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Status Determination and Optimum Yield of the Most Common Species in Suez Canal Lakes, Egypt

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ABSTRACT

Fisheries are imperative sources of food, employment, trade and revenue in many developed and developing coastal nations. The lakes' fisheries play an important role in Egyptian economy, where they afford about 39% of harvested fish in Egypt (2000-2020). Suez Canal has three lakes; Timsah, Great and little Bitter Lakes. The Suez Canal lakes are considered as a significant fishery resource in Egypt with a mean annual catch of 4403 ton. They harvest high economic species like mullets, cichlids, shrimp, molluscs, crab, striped piggy, seabass, seabream, cuttlefish and rabbitfish. There are about 829 sailing boats operated in Suez Canal Lakes working with several fishing methods; gillnets, trammel nets, crab nets and beach seine. Catch and fishing effort statistics have vital importance for the evaluation of an exploited fish stock status. The catch per unit fishing effort (CPUE) is a good measure of the relative abundance of the exploited stocks. In addition, information about effort and catch per unit effort is essential data for the estimation of Maximum Sustainable Yield (MSY) and the corresponding level of fishing effort (f_{MSY}) by means of surplus production models. The present work was prepared to evaluate the fishery status of Suez Canal lakes and to estimate the maximum sustainable yield for the most common stocks in order to give a detailed information about the fishery status of Suez Canal lakes for maintaining this valuable fish resource, and achieving its sustainable management.

INTRODUCTION

Egyptian lakes (Northern and inland lakes) are very important source of food, employment, and income for Egyptian people. They greatly contribute to the economy of country **(Mehanna, 2008, 2020, 2021)**. Suez Canal is one of the routes for the immigrant animals either from the Red Sea or the Mediterranean, and considered as appropriate environment for these animals to establish. Three lakes were well-known along Suez Canal namely Timsah, Great and little Bitter Lakes (Fig. 1). These lakes are one of the important fish production sources in Egypt, where they yield high marketable fish species like grey mullets, prawns, crabs, molluscs, *Tilapia* spp., *Pomadasys stridens*, *Sparus* *aurata* and *Siganus rivulatus* with mean value of about 4403 ton from 2000 to 2020 **(GAFRD, 2000-2020)**. There are about 829 sailing non-motorized boats (Fig. 2) operated in Suez Canal lakes using numerous fishing techniques; gillnets, trammel nets, shrimp nets, beach dredge, hattata, crab nets and beach seine **(Eid, 2019; Mehanna *et al.*, 2019a&b; GAFRD, 2022; Mehanna *et al.*, 2023)**.

The necessity to implement a Precautionary Approach to fisheries management to avoid severe damage to fish stocks was firmly established by the UN Fish Stock Agreement **(UNFSA; UN, 1995).** This led to a focus on estimating and avoiding Limit Reference Points LRP for spawning stock biomass (SSB) and fishing mortality (F). Following UNFSA, rebuilding already depleted fish stocks and the sustainable management of healthy stocks received emphasis at the World Summit on Sustainable Development (WSSD) in Johannesburg **(UN, 2002)**. The accord calls for actions to "Maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015". The focus thus shifted from avoiding limits under UNFSA to achieving maximum sustainable yield (MSY) targets under WSSD.

The fishery statistics (catch and effort data) are fundamental in the field of fisheries management and fish stock assessment, since it encompasses the basic parameters for the surplus production models that recognized to assess the equilibrium or sustainable yield that may be harvested from a fishery for a definite value of fishing effort **(El-Gammal *et al.*, 1994; ElAzim *et al.*, 2017; Mehanna *et al.*, 2025)**. An accurate estimation of fishing effort is crucial for assessing and managing different fish stocks. The most commonly used technique up-to-date for evaluating the biomass or the relative abundance of the exploited fish stocks is the estimation of the catch per unit effort (CPUE) as an index of relative abundance of fish stocks.

In the present analysis, the surplus production model of **Schaefer (1954)** as incorporated in ASPIC **(Prager, 2005)** was applied to the Suez Canal lakes' fishery to assess the current status of the different common stocks and provide reference points to fishery managers. Although biomass models are not able to account for changes in fishing pattern and do not explicitly represent the age-structured complexity of fish stocks (e.g. variations of natural mortality with age) and reproduction process, they are considered as robust tools to assess the dynamic response of fish populations to exploitation and eventually provide a scientific advice on the state of the stocks **(Ludwig & Walters 1985, Hilborn & Walters 1992, Laloë 1995, Prager 2000)**.

Fig. 1. Timsah and Bitter Lakes

MATERIALS AND METHODS

1. Study area

Timsah Lake (Fig. 1) lies in the middle of Suez Canal between 30° 34' 0.01" N and 32° 16' 59.99" E. It is a small shallow lake with a surface area around 14km^2. The lake's depth ranged between 4 and 13m. Lake Timsah obtains saltwater mostly from the Suez Canal and freshwater from diverse sources comprising the Ismailia Sweet freshwater canal, incompletely treated waste-water through numerous agricultural, industrial, domestic sewage drains like Al-Mahsama, Al-Wadi, Al-Bahtimi, Al-Dabiaia and Alforsan drains **(EEAA, 2010, 2011)**.

The Bitter Lakes are the biggest water bodies along of the Suez Canal (Fig. 1), comprising around 85% of the system's water. The Little and Great Bitter Lakes are hypersaline water bodies located between 30° 13′ 15″ and 30° 24′ 55″ N and 32° 18′ 15″ and 32° 28′ 31″ E. The surface area of Bitter Lakes is around 250km^2, and performing as a buffer for the canal, which reduces the influence of tidal currents **(Mehanna *et al.*,**

2019a&b; Mehanna *et al.*, 2023). The surface area of Great Bitter Lake is around 194km^2, with depths varying between 18 and 28m.

2. **Collection of fishery statistics**

Data regarding the yearly total catch and the catch of the common species as well as the fishing effort of Suez Canal lakes were gotten from the General authority for Fish Resources Development office in Ismailia and from the annual statistical book **(GAFRD, 2000, 2020)**. The gathered data were investigated to calculate the catch per unit of fishing effort (CPUE) which act as a function of stock biomass.

3. **Stock assessment model (ASPIC)**

ASPIC is a computer program allowing estimating the parameters of a non-equilibrium surplus production model from one or more series of catch and effort data **(Prager, 1994 & 2000)**. Initially based on the logistic model **(Schaefer, 1954)**, the most recent version of the program allows for selecting between logistic and generalized production models **(Prager, 2005)**. The fitting procedure includes estimation conditional on observed catch (effort), assuming lognormal observation error in fishing effort rate (catch), i.e. it relies on an observationerror estimator. The parameters were then estimated by minimizing the least squares between predicted and observed efforts, equivalent to maximum likelihood estimation under the assumptions used. The logistic surplus production model of **Schaefer (1954 & 1957)** as realized in ASPIC 5 computer software was used to evaluate the fishery status of different species in Suez Canal lakes. The maximum sustainable yield (MSY) and the optimum level of fishing effort (f_{opt}) were valued based on the formula: $dB_t/dt = rB_t – r/K*B_t^2$, where B_t is the biomass of the stock at time t, K is the carrying capacity of the habitat where the stock lives, and r is the intrinsic rate of growth of the stock. Schaefer's model has K= -a/b, B_{MSY} (the equilibrium biomass for MSY)= K/2, MSY= aK/4, and f_{MSY}= a/2.

RESULTS AND DISCUSSION

1. Catch and effort data

Catch, effort, and catch per unit fishing effort CPUE are crucial inputs for the surplus production models to assess the fishery status of any fish stock. The available fishing effort data in this study were the standardized number of fishing boats which fluctuates from season to another between a minimum of 750 fishing boats during the fishing year 2000 and a maximum of 829 fishing boat during 2020. The boats operating in Suez Canal lakes are wooden small sailing and oaring boats. The fishing boats never exceed 7m in length and have an average width of about 1.8m, with two or three fishermen are working on each boat. Both trammel (three layers nets) and gill nets (one layer nets) were used in different ways.

The catch per unit fishing effort has been comprehensively applied to measure changes in the abundance of fish population. The CPUE gives the first sight about the relative abundance of the different fish stocks and consequently the status of the fishery

(El-Gammal *et al.*, 1994; Mehanna & El-Gammal, 2007a; Mehanna & Haggag, 2010; Mehanna *et al.*, 2019a,b; Mehanna *et al.*, 2023; Mehanna *et al.*, 2025). The total CPUE during the period from 2000 to 2020 (Fig. 2) fluctuated between a maximum value of 7.9 ton / fishing boat during the fishing season 2005 and a minimum value of 2.8 ton / fishing boat during the fishing season 2018 with an average of 5.64. Generally, there is a decreasing trend in the relative abundance CPUE of different fish, molluscan and crustacean species in the lakes.

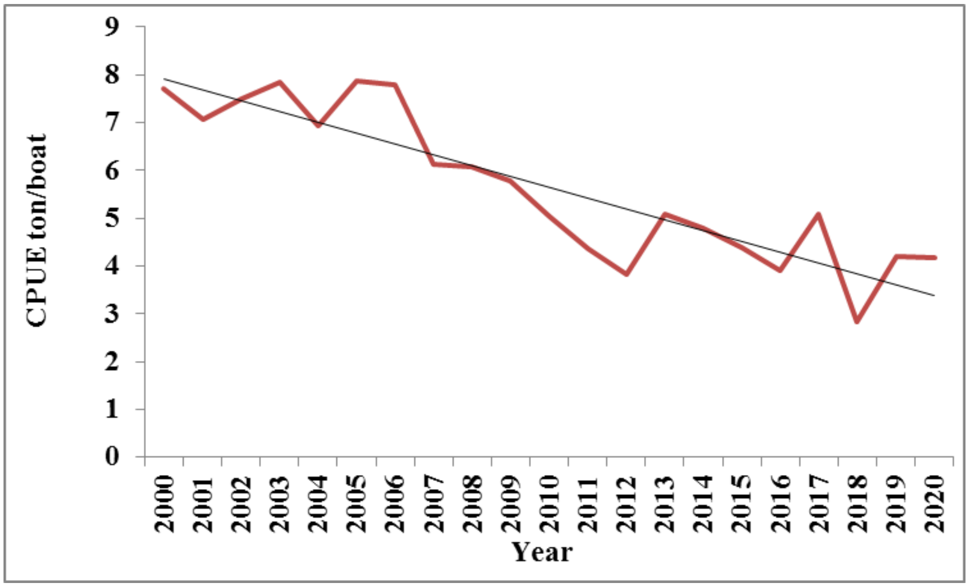


Fig. 2. Catch per unit effort (ton/ boat) for total catch from Suez Canal lakes

On the other hand, CPUE for mullet catch fluctuated between a maximum value of 3.17 ton/fishing boat during the fishing season 2002 to a minimum value of 0.45 ton/ fishing boat during the fishing season 2016 with an average of 1.37 ton/boat.

CPUE for bivalve varied between a maximum value of 2.64 ton / fishing boat during the fishing season 2006 to a minimum value of 1.08 ton / fishing boat during the fishing season 2018 with an average of 1.81ton/boat.

CPUE for crab fluctuated between a maximum value of 1.14 ton / fishing boat during the fishing season 2000 to a minimum value of 0.30 ton / fishing boat during the fishing season 2018 with a mean of 0.68 ton/boat.

CPUE for shrimp varied from a maximum value of 0.72 ton/fishing boat during the fishing season 2001 to a minimum value of 0.15 ton/fishing boat during the fishing season 2018 with an average of 0.40 ton/boat.

CPUE for *Tilapia* species fluctuated between a maximum value of 0.52 ton / fishing boat during the fishing season 2001 to a minimum value of 0.10 ton / fishing boat during the fishing season 2018 with a mean of 0.26 ton/boat.

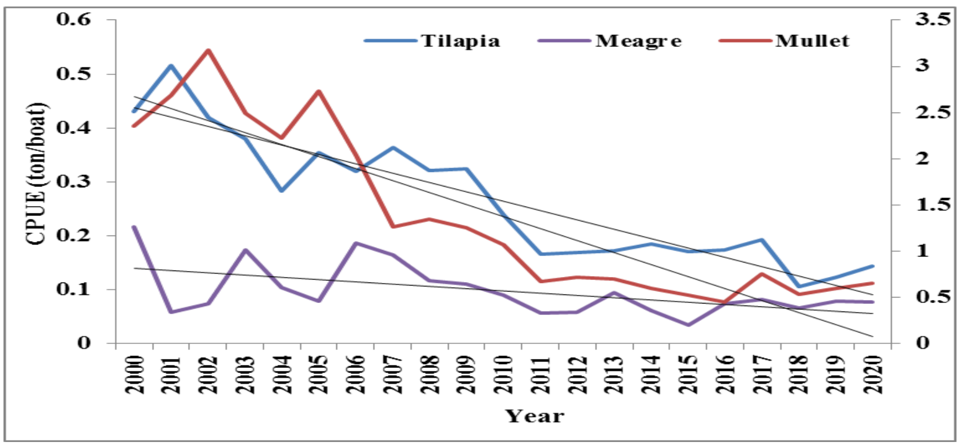
CPUE for cuttlefish fluctuated between a maximum value of 0.33 ton / fishing boat during the fishing season 2000 to a minimum value of 0.10 ton / fishing boat during the fishing season 2018 with a mean of 0.17 ton/boat.

CPUE for striped piggy catch varied between a maximum value of 0.44 ton/fishing boat during the fishing season 2000 to a minimum value of 0.076 ton/fishing boat during the fishing season 2009 with a mean of 0.16 ton/boat.

CPUE for sparid species ranged between a maximum value of 0.39 ton / fishing boat during the fishing season 2000 to a minimum value of 0.04 ton / fishing boat during the fishing season 2018 with a mean of 0.10 ton/boat.

CPUE for meagre catch fluctuated between a maximum value of 0.22 ton / fishing boat during the fishing season 2000 to a minimum value of 0.035 ton / fishing boat during the fishing season 2015 with a mean of 0.10 ton/boat.

The decrease in the values of CPUE for the different common species in the past 20 years indicating the decrease in the relative abundance for the investigated fish populations in the Suez Canal lakes.



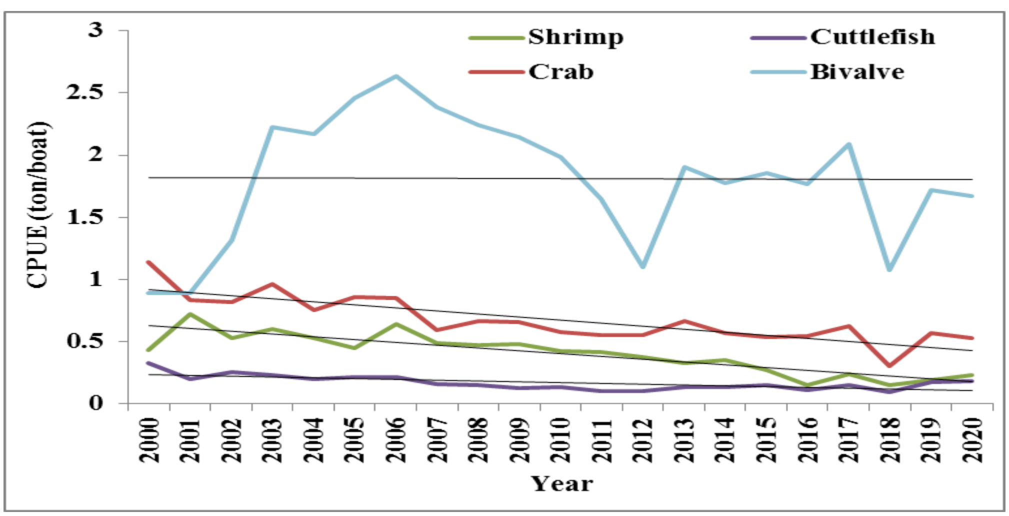


Fig. 3. Catch per unit effort of the common species in Suez Canal lakes during 2000-2020

2. ASPIC

The model fitted to the 2000-2020 time series data of the total production from Suez Canal lakes (Fig. 4). The MSY was estimated to be 8112.5 ton with f_{MSY} at 468 boat which means that the present level of fishing effort (829 boat during 2020) is higher than that produces MSY by about 43.5%.

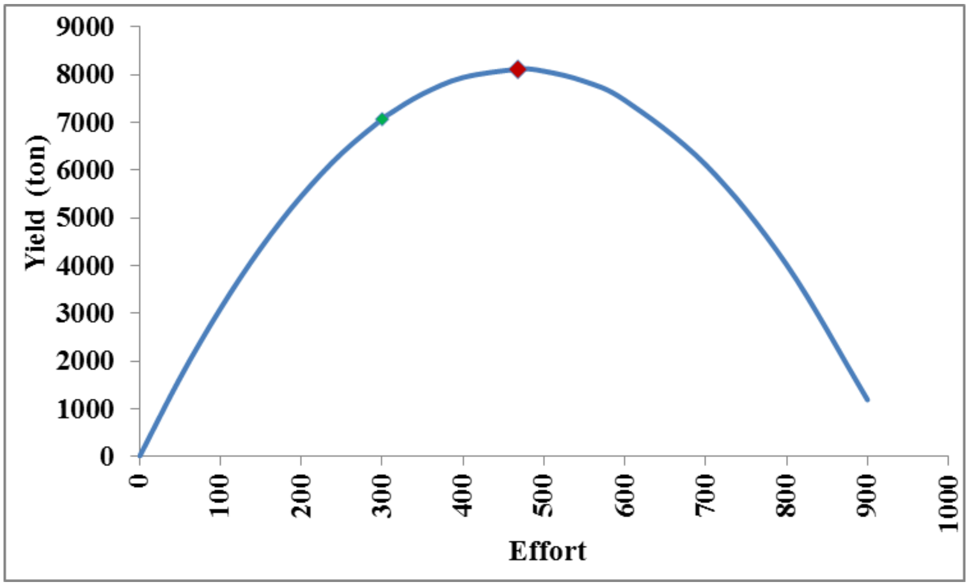


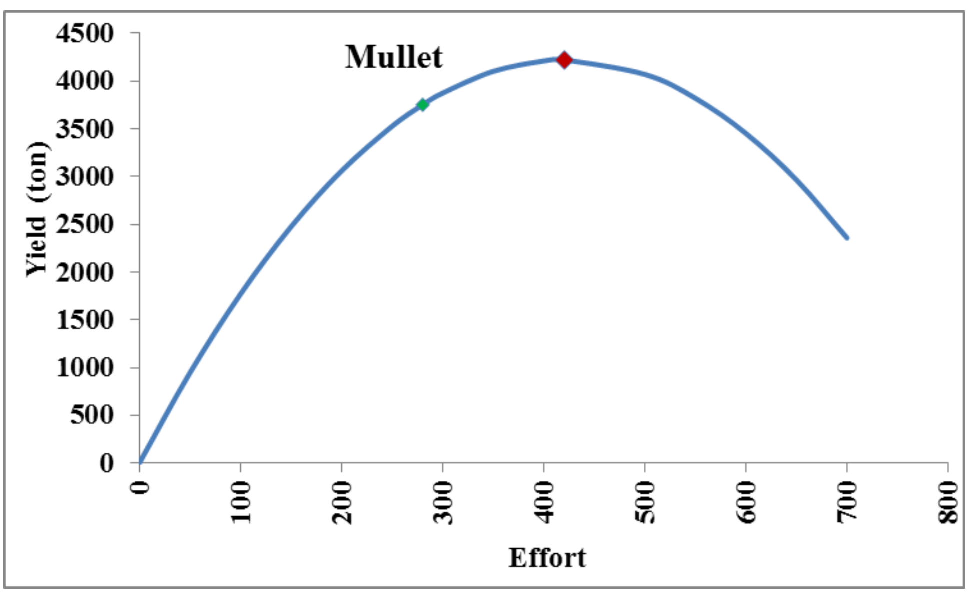
Fig. 4. Yield curve of Suez Canal lakes fishery (Red point= MSY; Green= 2/3f_{MSY})

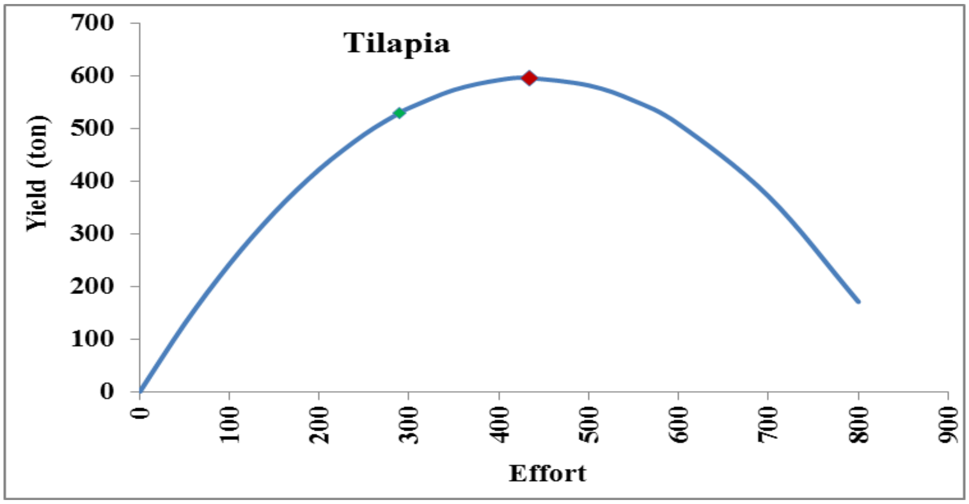
For the common species, a maximum sustainable yield of 4220.29 ton of grey mullet can be obtained at f_{MSY} equal 421 boat. This means that the present level of fishing effort is higher than that produces MSY by about 49.2% (Fig. 5). For tilapia fishery in Suez Canal lakes, a maximum sustainable yield of 596.67 ton can be obtained at f_{MSY} equal 434 boat. This means that the present level of fishing effort should be reduced by about 47.6% (Fig. 5). For striped piggy fishery, a maximum sustainable yield of 307.3 ton can be obtained at f_{MSY} equal 445 boat. This means that the present level of fishing effort should be reduced by about 46.3% (Fig. 5). For meagre fishery, a maximum sustainable yield of 170.64 ton can be obtained at f_{MSY} equal 448 boat. This means that the present level of fishing effort should be reduced by about 45.9% to achieve a maximum sustainable yield of 170.64 ton (Fig. 5) (the current recorded catch was 63 ton in 2020). For sparid fishery, a maximum sustainable yield of 320.92 ton can be obtained at f_{MSY} equal 419 boat. This means that the present level of fishing effort should be reduced by about 49.4% to achieve a maximum sustainable yield of 320.92 ton (Fig. 5) (the current recorded catch was 63 ton in 2020).

For shrimp fishery, a maximum sustainable yield of 764.28 ton can be obtained at f_{MSY} equal 443 boat. This means that the present level of fishing effort should be reduced by about 46.6% (Fig. 5). For cuttlefish fishery, a maximum sustainable yield of 270.8 ton can be obtained at f_{MSY} equal 460 boat. This means that the present level of fishing effort should be reduced by about 44.5% (Fig. 5). For crab fishery, a maximum sustainable yield of 1096.9 ton can be obtained at f_{MSY} equal 455 boat. This means that the present level of fishing effort should be reduced by about 45.1% (Fig. 5).

The target control is more conservative than threshold, and defines a desired rate of fishing and acceptable levels of stock biomass **(Mehanna & El-Gammal, 2007a)**. So, the use of 2/3 f_{MSY} as a target reference point is safer than the use of the limiting or threshold reference point (f_{MSY}). The use of 2/3 f_{MSY} criteria revealed that the present level of fishing effort must be reduced by about 61.9% for total catch, 65.9% for grey mullet, 64.7% for tilapia, 64.0% for shrimp, This reduction in fishing effort will be associated with an increase in the catch by 110.4% for total catch, 594.7% for grey mullet, 349.5% for tilapia catch, 253.8% for shrimp catch, 62.6% for cuttlefish. 126.7% for crab, 84.6% for striped piggy fishery, 140.8% for meager fishery and 448.6% for sparid fishery. From the obtained results, it is clear that all commercial species in Suez Canal lakes are over exploited and to achieve the sustainability of these stocks the fishing effort should be reduced by about 40 to 50%. This could be achieved by reducing the number of fishing hours, number of fishing days, and/or establish an effective closed season. Also, all fishing techniques in Suez Canal lakes should be reviewed and the destructive ones should be prohibited.

The reduction of targeted fish stocks in Suez Canal lakes was observed in a number of studies **(Mehanna 2004, 2005; Mehanna & El-Gammal, 2007b, 2008; Mehanna *et al.*, 2016; Abdel Azim *et al.*, 2017; Eid, 2019; Mehanna *et al.*, 2019a&b; Mehanna *et al.*, 2023; Mehanna *et al.*, 2024)**. Based on the analytical models, the previous studies revealed that the grey mullet fishery, sparid fishery, striped piggy fishery, shrimp fishery and bivalve fishery in Suez Canal lakes are over-exploited and need urgent management regulations to conserve their productivity and to achieve their sustainability. The present study confirmed the fishery over fishing situation of Suez Canal lakes.




Tilapia
Yield (ton)
700
600
500
400
300
200
100
0
0
100
200
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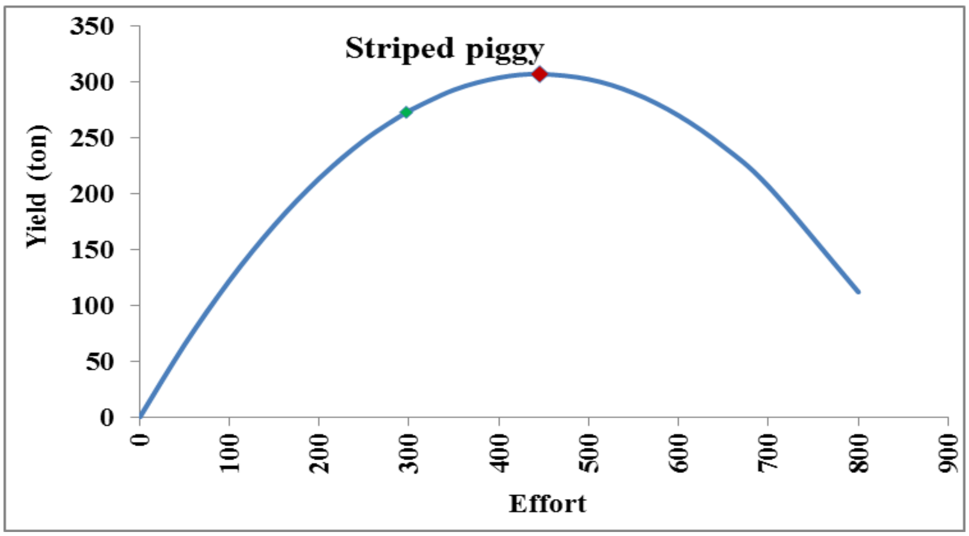
600
700
800
900
Effort


Striped piggy
Yield (ton)
350
300
250
200
150
100
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0
0
100
200
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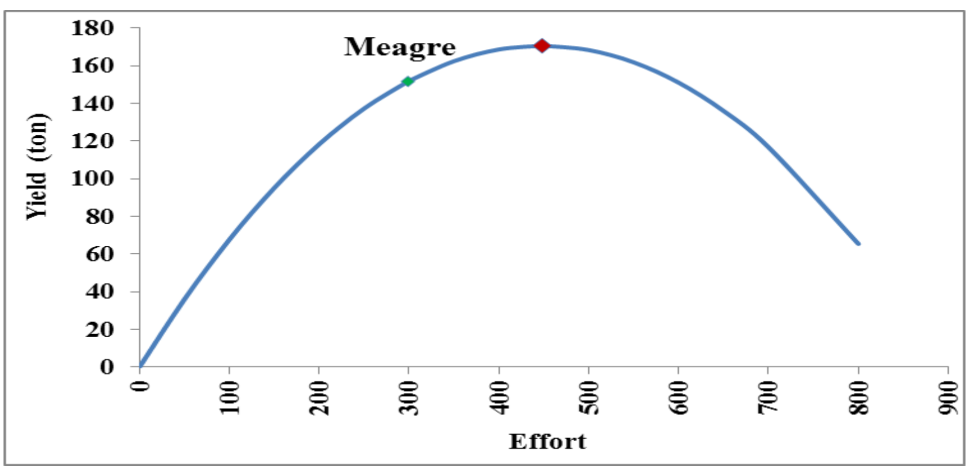
400
500
600
700
800
900
Effort


Meagre
Yield (ton)
180
160
140
120
100
80
60
40
20
0
0
100
200
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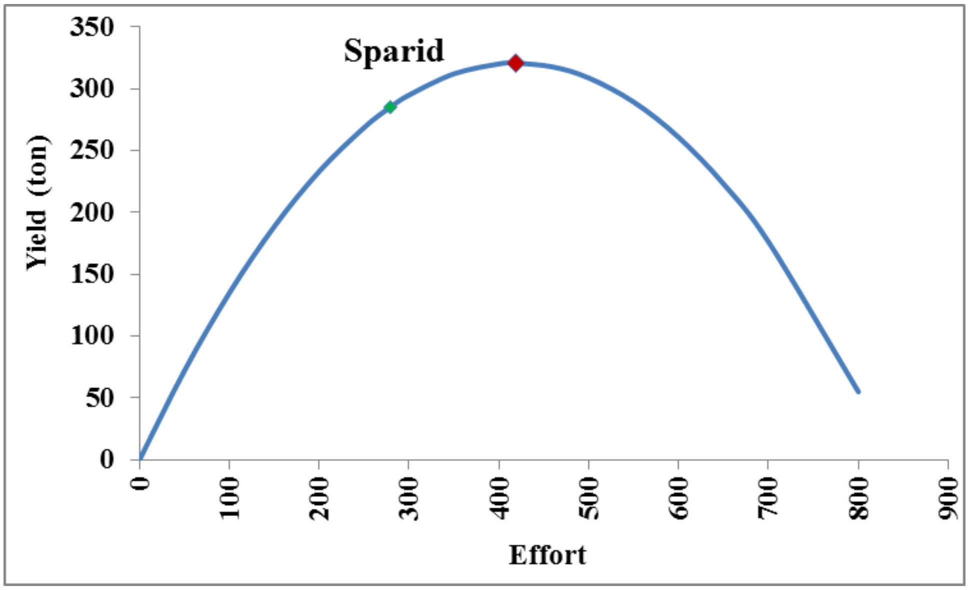
600
700
800
900
Effort


Sparid
Yield (ton)
Effort
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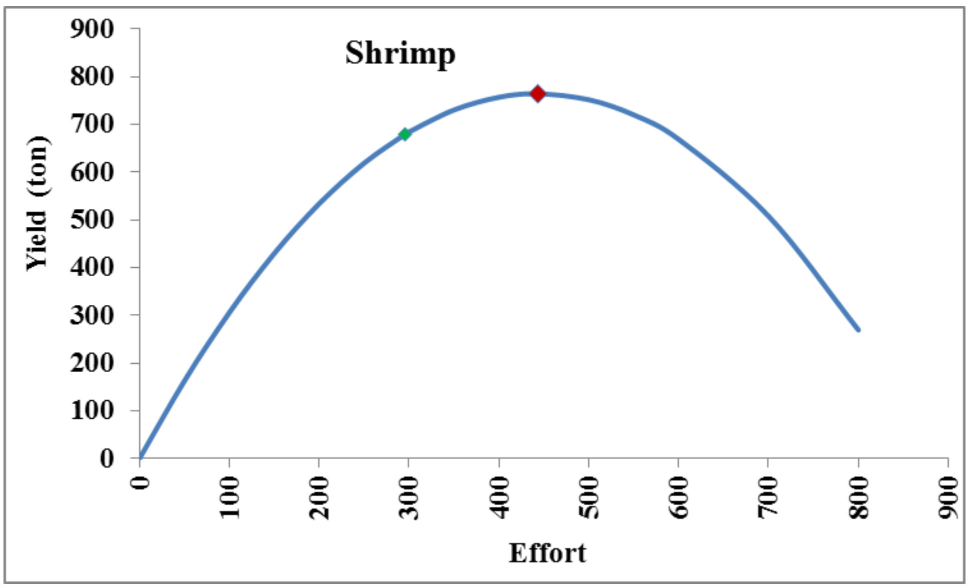
Shrimp
Yield (ton)
Effort
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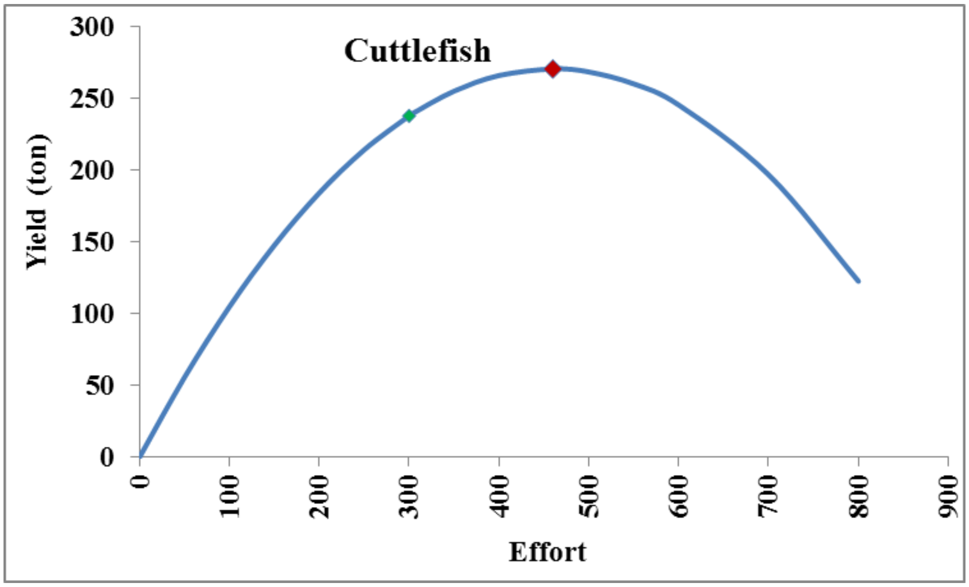

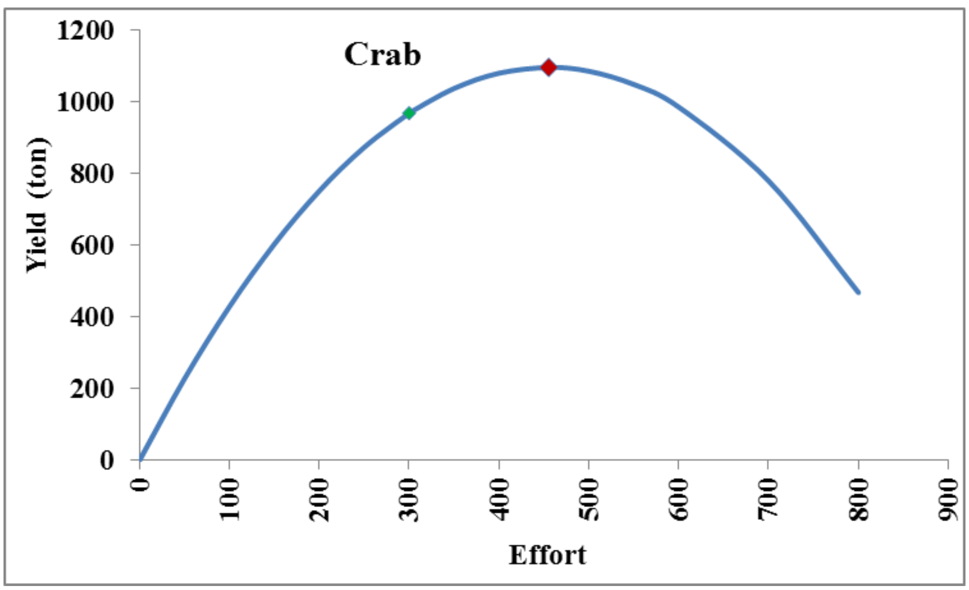

Fig. 5. Surplus production model of commercial species in Suez Canal lakes with the target reference points (Red point= MSY; Green= 2/3f_{MSY})

CONCLUSION

The present study focused on the evaluation of fishery status of Suez Canal lakes fisheries and assessing the different common stocks to estimate the optimum fishing effort which will give the maximum sustainable yield. The obtained results designated an overexploited status for both total and different commercial stocks in the lakes. In general, the common species (Grey mullet, striped piggy, cichlid, meager, sparid species, shrimp, crab and cuttlefish) showed a decline trend in their relative abundance with years.

Also, the majority of catch was composed of small-sized fishes that didn't reach its maturation. So, it could be recommended that the recording system in the lakes should be improved and the catch should be recorded for each lake separately. All fishing gears should be re-evaluated and the illegal and destructive ones should be prohibited. Also, fishing effort in the lakes should be decreased by 40 to 50% of its current value and controlled used the most recent techniques for monitoring like VMS.

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REFERENCES

Abdel-Azim, H. A.; Mehanna, S. F. and Belal, A. A. (2017). Impacts of Water Quality, Fishing Mortality and Food Availability on the Striped Piggy *Pomadasys stridens* Production in Bitter Lakes, Egypt. Ann. Mar. Sci., 1(1): 19-27.

EEAA (Egyptian Environmental Affairs Agency) (2010). Annual Report for the Survey Program of the Egyptian Lakes Lake El-Temsah: 1-10.

EEAA (Egyptian Environmental Affairs Agency) (2011). Annual Report for the Survey Program of the Egyptian Lakes Lake El-Temsah 1-10.

El-Gammal, F. I.; Al-Zahabi, A. S. and Mehanna, S. F. (1994). Preliminary analysis of the status of trawl fishery in the Gulf of Suez, with special reference to shrimp fishery. Bull. Inst. Oceanogr. Fish., ARE, 20 (2): 157-174.

Eid, N. M. (2019). Comparative study on stock assessment of family Mugilidae between Timsah and Bitter lakes, PhD Thesis, Suez Canal University.

GAFRD (2000-2020). Annual statistical report of General Authority for Fish Resources Development GAFRD.

Hilborn, R. and Walters, C. J. (1992). Quantitative fisheries stock assessment: choice, dynamics and uncertainty, Rev. Fish Biol. Fish., 2: 177–178.

Laloë, F. (1995). Should surplus production models be fishery description tools rather than biological models? Aquatic Living Resources, 8: 1-16.

Ludwig, D. and Walters, C. (1985). Are age structured models appropriate for catch-effort data? Canadian Journal of Aquatic and Fisheries Sciences, 46, 1066-1072.

Mehanna, S. F. (2004). Population dynamics of keeled mullet, *Liza carinata* and golden grey mullet *Liza aurata* at Bitter Lakes, Egypt. Egypt. J. Aquat. Res.30 (B): 315–321.

Mehanna, S. F. (2005). Stock assessment of the blue swimmer crab *Portunus pelagicus* (Linnaeus, 1766) at the Bitter Lakes, Suez Canal, Egypt. Egyp. J. Aquat. Biol.& Fish., 9 (3): 187-213.

Mehanna, S. F. (2008). Northern Delta Lakes, Egypt: constraints and challenges. Tropentag 2008, Hohenheim University, Germany, 7 – 9 October, 2008.

Mehanna, S. F. (2020). Challenges faced the small scale fisheries and its sustainable development. ICAR- Central Marine Fisheries Research Institute, Research Centre Mangalore, 7-10 January 2020.

Mehanna, S. F. (2021). Egyptian Marine Fisheries and its sustainability, pp. 111-140. In: Sustainable Fish Production and Processing (Ed. Galanakis, Ch. M.). Academic Press, Elsevier, 325 p.

Mehanna, S. F. (2025). Climate Change Impacts on Egyptian Fisheries and Aquaculture. In: Khalil, M.T., Emam, W.W.M., Negm, A. (eds) Climate Changes Impacts on Aquatic Environment. Earth and Environmental Sciences Library. Springer, Cham. https://doi.org/10.1007/978-3-031-74897-4_6

Mehanna, S. F.; EL-Azim, H. A. and Belal, A. A. (2016). Impact of metal pollution, food availability and excessive fishing on *Rhabdosargus haffara* stock (family: Sparidae) in Timsah Lake. Environ. Sci. Pollut. Res., 23: 15888-15898.

Mehanna, S. F. and El-Gammal, F. I. (2007a). Gulf of Suez fisheries: current status, assessment and management. J. King Abdulaziz University, Mar. Sci.,18: 3-18.

Mehanna, S. F. and El-Gammal. F. I. (2007b). Population characteristics and reproductive dynamics of the thinlip mullet *Liza ramada* (Risso, 1810) at Suez Canal Lakes, Egypt. Egyp. J. Aquat. Biol. Fish., 11 (3): 307-324.

Mehanna, S. F. and El-Gammal, F. I. (2008). Population dynamics and management of white shrimp *Metapenaeus stebbingi* (Penaeidae) at Lake Timsah, Suez Canal, Egypt. Asian Fish Sci, 21 (3): 305-317.

Mehanna, S. F.; El-Sherbeny, A.; El-Mor, M. and Eid, N. (2019a). Comparative study on *Liza ramada* (Risso, 1827) fishery status and management between Suez Canal Lakes, Egypt. Egypt. J. Aquat. Biol. Fish., 23(3): 271-282.

Mehanna, S. F.; El-Sherbeny, A.; El-Mor, M. and Eid, N. (2019b). Age, Growth and Mortality of *Liza carinata* Valenciennes, 1836 (Pisces: Mugilidae) in Bitter Lakes, Suez Canal, Egypt. Egypt. J. Aquat. Biol. Fish., 23(3): 283-290.

Mehanna, S. F.; Eid, A. M. S.; Ali, B. A. and Gad, S. M. (2023). Fishing gears, catch composition and relative abundance of commercial species in Suez Canal lakes, Egypt. Egyptian Journal of Aquatic Biology & Fisheries, 27(5): 197 – 211.

Mehanna, S. F.; Eid, A. M. S.; Ali, B. A. and Abdel-Baky, W. (2025). Present fishery status of the most common species in Bardawil lagoon, Egypt based on maximum sustainable yield estimation. Egyptian Journal of Aquatic Biology & Fisheries, 29(2): 2161 – 2178.

Mehanna, S. F. and Haggag, H. M. (2010). Port Said Fisheries: current status, assessment and management. 3rd International conference on Fisheries and Aquaculture, 29 November-1December, Cairo, Egypt. www.cabdirect.com.

Mehanna, S. F.; Nasr, R. A. and Magdy, S. M. (2024). Impacts of Water Quality, Excessive Fishing Effort and Sediment Composition on Some Edible Bivalves in Suez Canal Lakes, Egypt. Egyptian Journal of Aquatic Biology & Fisheries, 28(4): 515 – 528.

Prager, M. (1994). A suite of extensions to a nonequilibrium surplus-production model. Fisheries Bulletin, 92: 374-389.

Prager, M. (2000). User's manual for ASPIC: A stock-production model incorporating covariates. Program version 3.82, Miami Laboratory document (5 ed., p. 32p). Miami, USA.

Prager, M. (2004). User's manual for ASPIC: A stock production model incorporating covariates (ver. 5) and auxiliary programs. Beaufort Laboratory Document. Miami, USA.

Prager, M. (2005). Users manual for ASPIC: a stock-production model incorporating covariates (ver. 5) and auxillary programs. Beaufort Lab. Doc., No. BL-2004-01.

Schaefer, M. B. (1954). Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Inter-Am Trop. Tuna Comm. Bull., 1 (2): 23–56.

Schaefer, M. B. (1957). A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bull I-ATTC/Bol CIAT2: 247–268.

UN. (1995). Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. http://www.un.org/depts/los/convention_agreements/texts/fish_stocks_ agreement/ CONF164_37.htm

UN. (2002). Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August–4 September. Chapter I. Resolutions adopted by the Summit. 2. Plan of Johannesburg Plan of Implementation of the World Summit on Sustainable Development, IV. Protecting and managing the natural resource base of economic and social development, Paragraph 31. https://selectra.co.uk/ sites/selectra.co.uk/files/pdf/WSSD_PlanImpl.pdf