Journal of Sustainable Development in Social and Environmental Sciences
http://jsdses .journals.ekb.eg/

P-ISSN: 2812-6335 E-ISSN:2812-6343

The Sustainable Development of Fish Resources in Lake Bardawil, North Sinai Governorate Using Geographic Information Systems: A Study in Economic Geography

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doi: 10.21608/jsdses.2023.200387.1014

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ABSTRACT

Lake Bardawil is one of the purest Egyptian fish lakes. It is famous for its production of the finest types of luxury fish such as gilthead bream, basses, and soles which are internationally ordered. The lake's production of luxury fish was about 1592 tons in 2020; i.e., 0.7% of the total fish production from Egyptian lakes. Investigating the development of fish production of the lake showed apparent fluctuation in the quantities produced during 2011-2020: the production reached its peak in 2011, scoring about 4529 tons; then it decreased continually to reach its lowest score (1592 tons) in 2020, at a rate of change by 64.8%. Studying the lake's fish classification showed that gilthead bream ranked first in terms of production by 30.6% of the total production of the lake in 2020, while soles ranked last coming by 4%. In order to achieve the sustainable development of the lake's fish resources, the study addressed some underlying problems and obstacles that could be controlled and resolved. The study recommends the periodical cleanliness of the lake's straits to maintain its ecological balance, and the ban on illegal fishing practices which adversely affect both the aquatic environment at the bottom of the lake and, in turn, the biological stock of fish.

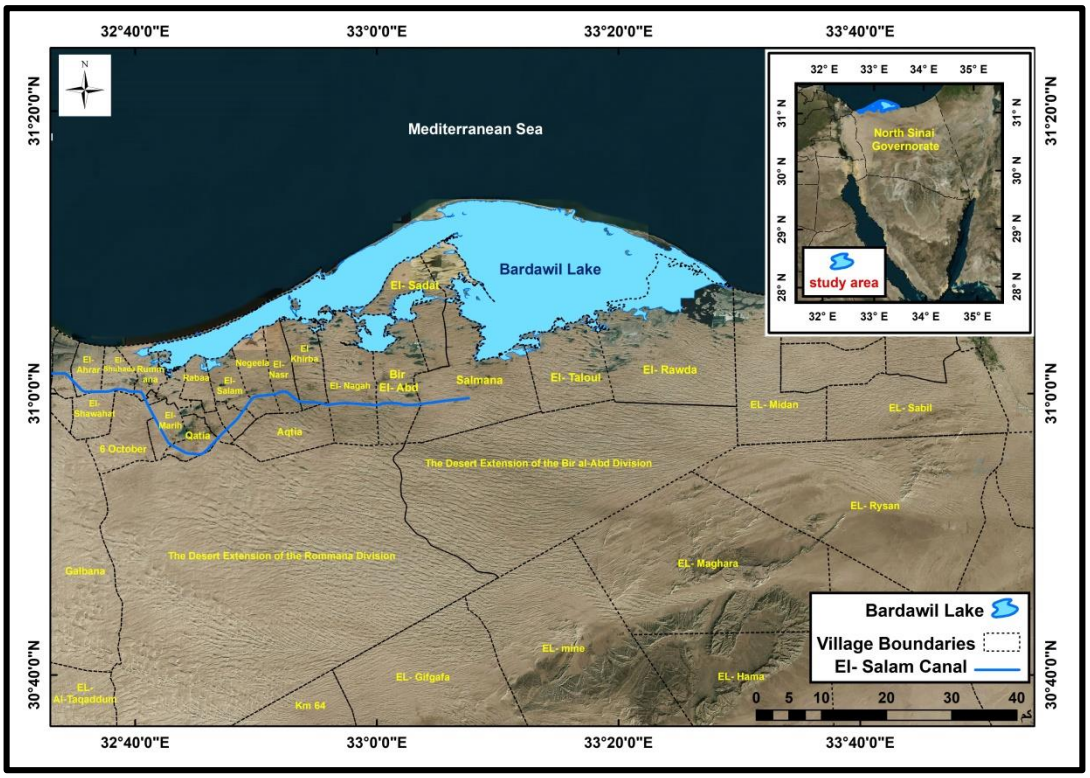
Keywords: Sustainable development, fish resources, Lake Bardawil, economic geography, geographic information systems, North Sinai Governorate.

Introduction

Sustainable development is ecologically defined as the protection of natural resources from human practices; avoiding the overuse of fertilizers and pesticides that pollute surface-, ground-, lake-water; and the overexploitation of fisheries at unsustainable levels **(Mohamed et al., 2015, p. 349).** The sector of fish resources in Egypt is of great significance concerning food security and economic and social development. Besides, fish resources represent the ideal solution to fill the food gap and the individual's need for animal protein **(Kuwaylah, 2017, p.125).** It is also the animal sector that has the utmost great potential for sustainable development, which is commensurate with the development of Lake Bardawil, the second largest Egyptian lake after

Lake Al-Manzla: measuring about 160 thousand acres, and representing about 1.2% of the total Egyptian fish resources and about 8.5% of the total area of the Egyptian lakes **(Al-Shahid, 2021, p. 559).** In order to achieve sustainable development, the main goal of developing fish resources lies in doubling fish production and maintaining the increase of the average per capita consumption of fish.

- **Location of the study area:** The study area is located in North Sinai Governorate between two latitudes: 31° and 31° 15′ North, and between two longitudes 32° 40′ and 33° 30′ East. It is boarded by the village of Al-Midan on the east, the village of Baluza on the west, the road of Qantara/Al-Arish on the south, and the Mediterranean Sea coast on the north. The lake is 641.8 km^2, representing 2.3% of the area of Sinai Governorate which is 27.8 thousand km^2, As shown in Figure (1).



Source: Digital maps of North Sinai Governorate, scale 1:50000, 2008, Central Agency for Public Mobilization and Statistics, 2017, GIS unit, unpublished data, visible satellite, SAS Planet nightly 2022 using Arc GIS 10.5.

Figure 1: study area – Lake Bardawil in North Sinai Governorate

- **The objectives of the study**: The study aims at identifying the problems of fish resources in relevance to fish production, from which Lake Bardawil suffers; the classification of the lake's fish in relation to species' contribution to fish production; and the plans or steps for developing fish resources and achieving sustainable development in this vital sector.

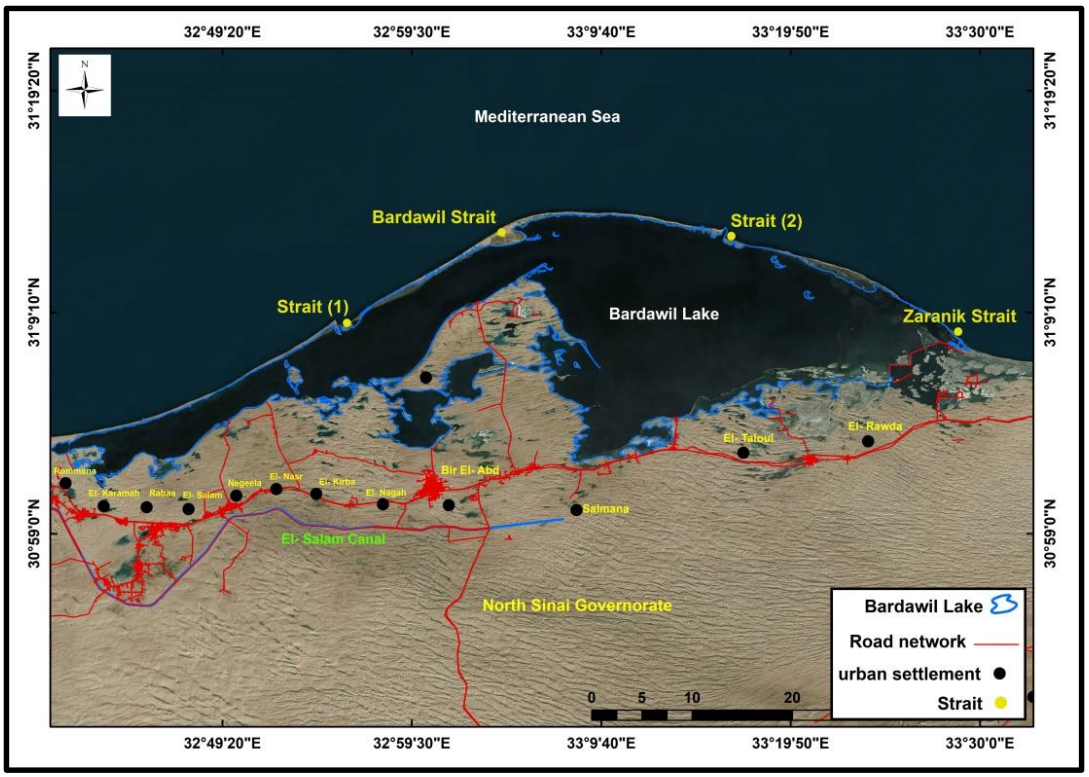
The study investigated the development of fish production in Lake Bardawil in North Sinai Governorate, the classification of fish production in the lake, and the main obstacles facing fish farming in the lake as follows:

First: The development of fish production in Lake Bardawil

Lake Bardawil is one of the most important Egyptian lakes in the production of luxury fish.

However, its productivity of fish caught was about 2.8 thousand tons; i.e., representing about 0.4% of the total Egyptian fish production during the period 200-2018; and the productivity of acres was about 17.5 kg of fish **(Ibrahim, 2009, p.5)**. This very low productivity was an indicator of a decline in fish stocks within the lake. Such decline in production was due to the spread of overfishing; the silting of straits without being cleaned for a long time; and the administrative decisions which harmed fish stocks and innovated new crafts leading to catching high quantities of the seed mothers of luxury fish such as gilthead bream and basses, and depleting fish stocks for luxury species.

Lake Bardawil is a high-salinity shallow lake. Its depth ranges from less than one meter to more than six meters. It is separated from the Mediterranean Sea by a sandbar. The length of the lake from east to west is 41 km and its width from north to south is 73 km. The lake has an eastern sound known as Lake Zarangik which is 60 km long and around 3 km wide **(Mahsoub, 1989, p.60)**. Figure (2) shows that the lake is separated from the Mediterranean Sea by a sound ranging in its width from 8.1km west to only several meters east, and it is connected to the sea through several natural straits which are: Abu Hussein, Jibral Al-Salal, Al-Zaranique, and two industrial straits - excavated in 1955- called: Bougaz (1) [“Bougaz” is the Arabic word for “strait” in English] which is located on the west of the village of Mohammadiya by about 40 km, being of 1350 meters long, 110 meters wide, and 4 meters deep; and Bougaz (2) which is located in front of the village of Al-Tamol, being of 1240 meters long, 165 meters wide, and 5 meters deep **(Al-Sabai, 2010, pp. 106-116).**



Source: Digital maps of North Sinai Governorate, scale 1:50000, 2008, Central Agency for Public Mobilization and Statistics, 2017, GIS unit, unpublished data, visible satellite, SAS Planet nightly 2022 using Arc GIS 10.5.

Figure 2: straits in Lake Bardawil, North Sinai Governorate, 2023

Lake Bardawil is one of the most important sources of fish resources in Egypt in general and in Sinai in particular. It is characterized by the high fertility of fish and the wide variety of fish species with high nutritional and economic value such as shrimps, crabs, corals and mullets family

fish, soles, gilthead bream, and basses. It includes the fishing areas of Bir al-Abed and al-Arish in North Sinai. Besides, it is famous for its production of salt, ranking third in Egypt's production of salt by 16.6% in 2017 **(Al-Tamami, 2021, p. 437)**. Also, this is an activity contributing to the economic development of the North Sinai Governorate in addition to fish production.

The development of fish production in Lake Bardawil during the period 2010-2020 is addressed. The following table (1) and chart figure (3) show that:

The total natural fisheries were 418683 tons in 2020. The total quantity of fish production from Egyptian lakes (according to a classification by the source) was 237758 tons in 2020; i.e., representing a percentage of 56.8% of the total Egyptian natural fisheries, of which Lake Bardawil scored about 1592 tons in 2020; i.e., 0.7% of the total fish production of Egyptian lakes **(General Authority for Fish Resources Development, 2020, p. 18).**

Table (1) production development of Lake Bardawil in North Sinai Governorate during 2011-2020 in terms of "ton".

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quantity	4529	3844	3237	2758	4704	4093	3050	2610	3215	1592
Rate of Change %	-	-15.1	-15.8	-14.8	70.5	-12.9	-25.5	-14.4	23.2	-50.5

Source: prepared by the researcher, based on data from General Authority for Fish Resources Development, unpublished data, 2011-2020.

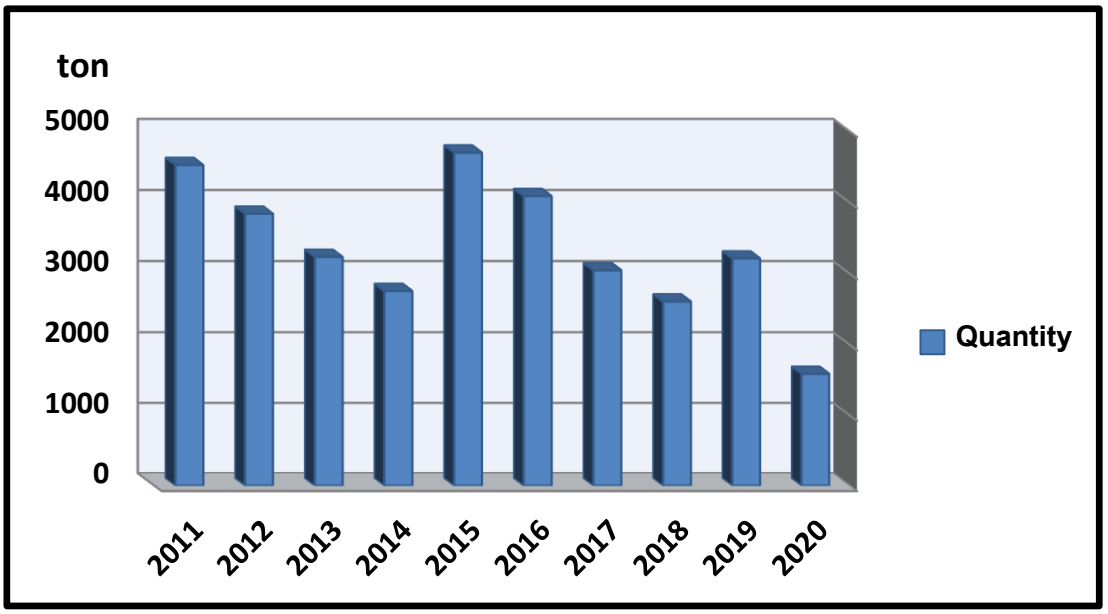


Figure 3: development of fish production from Lake Bardawil in North Sinai Governorate during the period 2011-2020

As shown in table (1) and figure (3), there was a continual decline in the quantities of fish produced in 2011. This decline continued till 2014, reaching 2758 tons by a declining percentage of 39.1%, compared to the production rate in 2011. Then, the production increased to reach its peak, scoring 4704 tons in 2015 by an increasing percentage of 70.5%, compared to

2014's. Afterwards, it was gradually declining during the period 2016-2020 till it reached its lowest rate, scoring 1592 tons in 2020 by a declining percentage of 50.5%, compared to 2019's. The cause of this decline in production was due to the cutting down of the fishing season for only two months as a result of the security procedures, which affected the quantities of fish production from Lake Baedawil **(General Authority for Fish Resources Development, 2020, p.3).**

Fish production from Lake Bardawil is one of the development hubs in North Sinai. It positively contributes to the production of high-quality fish with international standards to cover the deficit in the country's animal protein. It also has a significant economic impact on North Sinai's overall development, the most important of which are the agricultural and animal development: consisting of 114 thousand acres of agricultural reclamation areas located south of Lake Bardawil and irrigated by the waters of El0Salam canal. The matter which has led to the establishment of several agricultural manufacturing projects, including the drying and packaging of fish. Moreover, fish production from Lake Bardawil is one of the vital protein sources for residents of North Sinai governorate and other neighboring governorates. As for the industrial development, the lake's fish production is an essential ingredient for the construction of industries dependent on fish production. This is thanks to the existence of the industrial zone under construction at A- Abed well; therefore, there would be an expansion in the establishment of factories of fish sorting, packaging, cooling and freezing in order to maintain fish conservation at the Al-Abed well industrial area. Also, fish production from Lake Bardawil plays a major role in foreign trade since a portion of fish produced from the lake is exported to the European Union's external market. This contributes to the rise of the State's national returns and the provision of hard currency and employment opportunities for fishermen and their families in North Sinai governorate, where about 5,000 fishermen are working in the lake with no other source of income but fishing.

Second: Classification of fish production in Lake Bardawil

Lake Bardawil is an important area for development in North Sinai because of its various resources for development and its pollution-free area **(Amany R., 2018, p.1194)**. it represents a marine environment that is free of pollution: with no agriculture sewage or drainage channels ending up or leading to the lake. Therefore, its production has a universal reputation in overseas markets, especially from gilthead bream and basses. Moreover, it is a natural breeding of sea fish with high commercial and economic values. This classification reflects the ecological balance in Lake Bardawil, as this balance is greatly related to the water interchange between the sea and the lake through straits **(General Authority for Fish Resources Development, 2019, p.25).** The following table shows the classification of fish in Lake Bardawil.

Table (2) and figure (4) declare the production of Lake Bardawil is mostly of sea species since they are fed through the seawater directly by Al Zaranique Bougaz and Bougaz (1); the lake is as well free of Nile fish because of its distance away from Nile Delta.

Table (2) classification of fish in Lake Bardawil according to the produced quantities (by the ton) in 2020.

Species	Crustaceans		Mullets family fish	Gilthead Bream	Soles	Basses	Jewfish	Non-classified fish	Total
	Crabs	Shrimps							
Quantity	448	16	359	487	63	79	8	130	1592
%	28.1	1.01	22.6	30.6	4	4.9	0.5	8.2	100

Source: prepared by the researcher, based on data from General Authority for Fish Resources Development, fish production quantities, 2020.

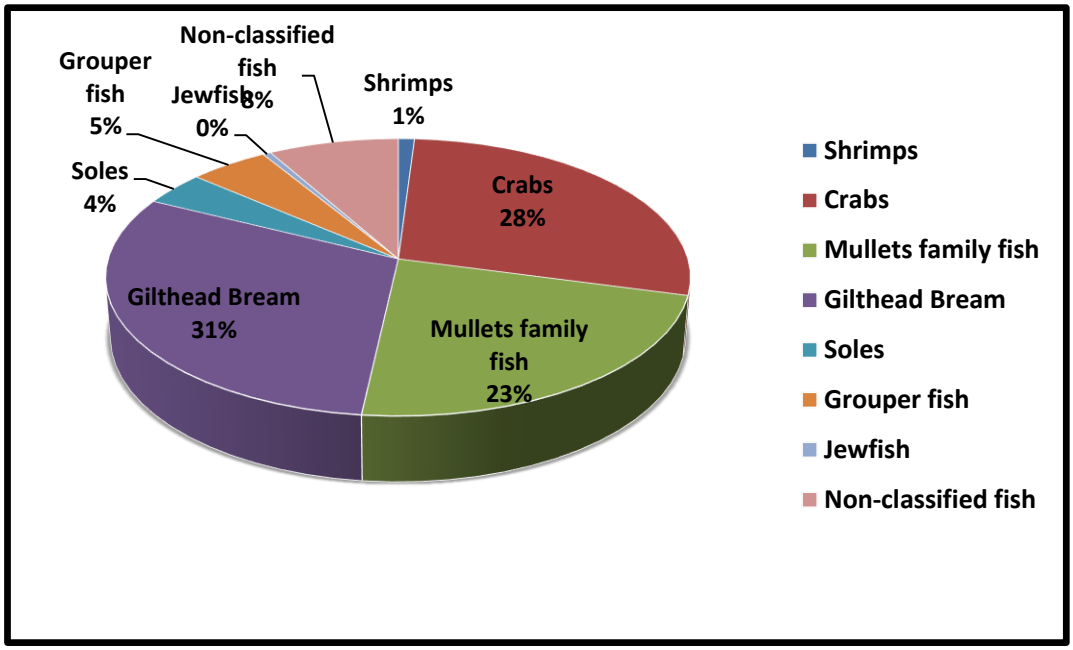


Figure 4: fish production distribution in Lake Bardawil in 2020

- **Gilthead Bream** (or Sea Bream) ranked first in the fish classification of Lake Bardawil, scoring 487 tons; i.e., by 30.6% of the total production of the lake. Bream represented the most prominent sea species of commercial and economic value. These increased quantities reassured the importance of Lake Bardawil in bream production thanks to the lake's low salinity. This degree of salinity positively affects the growth of seagrass on which bream feed and without which they lose the suitable environment for their existence in the lake.
- **Crustaceans** (Crabs and Shrimps) ranked second in production: crabs' score was 448 tons; i.e., 28.1%, and shrimps' score was 16 tons; i.e., 1.01% of the total production of the lake. This high production of crustaceans was because of the existence of a suitable environment where they inhabited the entrances of Zaranique Bougaz. In spite of such high production, crabs are of low commercial and economic value due to their little-flesh nature and the difficulty encountered while catching them.
- **Mullets family fish** ranked third, scoring 359 tons; i.e., by 22.6% of the total production of the lake in 2020. This was because of the suitability of its water properties in terms of temperature and salinity: Mullets could live in varying degrees of salinity, provided of being not less than 30 parts per thousand. Furthermore, the lake was considered a refuge for fry mullets to live in thanks to the availability of nutrition and calmer water than that of the Mediterranean Sea **(Hassanien, 1995, p. 53)**. Besides, mullets are fish of great adaptation to living in various ranges of salinity.
- **Non-classified fish** such as S. Rivulatus (Rabbitfish), Bogue, Spotted Seabass, and Sea Snake ranked fourth, scoring about 130 tons; i.e., by 8.2% of the lake's total production. These species are seasonal and under the influence of the supply and demand of buyers **(General Authority for Fish Resources Development, 2019, p. 30).**
- **Basses** ranked low productivity, scoring 79 tons; i.e., by 49% of the lake's total production. They generally preferred to live in straits. Yet the continual silting in straits and uncleanliness had consequently resulted in the escape of these species from the lake.
- Eventually, **Soles**' production scored 63 tons; i.e., by 4% of the lake's total production. Therefore, they ranked last in spite of their high nutritional value **(Fahmy, 2017, p.190).**

Third: Main obstacles confronting fish farming in Lake Bardawil

Investigating the development of Fish production in Lake Bardawil clarifies both its fluctuation in terms of quantities in spite of the increasing numbers of fishing boats in the lake: being around 1094 boats in 2000 and reaching around 1228 ones in 2019 **(Younis et al.,2000,p.72)**, and its changed ranks in the classification. The current study aims at investigating the problems and obstacles confronting fish production in Lake Bardawil, and providing suggested mechanisms to achieve sustainable development of fish resources in the lake.

Sustainable development seeks to maintain a balance among economic systems without depleting natural resources, putting into consideration ecological security and natural resource preservation for future generations. Thus, the environment should be highly considered since it is the base of development. Yet, any depletion of natural human resources which are essential for every agricultural, animal, and industrial activity could have harmful effects on development in general **(Mohamed et al., 2015, p. 338)**. The state seeks to duplicate fish production towards around 2 million tons as a target of sustainable agricultural development strategies in 2030 and to maintain the increasing average per capita consumption of fish to more than 18 kilograms per individual **(Bassuony et al., 2020, p.210)**.

There are a number of highly challenging problems against fishing in Lake Bardawil on the ecological, commercial, productive, and healthful levels. They adversely affect fish productivity, which in turn harms the total fish production in the lake. The most outstanding problems are as follows:

1. **Ecological problems:** the most prominent problems facing fishermen in Lake Bardawil are the widespread solid wastes like iron, old ships, and tires at the bottom of the lake; the widespread spinal snails and sea turtles; and the existence of fixed light. Investigating the relative significance of these elements shows that the widespread spinal snails and sea turtles rank first, scoring about 70,59% of the total problems facing the study sample of fishermen in 2019 **(Younis et al., 2020, p. 1024).**

2. **Production problems:** They are represented in fishing during daylight hours, which typically reduces production; the uncleanliness of straits and their silting; the insufficiency of workers in number; the increasing prices of fishing supplies; the high costs of gas and oil; the variety of increased-value fees for fishing, entrance permission, and production; the widespread existence of illegal fishing nets and motors; the widespread practices of illegal fishing; and the short time allowed for fishing by the administration. The most prominent problem of these problems is that of straits' silting, which can be addressed as follows:

- The straits' silting problem:

The straits or "openings" are one of the sources of supplying the lake with fry fish which feed and grow in lakes with other species of freshwater fish **(Hashim, 2015, p. 17)**. The phenomenon of silting inside the two straits of the lake; i.e., Bougaz (1) and (2), adversely affects the lake's fish resources. When a layer of silt is formed inside the strait, the connection between the sea and the lake is weakened. As this formed silting accumulates, it consequently reduces the efficiency of straits: the lack of periodical cleanliness processes results in decreasing the seawater flow and increasing the freshness of the lake water. Therefore, sea fish production is restricted to the areas next to the lake's straits **(Maiyza Sh., 2019, p. 189)**. Thus, certain necessary procedures should be followed for the protection and cleanliness of these straits from silting sediment and grass to let the lake renew its water, preserve its salinity percentage, and maintain its suitable quantities of fry fish which keep the ecological balance and continual fish supply within the lake.

3. **Health problems:** the lake's fishermen suffer from a number of problems such as the reoccurrence of getting or catching a cold, sunstroke, and seasickness; the non-obtaining of health insurance; and the lack of centers for health care; which all adversely affect the productivity.

4. **Commercial problems:** the most significant commercial problems adversely affecting the lake's fishermen are the lack of freezers in every berth to preserve and store fish; the over-controlling of the representative in selling-and-buying processes, prices, and monopolies of merchants; the lack of auctions of demand and supply; and the lack of free markets in every berth.

Additionally**, there are some other problems** that threaten the lake, such as:

- **The widespread bowls and aquatic plants**: this problem leads to the stagnation of water and the changing of its properties and features in a way resulting in the lake's pollution which adversely affects the fish reproduction, their death in great numbers, the prevention of water arrival to the lake's boundaries, the drought of beaches' areas to which fish mothers seek for reproduction, the difficult movement for fishing boats and for environment and landscapes police patrols, and the rising of the lake's floor level due to the silting resulting from the existence of great quantities of bowls and other aquatic plants.
- **The problem of immigrant birds' arrival**: the lake suffers from the arrival of huge numbers of immigrant birds flocking to it from cold areas during the winter, reaching more than 20.000 birds annually, the matter which leads to huge fish loss **(said, 2004, p. 257).**
- **Illegal fishing methods:** the lack of awareness of fishing methods – which could harm the fish stock- leads to the widespread existence of violations such as coastal bulldozer practices whose usage is illegal and unpermitted, leading to the depletion of the lake's fish resources and, in turn, the reduction of its fish production.

Sustainable development works on achieving the best use and exploitation of resources as it considers resources to be limited. Therefore, it precludes their waste or destruction and works on its appropriate usage, reducing risks and ecological effects to achieve balance through which economic development can be achieved (Mohammad et al., 2015, p. 343). In order to achieve sustainable development for fish resources in Lake Bardawil, **there are solutions and suggestions to be adopted as follows**:

1. The lake's administration and the state should care for eliminating any waste from the lake as well as carrying out continual cleanliness processes to get rid of the accumulated silt and to maintain a suitable depth for fishing.

2. The necessity of activating the role of cooperative associations towards the lake's fishermen to overcome the high-price problem of fishing tools. Besides, the lake's administration should prevent illegal fishing practices which adversely affect both the lake's water environment and, in turn, the biological stock of fish.

3. The necessity of imposing strict censorship on the nets used in fishing in order not to catch fry fish for the sake of keeping their existence. Furthermore, the necessity of reconsidering the lake's fees for license, fishing, and entrance. These fees raise the cost of fishing and, in turn, reduce the profits resulting in low incentives and motivation towards fishing.

4. The lake's administration and the authority for fish resources should work on providing health centers or units in every berth to enable every fisherman to obtain medical services at nominal prices. Also, the state should allocate a large place for selling fish at market price. In addition, the lake's administration should provide commercial information, especially that at market price for fish caught one by one.

5.

6. Fishermen's awareness of the importance of the economical administration for used fishing units; how serious and dangerous used fishing tools are, especially fishing nets with illegal

spaces; the methods of fishing with their effects on the fish stock concerning the current situation and the future vision of both the lake's economics and fishermen's income.

Results and Recommendations

A. Results: the most significant results the study concludes with are briefly as follows:

1. The fish production of Lake Bardawil in 2020 was around 1592 tons; i.e., 0.7% of the total fish production from Egyptian lakes.

2. As declared through studying the lake's fish production development during 2011-2020, there are apparent fluctuations in fish production, till it reached its lowest rank in 2020, coming with about 1592 tons.

3. Gilthead bream ranked first in the fish classification of Lake Bardawil, scoring 487 tons; i.e., by 30.6% of the total production of the lake, followed in rank by crustaceans scoring 28.1%, while mullets family fish ranked third scoring 4% of the lake's total production in 2020.

4. The lake encounters a number of problems and obstacles, the most important of which are the strait's silting; and those concerning production, marketing, and illegal fishing. A number of suggested solutions are presented to achieve the sustainable development of fish resources in Lake Bardawil.

B. Recommendations: they are in terms of suggestions concerning the development of fish resources in Lake Bardawil, North Sinai Governorate, such as:

1. Committing to the application of fishing law to manage the administration of Lake Bardawil's water in accordance with the lake's sustainable development program and waste prevention; and its natural openings' cleanliness.
2. Establishing a medical center with subunits in every berth under the administration of the general authority to prevent medical services.
3. Establishing an ice factory in every berth to maintain the quality and preservation of fish.
4. Obliging social insurance for fishermen to be allowed to practice fishing inside the lake.
5. Providing commercial information concerning the market price of every produced species from the lake.

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