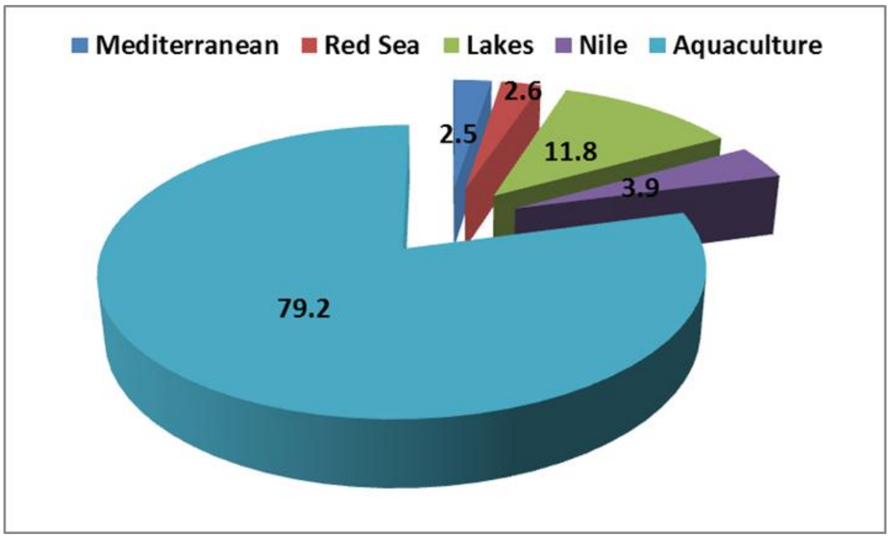

Fig. 2. Lakes contribution (%) to the total fishery resources in Egypt

Lake Manzalah (31°15'60.00" N 32°11'60.00" E) is considered one of the most important sources of inland fishery in Egypt (Fig. 3). It is the largest and one of highly important natural lakes in Egypt, producing about 35.6% of the total production from the Egyptian lakes and 47.5% of the total production from the Delta lakes. It is connected to the Mediterranean Sea via five inlets **(Shafei, 2015)** which allow water exchange and help to have diverse economical fish species **(Mehanna *et al.*, 2020)**. Lake Manzalah has an area of about 404.7Km^2, with an average depth of 1.2m. It is located in the northeastern part of the Nile Delta and extends to connect to three governorates, Port Said, Dakahlia and Damietta. The lake's catch is composed of a mix of marine and fresh water species, viz. shrimp, tilapia, mullet, sole, crab, sea bass, spotted seabass, grass carp, catfishes, eel and pagrid species. The most widely used fishing gear is that of a small-scale type with a surrounding net (locally known as El-Tara). The trammel net (El-Daba), the seine/hand catching combination (El-Laffa), the basket traps (Gawabi) and the bottom trawls (El-Kerba) fishing techniques are also used in the lake. The development of the Egyptian lakes is one of the giant national projects in the country that is directed to develop and raise the efficiency of the lakes and overcome the challenges and problems they face.

Lake Manzalah faces a number of problems, including the shrinking of the area due to erosion, filling up and drought, water pollution due to the discharge of wastewater, sewage, industrial and agricultural, as wel as the spread of aquatic plants (Fig. 4). Over-fishing, illegal fishing practices, illegal harvesting of fish fry, and the blockage of inlets are another challenges facing the lake development. These challenges have seriously influenced the fish quality and quantity harvested from the lake.

The national project for the purification and development of Lake Manzalah, which is supervised by the Engineering Authority of the Armed Forces, started in 2017 and continued to 2022. The project includes pollutant removal, weeds and aquatic plants removal as well as making a radial canals and deepening the lake and its inlets. In addition, the project is directed to build suitable housing for fishermen who work in the lake to prevent any encroachments.

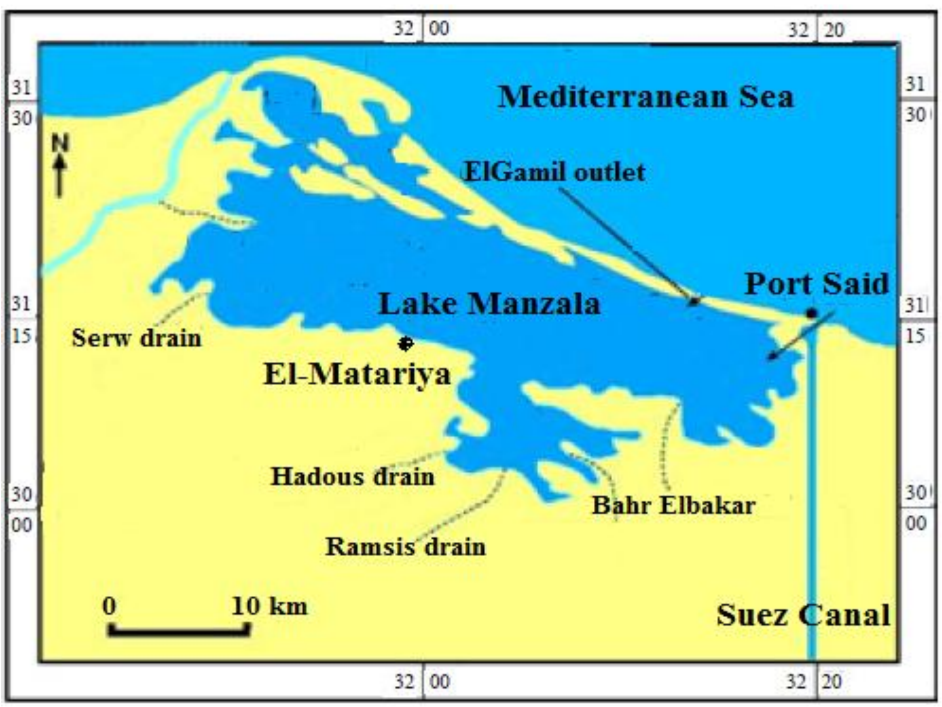

Fig. 3. A map of Lake Manzalah

Fig. 4. Some challenges in lake Manzalah

The objective of fishery management is not to maximize the profit of individual fishing fleets but to run the entire fishing industry in a sustainable way. Even if the fishing is done at open access equilibrium OAE (The point at which revenue curve is intersected by the cost line), all the involved parties can earn normal profit **(Christensen, 2010)**. Additionally, cost and price changes unavoidably result in different estimates for the MEY and effort levels. Moreover, sometimes fishery economists and most of the time, policymakers fail to fully understand the concept of economic efficiency of fisheries. The solution is not to target maximum economic yield (MEY) and let the whole fishing sector suffer **(Bromely, 2009)**. Instead, compared to MEY, the MSY is a more suitable reference for society as a whole.

Thus, the present study would provide detailed information about the productivity of Manzalah lake, with a comparison between the periods before and during the development project of the lake, as well as create some referential points for the conservation and sustainability of its populations, based on the surplus production modeling approach. The fishery status of the lake was evaluated by analyzing the available catch – effort data for the period from 2000 to 2016 to estimate the MSY and f_{MSY}.

MATERIALS AND METHODS

1. Collection of Fishery Statistics

Landings data concerning the annual catch, catch of each fish group and fishing effort of lake Manzalah were compiled from the General Authority for Fish Resources Development (GAFRD) commercial fishery statistics data base **(**GAFRD annual statistical book**, 2000 - 2020)**.

2. Catch composition

The catch composition of the different fishing gears was recorded during the monthly field trips to the lake landing sites (Port Said, Gheet Elnasara in Damietta and El-Matarya in Dakahlia). The fishermen were interviewed during the field trips to collect data about the fishing gears used and their characteristics, the real fishing effort and the problems they faced.

3. Abundance estimates

Catches and abundance estimates were determined for the economically important fish stocks in lake Manzalah for the periods 2000- 2016 and 2017- 2020. The GAFRD records before and after the purification operations were used to generate total biomass estimates.

4. Surplus production models

The catch, effort and abundance records were considered as the primary inputs in the surplus production models. The basic approach followed the methods described by **Jacobson *et al.* (2002)** and **Mueter and Megrey (2006)**. The study analysis depended on a discrete-time version of the simple logistic production model:

$$B_{t+1} = B_t + (\alpha - \beta\bar{B}_t).\ \bar{B}_t - C_t + \varepsilon_t$$

Where, α is the intrinsic rate of increase; β is a density dependent term; α, β > 0; B_t is the aggregate annual biomass at time t, and ε_t is a normally distributed random variable with mean 0 and constant variance, following **Mueter and Megrey (2006)**, $\bar{B}_t = (B_{t+1} + B_t)/2$. By definition, the annual surplus production in year t is the change in biomass from year t to year t+1 plus the catch in year t **(Quinn & Deriso, 1999)**. In this model, the maximum sustainable yield MSY = $\frac{\alpha 2}{4\beta}$, and the corresponding level of fishing mortality at MSY is $F_{MSY} = \frac{\alpha}{2}$, representing the annual proportion of the population removed by harvesting. The biomass level at MSY is given as $B_{MSY} = \frac{\alpha}{2\beta}$

The parameters α and β were estimated by the method of maximum likelihood using a process-error model.

RESULTS AND DISCUSSION

1. Catch composition

The most important commercially exploited fish species in lake Manzalah are cichlid species, catfishes, grey mullets, seabream, seabass and soles. The main three fish groups in the lake are tilapia, catfish and grey mullets; they constituted 83.5% of the lake catch in the period 2000-2016 and 93.7% of the lake catch during 2017-2020. Tilapia (Cichlidae) are the most dominant fish species in the catch; they composed of five species *Oreochromis niloticus, O. mozambicus, O. aureus, Tilapia zilli* and *Sarotherodon galilaeus*. Tilapia species constituted 47.1% and 43.5% of the lake catch during the two periods of study 2000-2016 and 2017-2020, respectively. Catfish (Clariidae), especially *Clarias lazara* and *C. garipinus,* and grass carp (Cyprinidae), especially *Cyprinus carpio* are marked in the second degree comprising 19.4% and 20.6% of the lake's catch in the two periods, respectively. Grey mullets (Mugilidae), especially *Liza ramada* and *L. saliens* are in the third degree, constituting 17% and 29.6% in the two periods, respectively. It is worth mentioning that, the catch composition altered during the last 50 years; the lake fishery transformed from a marine (mullet) to a freshwater (Tilapia) dominated fishery. Mullets and marine species declined from 65% of the total annual catch during 1920-1929 to 31.4% in 1960's to 8.9% in 1980's. In contrast, the tilapia and other freshwater species increased from 20% during 1920-1929 to 68.5% in 1960's and to 91.1% in the 1980's **(Montasir, 1937; Youssef, 1973; Bishai & Youssef, 1977; Shaheen & Youssef, 1978, 1979; Khalil & Bayoumi, 1988; Farouk, 2009; Mehanna *et al.*, 2014)**. This change could be attributed to the decline of salinity and the increase in the nutrients due to the increasing drain water inflows **(Maclaren, 1982; Mehanna *et al.*, 2014)**. During the development operations, the marine species contribution to the catch increased to reach 35% of the lake's production.

2. Catch trend

The annual total fish production from Manzalah lake during the period from 2000 to 2016 and from 2017 to 2020 (Fig. 5) was evaluated. In the first period 2000-2016, the total catch fluctuated between a minimum of 36783 ton during 2007 and a maximum value of 81365 ton during 2013, with an average of 56110.8±12699 ton. While in the second period, it varied from a minimum of 60538 ton during 2017 and a maximum of 82541 ton in 2020, with an average of 72057.5±13000 ton. The catch of the tilapia species varied from a minimum of 17364 ton during 2005 to a maximum of 39573 ton during 2000, with a mean of 26440.7±6648 ton. Grey mullet species were fluctuated between a minimum of 1838 ton (2006) and a maximum of 25317 ton (2013) with a mean of 9513.1 ±6620 ton. Catfish species contributed to a minimum of 5445 ton (2007) and a maximum of 21926 ton (2013) with a mean of 10889.4±4015 ton during all investigated period. During the project period (2017-2020), the total catch varied between 60538 and 82541 ton with an average of 72057.2±10870 ton. Tilapia catch varied between a minimum of 23885 ton (2017) and a maximum of 41147 ton (2020), with a mean of 31383±8206 ton. The grey mullet catch varied between a minimum of 18922 ton (2017) and a maximum of 23020 ton (2020), with a mean value of 21304.5±1818.9 ton. The catfish catch fluctuated between a minimum of 13559 ton during 2020 and a maximum of 17565 ton during 2019, with a mean value of 14842±1836.7 ton during the period from 2017 to 2020 (Fig. 6).

Generally, the fish production in lake Manzalah indicates a decreasing trend during the first period of study (2000-2016), and the same trend is noticed for tilapia species, the most common species in the lake (Figs. 5&6). While during the period of the project, an increasing trend was observed, which coincides with clearing the inlets and increasing the free fishing area after removing a huge quantity of aquatic plants.

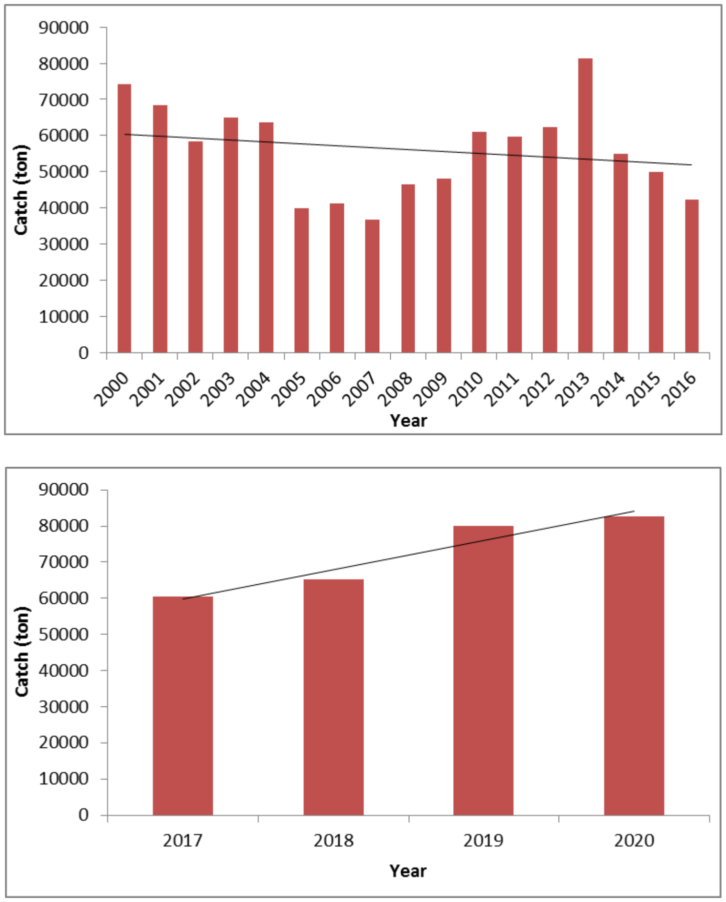

Fig. 5. Annual total catch trend from lake Manzalah before and during the development project

1. Surplus Production Models

The surplus production models were developed to determine the equilibrium or sustainable yield harvested from a fishery for a given level of effort. They provide a first assumption about the fishery and detect the preliminary status of it **(El- Gammal & Mehanna, 1999, 2002; Mehanna & El-Gammal, 2007; Mehanna & Haggag, 2011; Mehanna *et al.*, 2021)**. A large family of surplus production models is now present; however, but they are all similar to the classical models of **Schaefer (1954, 1957)** and **Fox (1970, 1975)**.

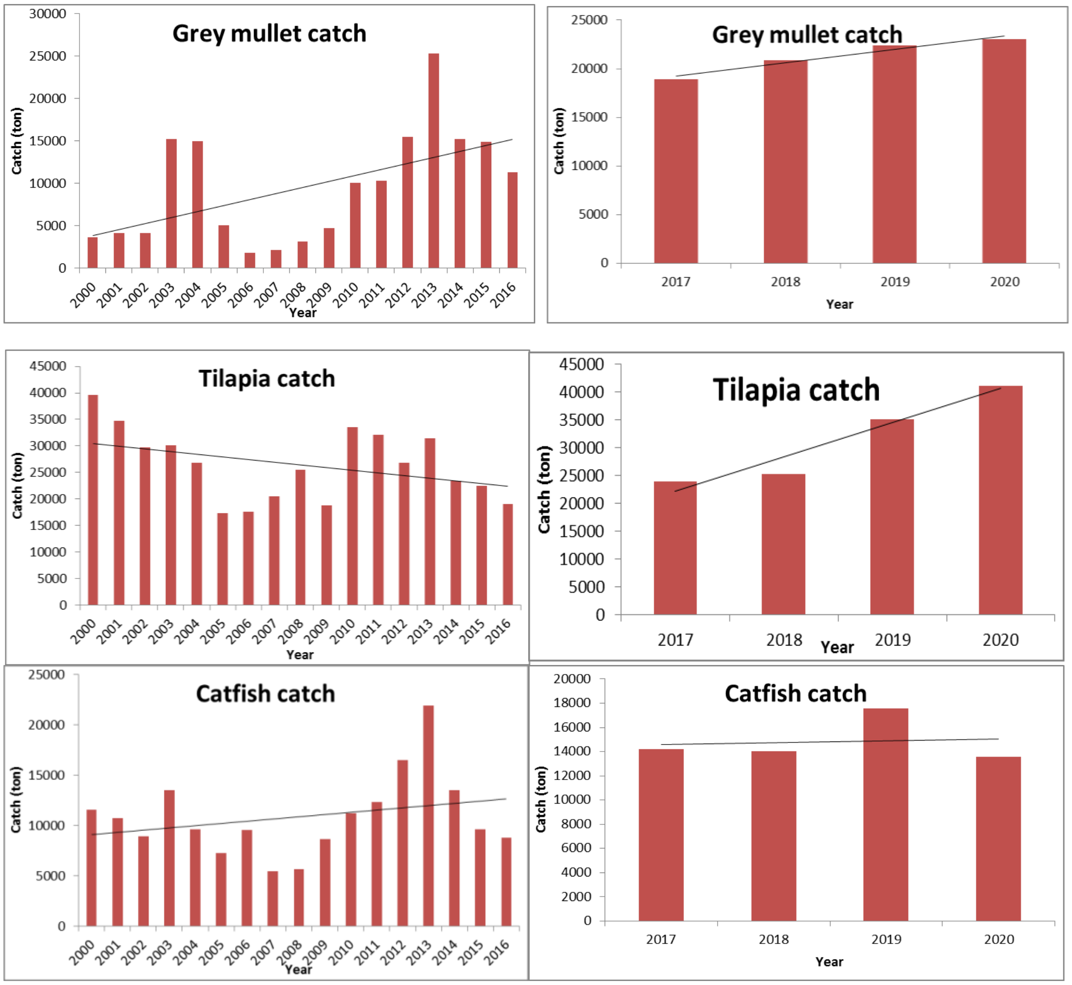

Fig. 6. Catch trend for the commercial species in lake Manzalah before and during the development project

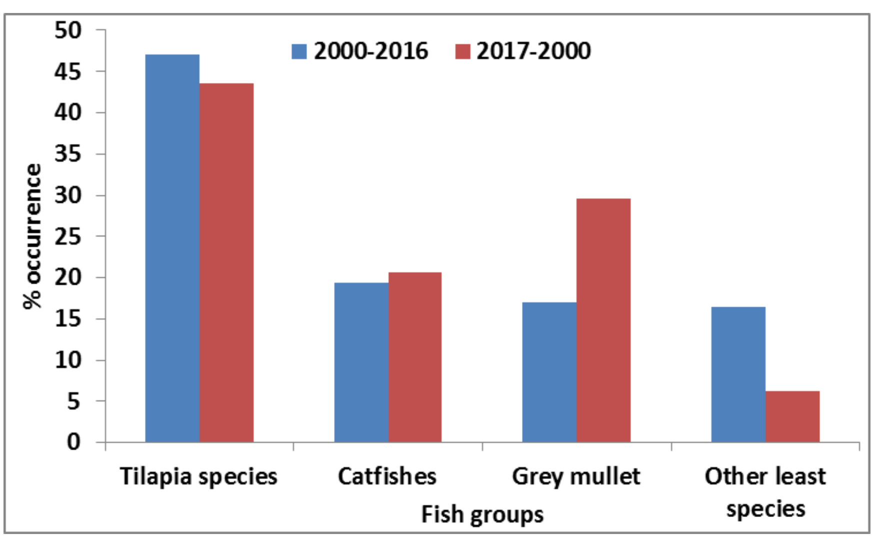

Fig. 7. Common species contribution to the lake production during the two periods of study

In the present study, the logistic model of Schaefer was applied to estimate the optimum level of effort that produces the maximum sustainable yield from lake Manzalah. The total catch and the fishing effort represented by the number of fishing boats were analyzed to give a preliminary evaluation about the status of Manzalah Lake fishery (Fig. 8). The results revealed that, a maximum sustainable yield of 69841.2 ton could be obtained at a fishing effort f_{MSY} of 3630 fishing unit for the period from 2000-2016 (the average catch is 56110.8 ton, and the average effort is 4731 unit). In the period 2017-2020, the average catch was 72057.5 ton at an average effort of 2713 unit. This reduction in the fishing effort is assumed to be associated with an increase in fish abundance index by about 47.6%. It is worth mentioning that, over-fishing is not the only challenge facing the development and management of lake Manzalah fisheries.

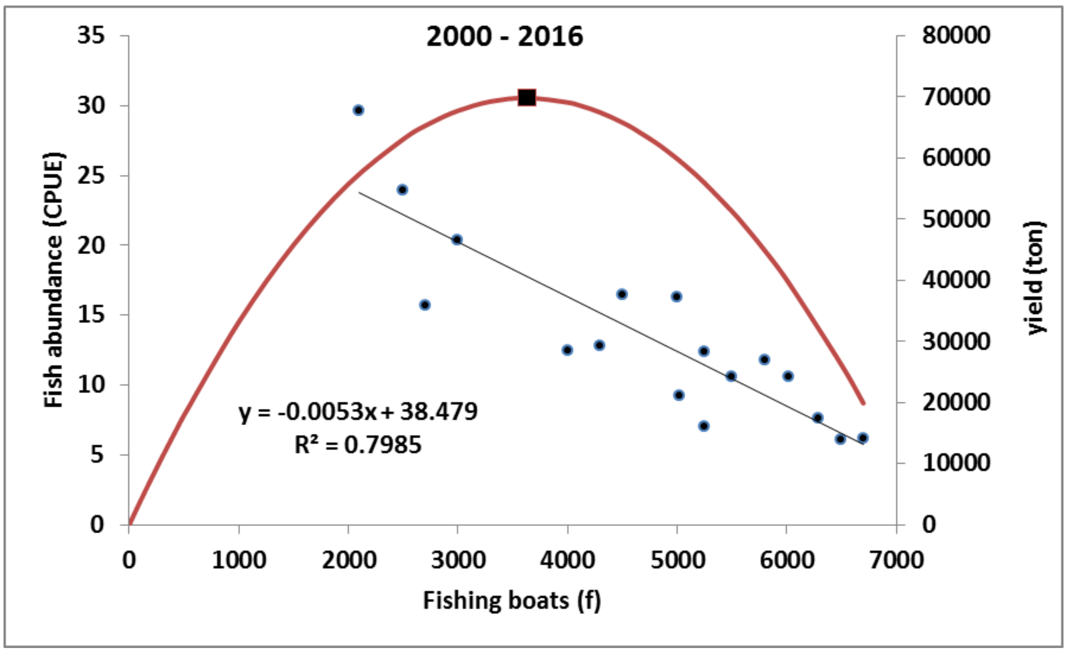

Fig. 8. Maximum sustainable yield and the corresponding fishing effort during the period 2000-2016.

Before the development project (before 2017), the problems facing the sustainable development of lake Manzalah are summarized in the followings: Degradation, filling up and drought which lead to the decrease in the lake area from 750 to less than 100 thousand feddan, pollution by all kinds of pollutants, spread of aquatic plants all over the lake, over-fishing, illegal fishing practices and illegal harvesting of fish fry, in addition to the blockage of Boughazes or inlets. Besides eutrophication where nutrients from the drains have created eutrophic condition in the southern part of the lake. This condition has changed the aquatic biota causing less diverse though high productive system. Finally, the low awareness of fishermen about environmental issues and the importance of fisheries regulation measures were among the problems encountering the lake under investigation. During the development project, some of these challenges were solved such as the removal of aquatic plants to free more area for fishing and cleaning the inlets to allow the exchange of water between the lake and the sea. Despite these great efforts to enhance the fish production from lake Manzalah, still more effective regulations are required, including the study of the biology, dynamics and reproductive cycle of the commercial fishes of the lake. This is an important step in setting the guidelines for fishery regulation measures and for constructing a management policy for the rational exploitation of the lake fish resources. In addition, stocking the lake with sufficient and suitable fish fry species after controlling and optimizing the water quality of the lake is of great importance to meet the afore- mentioned challenges. In addition, the regulation of mesh sizes, controlling gear types used and the prohibition of the destructive ones like trawling should be considered. Besides, a continuous clearance of the inlets and proposing new ones for the exchange of water masses between the lake and the open sea are two other points to be regarded. Futhemore, improving the system for collecting and compiling fisheries statistics by establishing fixed landing points along the lake is also important. Additionally, restoring the natural status of the lake by addressing Bahr El-Bakar drain problem to construct the sewage treatment plant and the construction of marine hatcheries to cover the excessive demand on fish fry and juveniles for aquaculture and prohibition their collection from wild are proposed tools to meet those challenges.

2. *Cost – benefit analysis*

Cost-benefit analysis was used to evaluate the Manzalah lake rehabilitation project since such an analysis can provide useful insights on the potential economic returns from rehabilitation projects.For Manzalah lake, the percentage of increasing the annual fish production from the lake before and during the development project is very low compared to the high cost paid in the cleaning, deepening and removing the aquatic plants. In addition, the est fish production after the cleaning operations that devoured millions of the Egyptian pounds was already achieved before the operations from the lake in 2013. The cost of habitat rehabilitation was very high compared to the economic return from fish production in the lake. It could be reduced if the problem of inlets silting was solved, opening new inlets and solving the problem of polluted fresh water thrown into the lake from the drains.

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