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A Comparative Economic Study Before and During the Current Purification and Development Operations in Lake Burullus

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ABSTRACT
This study was conducted to investigate the impact of development and purification processes as well as raising the efficiency of Lake Burullus on the economic variables that affect its fish production. The study was based on two sources of data: the statistical recorded data during ten years before (2000 to 2009) and ten years from the beginning of the development project (2010-2020). The other source was the data collected during the field trips by interviewing the local fishermen and officials of the company performing the purification and development operations in the lake. Both descriptive and quantitative economic analysis were used for the variables under study using standard statistical and economic models. The different phases of the development and purification project were reviewed, and its impact was measured in order to study the evolution of the quantity and value of fish production in Lake Burullus, the development of fish production efficiency per fishing units and fishermen during the two studied periods, then studying seasonal fluctuations, future expectations and instability coefficient of fish production during the cleansing and development operations. The results of the analysis showed a positive impact of the cleansing and development operations in the lake on all economic variables under study.

INTRODUCTION

Deltas are home to a large and growing proportion of the world's population, often living in conditions of extreme poverty. Delta ecosystems are ecologically significant as they support high biodiversity and a variety of fisheries; however, these coastal environments are extremely vulnerable to climate change. The Nile Delta, Egypt is among the most important and populous delta regions in the world and it is considered at risk of food insecurity and climate change. The fisheries sector, especially the small scale one, is vital for populations living in the Nile delta as a source of animal protein through subsistence fishing and as a source of employment as well as for the economy. Although, fisheries play an important role in the economy of Egypt, it faces numerous challenges affecting its productivity. Lake Burullus is one of the Nile Delta lakes and the most productive one in Egypt. It is the second largest natural lake with mean annual fish production of about 50,000 ton. For many years, the lake like other Egyptian lakes suffers from many challenges that changed its water quality due to the increase of the amount of untreated sewage waters dumped in it. Over fishing, illegal fishing methods, spread of aquatic plants, silting the Burullus inlet, illegal collecting of fish fry and the decrease of the total area are another threats affecting the quantity and quality of fish products from the lake **(Mehanna, 2008)**.

The development and purification operations of the Egyptian lakes started in February 2010 and continue until now. These operations were undertaken after the political leadership program “Rehabilitation of Egyptian lakes”. This study aimed at reviewing the purification and development operations carried out in Lake Burullus and its impacts on fish production and catch composition of the lake. In addition, the future expectations of the fish production for the next five years were estimated.

MATERIALS AND METHODS

Study area

Lake Burullus (Fig. 1), the second-largest natural lake, is located between the two Nile River branches (Damietta and Rosetta) between latitudes 31° 25′ and 31° 35′ N and longitudes 30° 31′ and 31° 05′ E. It is considered as the most productive lake in Egypt now **(GAFRD, 2020)**. The eastern sector of the lake is saline and represents the shallowest part; it contains a long canal connecting the lake to the Mediterranean Sea (El-Boughaz canal). While, the western sector of the lake is the deepest part and the freshest **(Beltagy, 1985)**; the lake is extremely shallow, with a depth ranging between 0.42 and 2.07m.

The huge amounts of drainage water enter the lake at its southern coast through several drains, and a little amount of seawater entering it through El-Boughaz canal. The main basin is divided into three sectors: the eastern, central and western basins, and each sector is characterized by a kind of homogeneity in the water and biological characteristics. The islands scattered in the lake are natural breaks between these three sectors. The present area of Lake Burullus is about 410 km^2 (less than 100,000 feddan) of which 370 km^2 is open water. Lake Burullus has an overall area of about 600 km^2 in 1900, while its area was estimated by 574 km^2 (136,620 feddan) in 1956 **(Masoud *et al.*, 2011)**. The size of the lake was declined to about 460 km^2 (110,000 feddan) in 1974 due to the land reclamation for agriculture in its southern part. The declining of the lake’s area continues year after year **(Shaltout & Khalil, 2005; Dumont & El-Shabrawy, 2007; Younis & Nafea, 2012)**, and the reduction percent during the last 100 years was about 30% of its origin area. This decrease is due to continuous land reclamation projects along the southern and eastern shores of the lake and expanding of fish farms in the southern of the lake.

Fig. 1. Lake Burullus and main drains

Data collection

The study is based on three types of data:

1. Annual fishery statistics books of General Authority for Fish Resources Development (2000 to 2020) and published data about the lake.
2. Interviewing the officials of the Arab Contractors Company, the responsible company for the purification and development operations in the lake.
3. Field trips to collect the real data about fish production and composition in the lake as well as interviewing the fishermen.

Data analysis

Both descriptive and quantitative economic analysis was used in this study by applying standard statistical and economic models including:

1. Linear regression analysis of some economic variables.
2. Phase multiple regression analysis that affects the production of Lake Burullus.
3. Estimating the relative importance of some economic variables used in the study.
4. Estimating the seasonal index to study the seasonality of fish production in the lake (the highest production in any season divided by the lowest production in that season).
5. Estimating the instability coefficient for both quantity and value of fish production in the lake.
6. Estimating the production efficiency of each fishing unit and each fisherman.

Applying the forecast model of Holt and Brown to predict some important economic variables during the next five years.

RESULTS AND DISCUSSION

1. Economic importance of Lake Burullus

Lake Burullus is the second largest lake in Egypt and the most productive one. The total area of the lake is about 108 thousand feddan constituting 42.8% of the northern lakes' area and 6% of the total Egyptian lakes' area. During 2020 (Table 1), the lake produced about 91852 ton, which represented 46.4% of the northern lakes fish production and 38.6% of the total Egyptian lakes production. The fishing fleet is small-scale fleet composed of about 2800 fishing boat forming 44% of the total number in the northern lakes and 24% of the number operating in the Egyptian lakes. More than 9000 fishermen are working in the lake, representing about 44% of the total fishermen in the northern lakes and about 18% of the fishermen in the Egyptian lakes. Lake Burullus contributes by about three billion LE, which is about 45% of the total income from northern lakes and about 36% of the income of the Egyptian lakes (Table 1).

Table 1. Importance of Lake Burullus based on 2020 records **(GAFRD, 2020)**

Egyptian fisheries	Total lakes	Northern lakes	Lake Burullus	Item
13582	**1812**	**244**	**100**	**Area (thousand acres)**
-	-	100	41%	% to the Northern lakes
-	100	-	5.5%	% to the total lakes' area
100	-	-	0.74%	% to the total area of Egyptian fisheries
418.68	**237.76**	**197.97**	**91.85**	**Production (thousand ton)**
-	-	100	46.4%	% to the northern lakes
-	100	-	38.6%	% to the all lakes
100	-	-	21.9%	%to the Egyptian fisheries
26.6	**11.7**	**6.4**	**2.8**	**Number of fishing boats (thousand boat)**
-	-	100	43.96%	% to the northern lakes
-	100	-	23.93%	% to the total lakes
100	-	-	10.52%	% to the Egyptian fisheries
128.5	**45.8**	**19.3**	**8.4**	**Human resources (thousand fishermen)**
-	-	100	43.63%	% thern deltaFor the lakes of the nor
-	100	-	18.34%	% For all lakes
100	-	-	6.53%	% For Egyptian fisheries
%61.1	**8**	**6.5**	**2.9**	**Production value (Billion pounds)**
-	-	100	44.61%	% For the lakes of the northern delta
-	100	-	36.25%	% For all lakes
100	-	-	0.5%	% fisheries For Egyptian

2. The general framework of the development and purification project

This huge project aimed at creating radial canals to improve the lake efficiency and increase the saline water flow, as well as deepening the lake. The project has three phases as follows: Phase 1 from February 2010 to June 2013 involved the purification and deepening of 1808 acres in addition to cleaning the Boughaze (inlet) with an estimated cost of 90 million LE. Phase 2 started in July 2013 to the end of December 2019 and aimed to deepen 1500 acres and remove an island in front of Boughaze. In addition, three radial canals were digged as well as two docks one for coast guards and the other for border guards. The third phase started in January 2020 to be ended in December 2022. This last phase aimed at removing all aquatic plants and purifying an area of 1500 + 1526 acres as well as digging a fourth radial canal. Additionally, Brembal canal was purified and deepened for about 11km, and the system of water entry to the canal was modified to run above the canal parallel to the Rasheed Branch of the Nile (Arab Contractors Company).

3. Catch trend

3.1. Before the project (2000 – 2009)

The mean annual fish production from the Egyptian fisheries was 906.7 thousand ton during the period from 2000 to 2009 (40% from natural resources and 60% from aquaculture), with an estimated annual increase of 40.8 thousand ton (4.5%). This is statistically significant at $P= 0.01$. The fish production fluctuated between a minimum of 724.4 thousand ton in 2000 and a maximum of 1,093 thousand ton in 2009 (**GAFRD 2000-2009**; Table 2). This huge increase in the fish production of Egypt is due to the great expansion in aquaculture. In respect to the northern lakes, the annual fish production fluctuated between a minimum of 106.1 thousand ton in 2007 and a maximum of 144.7 thousand ton in 2001, with a mean catch of 123.35 thousand ton during 2000-2009. The northern lakes' production showed a decreasing trend estimated at 4.53 thousand ton (3.6%) annually (Table 3), which is statistically significant at $P= 0.01$.

In Kafr El-Sheikh Governorate where Lake Burullus lies, the fish production comes mainly from aquaculture and varied from a minimum of 172.7 thousand ton in 2000 to a maximum catch of 441.6 thousand ton in 2009, with a mean catch of 307.4 thousand ton. The fish production from Kafr El-Sheikh showed an increasing trend with an annual value of 31.6 thousand ton (10.5%), which is statistically significant at $P= 0.01$. This increasing trend is due to the aquaculture production where Kafr El-Sheikh is the first governorate in Egypt in aquaculture production. Kafr El-Sheikh fish production in this period forms about 33.1% of the total production of Egypt with a minimum in 2000 (23.8%) and maximum in 2008 (40.4%). This reflects the relative importance of this governorate for food security in Egypt.

Lake Burullus produced about 55.2 thousand ton during 2000-2009 with a minimum of 51.8 thousand ton (2000) and maximum of 59.8 thousand ton (2002). A decreasing trend estimated at 0.843 thousand ton (1.7%) was noticed, and this decreasing was not statistically significant at $P= 0.05$. The lake constitutes 19.8% of the Kafr El-Sheikh fish production, and this contribution showed a decreasing trend due to the increase of aquaculture production in the governorate. On the other hand, Lake Burullus is considered as the second most productive lake in Egypt. It contributes by about 45.4% of the total fish production from the northern lakes, with a minimum of 37% in 2000 and maximum of 55% in 2007 (Table 2).

Table 2. Fish production from Egypt and the relative importance of Lake Burullus during the period 2000-2009

Catch / year	Fish production (thousand ton)				Relative importance for Lake Burullus		
	Total	**Northern lakes**	**Kafr El-Sheikh**	**Lake Burullus**	**Kafr El-Sheikh to total production**	**To northern lakes %**	**To Kafr El-Sheikh**
2000	724.4	141.20	172.7	51.8	23.8	37	30.0
2001	771.5	144.71	223.8	59.2	29.0	41	26.4
2002	801.5	133.82	220.5	59.8	27.5	45	27.1
2003	876.0	135.61	256.8	55.5	29.3	41	21.6
2004	865.0	132.85	262.4	55.0	30.3	41	21.0
2005	889.3	108.68	282.7	53.9	31.8	50	19.1
2006	970.9	108.35	365.2	53.0	37.6	49	14.5
2007	1008.0	106.13	407.0	58.3	40.4	55	14.3
2008	1067.6	108.96	441.5	52.3	41.4	48	11.8
2009	1092.9	113.15	441.6	53.4	40.4	47	12.1
Average	**906.7**	**123.35**	**307.42**	**55.22**	**33.15**	**45.4**	**19.79**

Table 3. Regression analysis of variation trend for Egyptian fish production, northern lakes, Kafr Elsheikh Governorate and Lake Burullus during the period 2000 to 2009

Parameter	Equation	Model used	F	r^2	Annual variation%
Total fish production	$Y = e^{6.553+0.045}X_t$ (19.21)**	Growth	368	0.99	4.5
Northern lakes production	$Y = e^{5.01-0.036}X_t$ (-5.14)**	Growth	26.46	0.77	-3.6
Kafr El-Sheikh production	$Y = e^{5.10+0.105}X_t$ (13.72)**	Growth	188	0.98	10.5
Lake Burullus production	$Y = e^{4.08-0.017}X_t$ (-1.84)n.s	Growth	3.384	0.65	-1.7

** Significant at *P*=0.01, n.s Non significant, Estimated t= Numbers in brackets, X_t is the time factor.

3.2. During the project (2010 – 2020)

The mean annual fish production from the Egyptian fisheries was 1637 thousand ton during the period from 2010 to 2020, with an estimated annual increase of 82.7 thousand ton (5.1%) which is statistically significant. The fish production fluctuated between a minimum of 1.3 million ton in 2010 and a maximum of 2.093 million ton in 2019. For the northern lakes, the mean annual catch was 144.38 thousand ton, with an estimated annual increase of 4.2 thousand ton (3.0%). The annual catch of northern lakes fluctuated between a minimum value of 117.14 thousand ton in 2011 and 197.97 thousand ton in 2020 (Table 4).

On the other hand, the mean annual fish production from Kafr El-Sheikh Governorate was 690.8 thousand ton, with an increase trend of 40.85 thousand ton (6.1%) but most of this production comes from aquaculture (Table 4). Kafr El-Sheikh Governorate contributes by 42.5% of the total fish production in Egypt during the period from 2010 to 2020. This contribution fluctuated between 38.3% during 2010 and 45.8% during 2013.

Lake Burullus produces a mean annual fish production of 65.2 thousand ton during 2010 to 2020, with an estimated annual increase of 3.21 thousand ton (5.2%) (Tables 4, 5). The fish production from Lake Burullus varied between a minimum of 45.54 thousand ton in 2011 and 91.85 thousand ton in 2020. The lake constitutes 9.3% of the Kafr El-Sheikh Governorate fish production and 45.1% of the northern lakes production. In the recent two years (2019 and 2020), the lake was the first in fish production from the Egyptian lakes and it produced the half of fish production from the northern lakes. This may be due to the development and purification processes carrying out in the lake (Table 4).

Table 4. Fish production from Egypt and the relative importance of Lake Burullus in the period 2010-2020

Catch / year	Fish production (thousand ton)				Relative importance for Lake Burullus		
	Total	**Northern lakes**	**Kafr El-Sheikh**	**Lake Burullus**	**Kafr El-Sheikh to total production**	**To northern lakes %**	**To Kafr El-Sheikh**
2010	1304.8	133.004	449.1	59.5	38.3	45	11.9
2011	1362.2	117.137	559.8	45.54	41.1	39	8.1
2012	1372.0	128.351	598.1	52.08	43.6	41	8.7
2013	1454.4	144.874	666.032	49.70	45.8	34	7.0
2014	1481.9	132.320	620.889	63.98	42.0	48	10.0
2015	1519.0	132.629	682.782	65.07	45.0	49	9.5
2016	1706.3	123.526	756.977	67.58	44.4	55	8.9
2017	1822.8	146.186	810.285	69.33	44.5	47	8.6
2018	1934.7	152.552	787.991	71.41	40.7	47	9.1
2019	2039.0	179.640	865.483	81.15	42.4	45	9.4
2020	2010.6	197.973	801.359	91.85	39.9	46.4	11.5
Average	**1637.06**	**144.38**	**690.80**	**65.20**	**42.52**	**45.13**	**9.34**

Table 5. Regression analysis of variation trend for the Egyptian fish production and Lake Burullus during the period 2011 to 2020

Parameter	Equation	Model used	F	r^2	Annual variation%
Total fish production	$Y= e^{7.086 + 0.051 X_t}$ (0.004)**	Growth	175.22	0.98	5.1
Northern lakes production	$Y= e^{4.77 + 0.029 X_t}$ (2.85)*	Growth	8.18	0.67	3.0
Kafr El-Sheikh production	$Y= e^{6.162 + 0.062 X_t}$ (8.817)**	Growth	77.54	0.91	6.1
Lake Burullus production	$Y= e^{30844 + 0.05 X_t}$ (405.9)**	Growth	20.30	0.77	5.2

** Significant at *P=0.01*, *significant at *P=0.05*, Estimated t= Numbers in brackets, X_t is the time factor.

4. Fish production value from Lake Burullus

The mean annual fish production from Lake Burullus was estimated at about 65.2 thousand ton providing about 1.5 billion LE annually. The average price per ton was about 21.9 thousand LE (Table 6).

Table 6. Fish production value in Egyptian pound (LE) from Lake Burullus during the last 11 years

Item / Year	Lake Burullus production (ton)	Value (Thousand LE)	Average price/ton (Thousand LE)
2010	59517	612825	10.3
2011	45544	473658	10.4
2012	52076	955063	18.3
2013	49704	728298	14.7
2014	63782	1036272	16.2
2015	65066	1104626	17.0
2016	67577	1409474	20.9
2017	69328	1767996	25.5
2018	71409	1940029	27.2
2019	81146	2912287	35.9
2020	91852	4133340	45.0
Average	**65181.9**	**1552170**	**21.94**

5. Fish production efficiency from Lake Burullus

5.1. Before the project (2000-2009)

In respect to the fishing units, the number of licensed fishing boats fluctuated during the study period between 5619 fishing unit in 2005 and 8770 fishing units in 2000 **(GAFRD annual books)**. The number of fishing boats in 2009 re-increased to reach 6221 fishing units, with an average number of 7545 units during the whole period. It was noticed that there is an annual decrease estimated at about 324 fishing unit, which is statistically significant at $P= 0.05$ (Table 7). On the other hand, the number of fishermen in the lake decreased from 26310 fishermen in 2000 reaching 18663 fishermen in 2009, with an average of 22635fishermen and an annual decrease estimated at 973 fishermen, which is statistically significant. It is worth mentioning that, the recorded number of fishing boats in the lake is underestimated and the real number may be doubled or tripled **(**personal observation, **Mehanna, 2008, 2021)**.

The catch per unit effort fluctuated between 5.9 ton/boat/year in 2000 and 9.6 ton/boat/year in 2005, with an average of 7.52 ton/boat/year and estimated annual increase of 0.286 ton/boat/year. While, the catch per fishermen varied from 1.97 ton/fisherman/year in 2000 to 3.2 ton/fisherman/year in 2005, with an annual average of 2.51 ton/fisherman/year and an estimated increase of 95.6 kg/ fisherman/ year, which is statistically significant (Table 7).

Table 7. Fish production, fishing effort and catch per unit of fishing effort from Lake Burullus during 2000-2009

Item / Year	Lake Burullus production (thousand ton)	No of licensed fishing boats	No of fishermen	Catch/boat ton/boat/year	Catch/fisherman ton/fisherman/ year
2000	51.8	8770	26310	5.9	1.97
2001	59.2	8770	26310	6.8	2.25
2002	59.8	8770	26310	6.8	2.27
2003	55.5	8770	26310	6.3	2.11
2004	55.0	6988	20964	7.9	2.62
2005	53.9	5619	16857	9.6	3.20
2006	53.0	8770	26310	6.0	2.01
2007	58.3	6674	20022	8.7	2.91
2008	52.3	6098	18294	8.6	2.86
2009	53.4	6221	18663	8.6	2.86
Average	**55.22**	**7545**	**22635**	**7.52**	**2.51**

5.2. During the project (2010-2020)

Generally, the number of licensed fishing boats showed a decreasing trend in this period and fluctuated between 1332 fishing unit in 2020 and 6195 fishing units in 2010 (GAFRD annual books), with an average number of 4841 units during the period 2010-2020. The annual decrease was estimated at about 229 fishing unit, which is statistically significant at P= 0.01 (Table 8). On the other hand, the number of fishermen in the lake decreased from 18515 fishermen in 2010 to 4000 fishermen in 2020, with an average of 14518 fishermen and an annual decrease estimated at 685 fishermen which is statistically significant. Notably, the recorded number of fishing boat and fishermen in the lake is greatly underestimated, and the real number may reach triple or four times this recorded number (personal observation, **Mehanna, 2020, 2021**).

The estimated catch per unit effort during this period fluctuated between 7.9 ton/boat/year in 2011 and 68.9 ton/boat/year in 2020, with an average of 17.95 ton/boat/year and estimated annual increase of 1.6 ton/boat/year (Table 8). While, the catch per fishermen varied from 2.65 ton/fisherman/year in 2011 to 22.96 ton/fisherman/year in 2020, with an annual average of about 6 ton/fisherman/year and an estimated increase of 3.3 ton/fisherman/year, which is statistically significant (Table 8).

By analyzing the obtained results before and during the development project of Lake Burullus, it was deduced that the fishing effort was greatly decreased in the recent years during the project implementation. This is as a result of improving and applying the fishing laws via preventing any new fishing licenses and controlling the fishing effort in the lake, as well as monitoring the fishing operations and banning the illegal fishing units. In addition, the fishermen who work randomly and without a license were controlled, and this in turn clearly led to a significant increase in the productivity of the fishing unit and the licensed fisherman. Accordingly, the economic return on the fisherman and its impact on improving the social situation for them and their families were increased.

Table 8. Fish production, fishing effort and catch per unit of fishing effort from Lake Burullus during 2010-2020

Item / year	Lake Burullus production (thousand ton)	No. of licensed fishing boats	No. of fishermen	Catch/boat ton/boat/year	Catch/fisherman ton/fisherman/ year
2010	59.5	6195	18515	9.6	3.20
2011	45.54	5725	17175	7.9	2.65
2012	52.08	5577	16731	9.3	3.11
2013	49.70	5390	16170	9.2	3.07
2014	63.98	5158	15474	11.2	4.13
2015	65.07	5700	17100	11.4	3.81
2016	67.58	5059	15177	13.4	4.45
2017	69.33	5638	16914	12.3	4.10
2018	71.41	4694	14082	15.2	5.07
2019	81.15	2786	8358	29.1	9.70
2020	91.85	1332	4000	68.9	22.96
Average	**65.20**	**4841**	**14518**	**17.95**	**6.02**

6. Economic factors impacting the fish production during 2010-2020

The most important economic factors determining the fish production of Lake Burullus are: lake area (acres, X_1), number of licensed fishing units operating in the lake (boat, X_2), number of fishermen (fisherman, X_3), productivity of the fishing unit (kg/boat/year, X_4), and productivity of the fisherman (kg/fisherman/year, X_5). By performing the multiple regression analysis of the variables determining fish production in the lake using both linear and logarithmic forms, the linear regression proved to be the best to present the analysis. It can be expressed by the following equation:

$$\mathbf{\acute{Y}_t = -159.45 + 2.004\, X_1 + 0.003\, X_6 \quad (4.310)^{*}\ (3.601)^{n.s}}$$
$$\mathbf{F = 39.68 \qquad r^2 = 0.919}$$

It is clear from the estimated model that the most important determinant variables for fish production in the lake are the lake area and the fisherman's productivity variables. Where if the lake’s area changed by 10% increase or decrease, the fish production will be changed by 20.04 thousand ton increase or decrease. Moreover, the change in productivity of the fisherman by 10% increase or decrease will lead to the change of the lake’s production by 0.3 thousand ton in the same direction. The relationship among these variables is direct and significant at $P= 0.01$, with a high correlation coefficient, indicating that the area and the fisherman's productivity are the most important factors affecting the lake's productivity.

7. Seasonal variations index of fish production in Lake Burullus

The index of seasonal variations in production is used to detect production fluctuations, and consequently the price changes that follow in order to develop appropriate policies to overcome these conditions and avoid their negative effects in the coming years and try to mitigate the impact of this on both producers and consumers, as well as on the changes that occur in prices. By studying the seasonality of production in Lake Burullus (Tables 9, 10), it could be distinguished between two periods: the first period in which the seasonal average exceeds the general seasonal average, which is the autumn and summer seasons, and the second period when the seasonal average is lower than the general average which is the spring and winter seasons. The seasonal average in the autumn season was 6025.6 ton, with an increase of 811.8 ton more than the general seasonal average which was 5213.8 ton. The seasonal average in summer was about 5704.6 ton, which was higher than the general seasonal average by 490.8 ton. In respect to spring and winter seasons, the seasonal average was 4943.3 and 4182 ton, respectively, with a decreasing values of 270.5 and 1031.8 ton less than the general seasonal average, respectively. It was clear that winter was the least season in fish production due to the unsuitable weather conditions, which reduces the fishing period in the lake and thus decreases production as well as the slow fish growth and activity in winter. While, the autumn and summer seasons were the highest seasons during the study period in the seasonal average, because these seasons are the seasons of reproduction and hatching of fish, and the weather in them is suitable for fishing operations, as the fisherman continues in the lake for a long period, and thus production increases in these seasons. Generally, the seasonal index of lake Burullus, which is estimated at 1.4 is considered high, and therefore fish production in the lake is greatly affected by ecological, biological and weather conditions.

Table 9. Monthly fish production from Lake Burullus during 2010-2020 **(GAFRD, 2010-2020)**

Month / year	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	59517	3961	4187	4517	5082	4613	5179	5466	5925	4981	4499	5528	5579
2011	45544	2750	3106	4202	4294	3363	3421	3453	3482	4542	4583	3652	4696
2012	52076	3383	3734	3790	4333	5212	5244	5617	4026	4478	4211	3864	4184
2013	49704	3250	2915	3728	4566	4632	4757	4780	3669	4638	4212	4353	4204
2014	63782	3563	4505	4395	4821	4921	4933	5138	5328	6369	6732	6537	6738
2015	65066	3606	4578	4369	4947	5042	5004	5225	5428	6457	6933	6611	6884
2016	67577	4165	4742	4487	4972	4881	5091	5430	5739	6931	7166	6736	7237
2017	69328	4468	4910	4856	5437	5082	5214	5405	6036	6890	7306	6954	7070
2018	71409	4589	4922	3913	5262	5150	5401	6109	7193	7064	7248	7365	7193
2019	81146	5286	5578	4999	5429	5475	6548	8127	9179	8031	7687	7611	7196
2020	91852	5217	5286	5867	7062	8358	8880	8415	8712	8405	8521	8847	8282

Table 10. Seasonal average and seasonal index of fish production from Lake Burullus during 2010-2020

Season	Month	Production	Seasonal average	Percentage	Seasonal index
Winter	Jan Feb Mar	3902 4318 4326	4182	80.2	1.4
Spring	Apr May Jun	4914 4837 5079	4943.3	94.8	
Summer	Jul Aug Sep	5475 5601 6038	5704.6	109.4	
Autumn	Oct Nov Dec	6058 5921 6098	6025.6	115.5	

8. Future expectations for the Egyptian and Lake Burullus fish production

Future forecasts are used in suggesting development plans and drawing up the future economic policies. Thus, different models were used to predict and compare among them, based on the efficiency of the model. From the models used, smoothing model of Holt was the best. The results of the analysis (Table 11) showed that the expected Egyptian fish production during the period 2021-2025 would continuously increase towards 2025 to reach about 2696.1 thousand ton. This indicates the clear impact of the purification and development operations that took place in the lake since 2010. The same increasing trend will be achieved for northern lakes where the expected fish production from these lakes was estimated at 211 thousand ton in 2025 (Table 11). Additionally, the predictive model showed a continuous increase in fish production from Lake Burullus reaching 96 thousand ton in 2025. These findings explain the necessity and importance of completing the purification operations of the lake for its positive and clear impact on the production of the lake in the coming years.

Table 11. Predicted fish production using E-views program

Year	Expected total fish production	Expected fish production from northern lakes	Expected fish production from lake Burullus
2021	2258.51	199.44	92.47
2022	2367.90	205.15	92.98
2023	2477.30	210.86	93.79
2024	2586.69	214.55	94.86
2025	2696.09	219.37	95.95

9. Coefficient of instability of Lake Burullus

The coefficient of instability for the quantity and value of fish production in Lake Burullus during the period 2010-2020 was estimated as it is an indicator for risk; the lower the value of the instability coefficient, the higher the risk ratio for investing in this field. Therefore, the investor has a background on the stability of the quantity and value of the output, and that enables him to set his plans and expectations on this basis. Consequently, this coefficient shows the extent of stability in the quantity and value of output and the changes that will occur in prices, whether by increase or decrease.

By examining the index of instability for fish production from Lake Burullus (Table 12), it was found that the highest values were recorded in 2010, 2011 and 2013 as 13.6, 14.8 and 24.4, respectively. This can be explained as these years coincide with the beginning of the purification and development operations. Furthermore, large parts of the lake were not suitable for fishing, in addition to the severe deterioration that the lake was exposed to and the disappearance of many fish species in general and marine fish in particular.

While, the instability coefficient was the least in years 2015, 2016 and 2017 (1.8. 0.6 and 1.5, respectively). Accordingly, year 2016 was the stability year in Lake Burullus which can be attributed to the fact that during this period a large part of the purification and development operations was done. These operations included deepening and clearing the Boughaz, purifying the main openings that feed the lake such as Bermbal Canal and Al-Khashaa Drain, as well as removing most of the vegetation covering the lake i.e. restoring life to the lake.

For the value of production, the coefficient of instability in the value of production was the highest in 2010, 2012 and 2019 (26.2, 31.3 and 122.1, respectively), where the risk rate rises to invest in this field. Whereas, the index value was the lowest in 2011, 2017 and 2018, and it was estimated at about 9.5, 4.8 and 6.9, respectively, thus the year 2017 was the most stable year in the lake's production value. This is due to the general increase in the fish prices (inflation), the increase in food awareness of the importance of fish in human health food, and the increase in the population growth rate.

Table 12. Estimated instability coefficient for Lake Burullus during 2010-2020

Item / year	Lake Burullus production (ton)	Value (Thousand LE)	Instability index in production quantity	Instability index in production value
2010	59517	612825	24.39	122.50
2011	45544	473658	14.83	9.51
2012	52076	955063	4.07	31.32
2013	49704	728298	13.56	23.59
2014	63782	1036272	5.37	12.11
2015	65066	1104626	1.76	21.38
2016	67577	1409474	0.63	13.58
2017	69328	1767996	1.49	4.78
2018	71409	1940029	2.97	6.85
2019	81146	2912287	5.64	26.15
2020	91852	4133340	5.77	26.59
Average	**65181.91**	**1552170**	**7.32**	**27.12**

CONCLUSION

This study aimed to investigate the impact of the development and purification processes and raising the efficiency of Lake Burullus on the economic variables affecting fish production and fishermen. The descriptive economic analysis and the quantitative economic analysis used were based on the collected data from the field and those from the company implementing the development and purification project in the lake. All different phases of the development and purification project were reviewed, and its impact was measured. In addition, the seasonal fluctuations, future expectations and the coefficient of instability of production during 2010-2020 were analyzed. The results of the analysis showed the positive impact of the purification and development operations in the lake on all economic variables under study.

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